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Bibliographic research on the linkages between intellectual capital and Industry 4.0

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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]:

- 1^{st} 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.

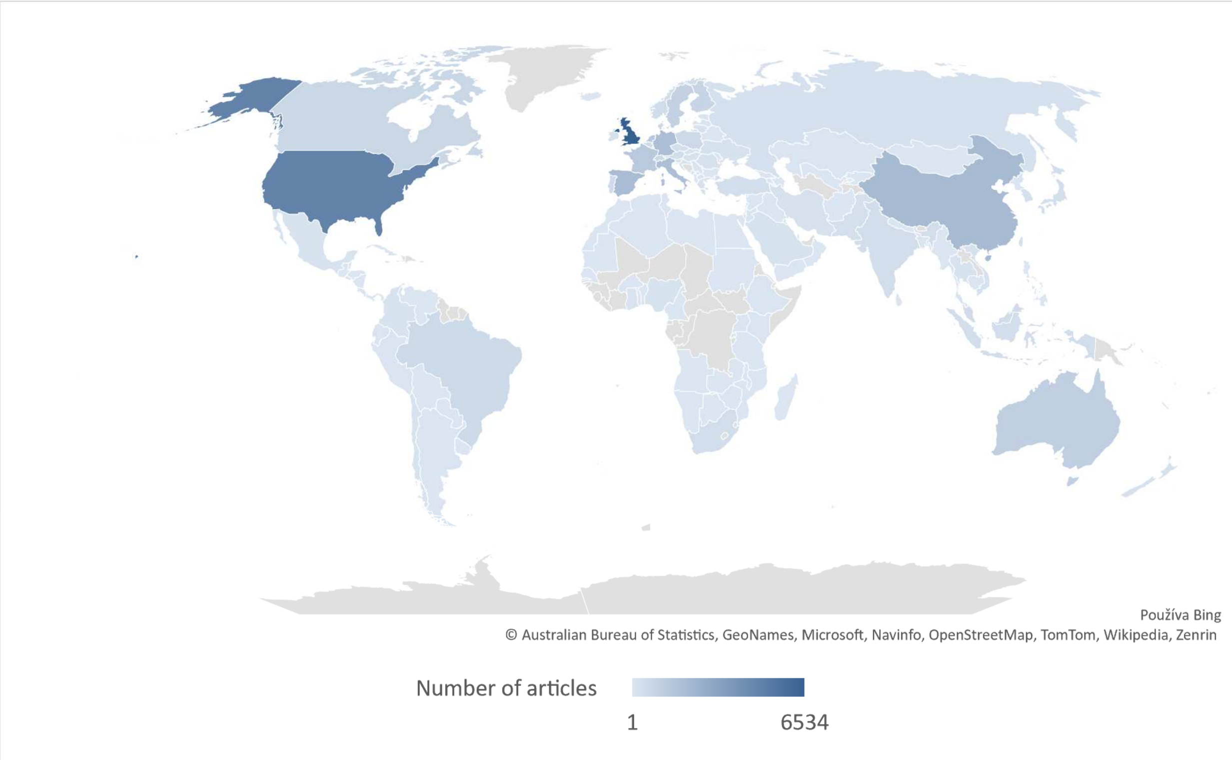

Figure 1 Wold map of the number of articles

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

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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.

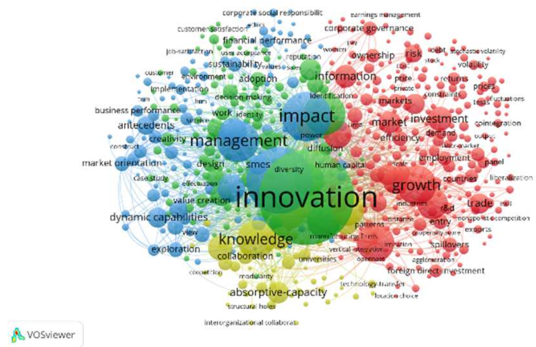

Figure 2 Analysis of keywords during 2011 – 2022

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.

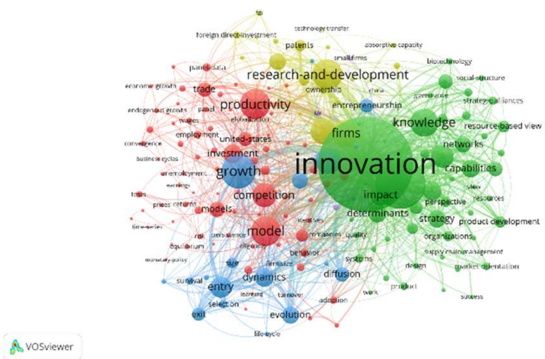

Figure 3 Analysis of keywords during 1980 – 2010

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.

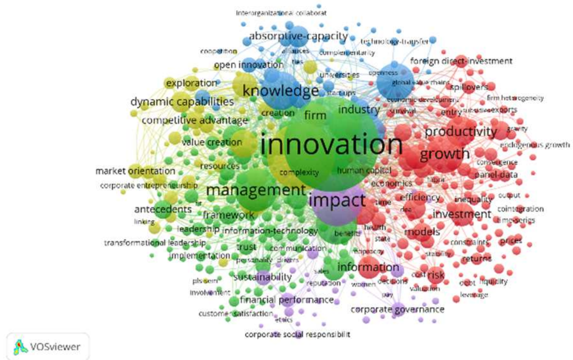

Figure 4 Analysis of keywords during 2011 – 2022

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).

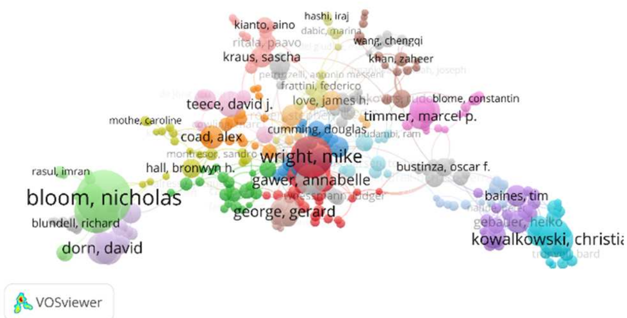

Figure 5 Co-authorship analysis by authors

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.

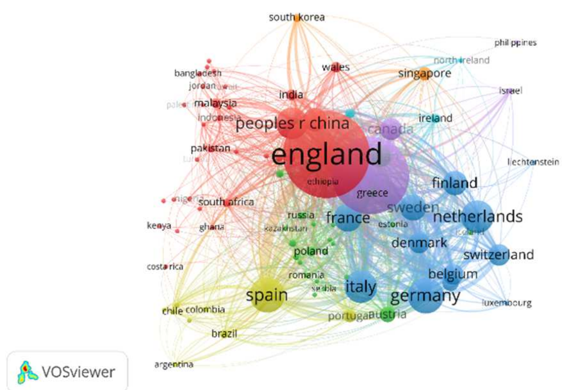

Figure 6 Co-authorship analysis by countries

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.

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Assessing business readiness for Industry 4.0: A bibliometric analysis of research trends

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Keywords: Industry 4.0, enterprise readiness, maturity models, bibliometric analysis.
Abstract: This research provides a comprehensive analysis of the state of readiness assessment for enterprises in the context of Industry 4.0. It examines the most influential authors, countries, and journals in this field, identifies key research themes, and explores the evolving landscape of Industry 4.0. By bibliometric analysis, this study uncovers the intricate network of co-authorship and co-citation among researchers, journals, and countries. The analysis underscores the dominance of China in terms of both publication volume and citation impact, driven by its strategic "Made in China 2025" plan. The United States and India also make substantial contributions, reflecting the global nature of Industry 4.0 research. The key themes in this area include digital transformation, IT innovations, production, and supply chain management. This study pinpoints three distinct clusters of journals, demonstrating the multidisciplinary nature of Industry 4.0. In addition, a co-occurrence analysis of keywords highlights the most prevalent themes, including Industry 4.0, frameworks, big data, and performance. This research offers valuable insights into the research landscape, informing scholars and industry stakeholders of key players, trends, and emerging areas in assessing enterprise readiness for Industry 4.0.

1 Introduction

Industry 4.0 brings with it numerous challenges that are in synergy with the implementation of digital transformation, new technologies, process improvement, and changes in work methods, all aimed at enhancing the efficiency of manufacturing and decision-making processes within enterprises. We currently live in a world of extensive digitalization, in which industrial enterprises must adapt to new trends and technologies to improve their competitiveness and sustainability. Thus, it is essential to explore evaluative approaches for measuring the maturity level of companies within the context of Industry 4.0. This can aid in identifying the situation not only within the enterprise itself but also within the entire industry in national and international markets. Such insights can be valuable for developing of policies and strategies related to the concept of Industry 4.0.

Given the abundance of existing literature on Industry 4.0 in various countries, as well as the individual aspects of this concept, the aim of this article is to provide a systematic literature overview – a bibliometric analysis to determine the main research trends in the field of assessing business readiness within the framework of Industry 4.0. The main objective of this study is to offer a systematic review of existing literature and identify the top areas considered key in the examination of business readiness in the context of the Industry 4.0 environment. Research questions are formulated to reflect the objective of this article:

1. What are the primary trends in terms of publishing authors?
2. What are the primary trends in terms of publishing countries?
3. What are the primary trends in terms of publishing scientific journals?
4. What are the primary trends in terms of keywords?

After presenting the theoretical background of the issue, we explain the methodology of this research, followed by the presentation of findings and the conclusion.

1.1 Theoretical background

The scientific term and concept of Industry 4.0 was first presented in 2011 at the Hanover trade fair in Germany. This referred to the transformation process within global value chains. In the report "The Fourth Industrial Revolution" presented by K. Schwab at the World Economic Forum, Industry 4.0 encompasses industrial business processes that involve the organization of global manufacturing networks based on new information and communication technologies and the Internet [1].

Industry 4.0 has garnered significant attention in recent years, both from manufacturing companies and service systems. It primarily involves the integration of manufacturing facilities, supply chains and service systems to enable the creation of value-added networks [2].

Popkova et al. [3] define the term "Industry 4.0" as a new industrial model characterized by autonomously managing, fully automated, self-learning, and interactive production systems. These systems are centred around new digital and internet technologies, and human involvement is limited to their initial setup, control, and technical maintenance. Modern industrial professionals need to acquire new skills and these changes go hand in hand with social changes.

According to [1], Industry 4.0 represents a new industrial area created by the emergence and spread of new digital and internet technologies. These technologies have enabled the development of fully automated manufacturing processes that interact through physical objects without human intervention. Industry 4.0 produces both traditional and new industrial products that cannot be produced in other sectors of the real economy. The process of shaping and developing Industry 4.0 affects all spheres of the economic system, including the social sphere, characterized by significant changes related to the necessity of human adaptation to the new economic conditions. Companies optimize their processes using the opportunities provided by Industry 4.0 and employees (industrial professionals) either acquire the necessary skills for Industry 4.0 or seek employment in other industries, while consumers interact with these new industrial products.

It can be observed that the literature on Industry 4.0, as well as the research on readiness and current status, is relatively extensive. This motivated us to examine the trends in this existing literature. The bibliometric analysis approach is relatively new, but its added value is beyond question. Scholars employ bibliometrics to identify primary areas of research focus by analysing the existing body of literature in their respective fields [4] [5]. They utilize the network analysis methodology known as "co-word analysis" (occasionally referred to as "keyword co-occurrence analysis") to make associations between words (or concepts) that frequently co-occur in publications. The first description of this technique was provided by Callon et al. [6].

This method is often used in the social sciences and humanities, especially when it comes to examining the content of publications on specific topics. It evaluates various attributes of words, including their frequency of occurrence in documents, their associations with other words, their relevance to the topic, and their semantic implications [7] [8].

The main goal of "co-word analysis" is to uncover central themes, concepts, and connections within a text corpus. According to Wang et al. [9], this process has the ability to reveal associations that span numerous topics and disciplines, while uncovering patterns and evolving trends within the respective fields.

2 Methodology

To obtain answers to our research questions, we employed the systematic literature review (SLR) method, which is used to identify, evaluate, interpret, and categorize all relevant articles on the topic under study [10]. Based on the publications of these authors, the systematic literature review consists of the following steps:

1. Identification of research questions: Formulation of research questions to be addressed.
2. Literature search and selection: Development of a document retrieval strategy using a specific combination of keywords to gain a comprehensive overview of the studied area. Appropriate filters are then set to obtain the most relevant sample of articles.
3. Bibliometric analysis: Presentation of quantitative analysis and data visualization of the selected sample of articles to understand key characteristics of the subject, such as publication trends, journals and citations, collaborations, and the focus of keywords.
4. Content analysis: Conducting an in-depth content analysis of selected articles to summarize contributions from several related thematic areas. This enables an understanding of the current research landscape and the identification of future research possibilities.

Following the PRISMA protocols, the SLR methodology begins with the establishment of eligibility criteria. Table 1 contains the exclusion criteria used in our systematic literature review.

Table 1 Exclusion criteria

Exclusion criterion	Description
EC 1	Publications do not belong to SSCI, SCI-E, A&HCI and ESCI indexing
EC 2	Publications are not research papers and research paper reviews
EC 3	Publications published out of range 2011/1 – 2023/1
EC 4	Publications in different than English language

Source: own elaboration

This table clarifies that eligible sources in this study include articles published in academic journals that employ a rigorous peer review system. In this work, we used the online publication database Web of Science (WoS) as a search platform, where, to meet the specified requirement, one of the criteria was the utilization of literature published in journals indexed in Clarivate Analytics' group of indexes. Specifically, these were the

Social Sciences Citation Index (SSCI), the Science Citation Index – Expanded (SCI-E), the Arts & Humanities Citation Index (A&HCI), and the Emerging Sources Citation Index (ESCI).

Subsequently, we devised a direct search scheme to identify the initial set of articles. Based on the publication by Ghobakhloo et al. [11] and Sun et al. [10], the search scheme included the use of five primary search terms within the thematic group "Industry 4.0," namely, "Industry 4.0," "I 4.0," "Industrie 4.0," "The Fourth Industrial Revolution", and "Cyber-Physical Systems". According to Erboz [12], the last of these search terms represents a fusion of fundamental systems and pillars of Industry 4.0. Hence, we combined the individual search terms for different cyber-physical systems under this general term. Since our focus was on assessing the readiness level of companies in the context of Industry 4.0, this search came with the requirement to include additional key terms, namely, "readiness", “maturity”, and "dimension", as explained by Hajoary [13]. These key terms were chosen to target the search directly to the key topics of evaluating business readiness in the context of Industry 4.0.

The search scheme was further refined by limiting the results within the "Document Type" subsection to article types and article reviews. In addition, the search included a publication year restriction that defined the period as January 2011 to March 2023. The final restriction included the exclusion of publications in languages other than English.

The search strategy used in this work included primary searches for publications that focus on assessing business readiness in the context of Industry 4.0, as well as supplementary searches for publications that focus directly on key topics related to the evaluation of business readiness in Industry 4.0.

The result of this search was the identification of a total of 2,232 publications for querying all defined topics and keywords. Of the total number of publications, 807 were excluded based on the exclusion criteria (Table 1). The resulting set of 1,425 publications was used to create the bibliometric analysis. The pioneering word analysis technique was initially developed by Callon et al. in 1986. In recent times, bibliometric analysis has gained prominence as a valuable tool for scholars and librarians across various disciplines, enabling them to navigate extensive collections of scientific articles and uncover patterns and trends. One of the most widely used tools for conducting bibliometric analysis is the VOSviewer software. Detailed instructions on this robust and versatile tool for creating and visualizing bibliometric maps of scientific literature can be found in the VOSviewer documentation [14]. As the authors explain, VOSviewer helps users navigate the complex field of scientific literature and understand the trends and patterns prevalent within it. This software can be used to create maps that illustrate the interrelationships between different academic fields, authors, institutions, and other components, as well as to create and examine bibliometric diagrams of scientific publications.

VOSviewer utilizes several techniques for generating economic maps, such as the word co-occurrence algorithm, the bibliographic coupling method, and the co-authorship algorithm [15]. Once the bibliometric map is assembled, it can be customized to accentuate specific features or connections. It is essential to recognize that the conclusion of a bibliometric study is to understand patterns and trends of the map and ultimately derive insights about the research landscape from these findings.

3 Results and discussion

Using publications from the WoS database from 2011 to 2023, publication trends in the area of assessing business readiness in the context of Industry 4.0 were examined. Based on Figure 1, it is clear that there has been a significant increase in the number of published papers from 2019 to the present.

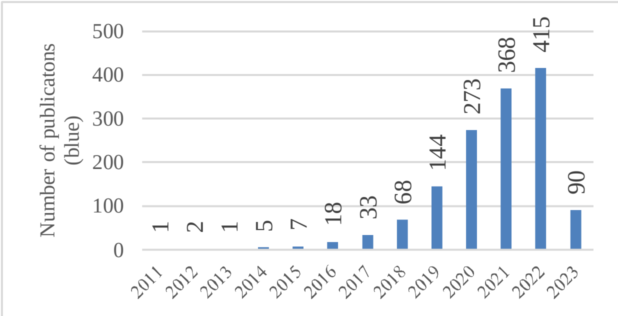

Figure 1 Publications trend
Source: own elaboration according to WoS (2023)

It has been shown that the number of publications more than doubled between 2018 and 2019. Almost 30% of all publications were published last year, and an increasing trend towards addressing this topic is expected in the coming years. Over the years, the number of publications on this topic has increased due to the growing interest in this field and concerns about Industry 4.0, as well as the technological benefits in the manufacturing industry resulting from the implementation of Industry 4.0 [16].

The most prolific authors are listed in the WoS database based on their total number of publications (CPP). Authors with the same number of publications are ranked among themselves based on the total number of citations without self-citations (CPC). Additional data includes the average number of citations per author's publication (PPCP) and the author's Hirsch Index (H-Index), which explains the impact of an author's work on their field of activity [17]. According to this method, the top 10 most productive authors are presented in Table 2. With 15 publications and 655 citations in the literature, Tortorella is the most contributing author in the field of assessing business readiness levels in the context of Industry 4.0. His average number of citations per publication is almost 44 citations, and his H-Index stands at 6, meaning that at least 6 of his 15 publications have been cited at least 6 times. Frank follows with 10 publications. Antony is the third most prolific author. The fourth, fifth, and sixth productive authors are Muller, Sony, and Singh. In the seventh position, with 7 publications, is Garza-reyes. Wuest, Jabbour, and Ghobakhloo occupy the 8th, 9th, and 10th positions with 6 publications.

Table 2 Top 10 most productive authors

Author	TNP	CPP	ACPP	H-Index
Tortorella, GL	15	655	43.67	6
Frank, AG	10	1077	107.70	7
Antony, J	9	20	2.22	3
Muller, JM	8	1074	134.25	8
Sony, M	8	156	19.50	5
Singh, RK	8	91	11.38	4
Garza-reyes, JA	7	260	37.14	4
Wuest, T	6	494	82.33	5
Jabbour, CJC	6	354	59.00	5
Ghobakhloo, M	6	165	27.50	5

Source: own elaboration according to WoS (2023)
Note: TNP – total number of publications; CPP – total number of citations excluding self-citations; ACPP – average citation per paper

To create a list of the most influential authors, authors were ranked based on the total number of citations in all their works. This list is shown in Table 3. Frank, AG, who is the second most prolific author with 10 publications, is also the most influential author with 1077 citations in the WoS database. His average number of citations per publication is almost 108 citations, and his H-Index is at 7, indicating that at least 7 of his 10 publications have been cited at least 7 times. Muller and Ayala are the second and third most influential authors with 1074 and 1060 citations, respectively. Following them are authors with CPC below 1000. Voigt and Dalenogare occupy the fourth and fifth positions. The most productive author, Tortella, is ranked as the 6th most influential author with a CPC of 655. He is followed in places 7 to 10 by the authors Buliga, Orzes, Wuest and Sarkis.

Table 4 provides information on authors, publication year, research focus, and the number of citations for the ten most influential articles during the study period. The publication year is also linked to the web link to the respective article. The most cited article was published by Frank et al. [18] and focuses on the examination of patterns in the implementation of Industry 4.0 technologies. The second most cited article by Muller et al. [19] explores how Industry 4.0 impacts the business models of small and medium-sized manufacturing companies. The third, fourth, and fifth most cited articles delve into cyber-physical systems, specifically addressing the issue of cyber-physical system security [20], key aspects, technologies, and emerging trends in industrial cyber-physical systems [21], and new challenges in data recording in intelligent cyber-physical systems that provide detailed access to various aspects of the physical world [22]. The aim of the article by Mittal et al. [23] is to critically evaluate the available maturity models of Smart Manufacturing and Industry 4.0 and analyze their suitability with regard to the specific requirements of small and medium-sized enterprises.

Table 3 Top 10 most influential authors

Autor	TNP	CPP	ACPP	H-Index
Frank, AG	1077	10	107.70	7
Muller, JM	1074	8	134.25	8
Ayala, NF	1060	5	212.00	3
Voigt, KI	947	4	236.75	4
Dalenogare, LS	834	1	834.00	1
Tortorella, GL	655	15	43.67	6
Buliga, O	548	2	274.00	2
Orzes, G	542	3	180.67	5
Wuest, T	494	6	82.33	3
Sarkis, J	447	4	111.75	3

Source: own elaboration according to WoS (2023)
Note: TNP – total number of publications; CPP – total number of citations excluding self-citations; ACPP – average citation per paper

The article by Sanders et al. [24] aims to analyze the relationship between Lean Manufacturing and Industry 4.0 and explore whether Industry 4.0 can implement Lean methods. The following most cited articles focus on the context of supply chain sustainability, specifically identifying and analyzing key challenges of the Industry 4.0 initiative in the context of supply chain sustainability in emerging economies with a focus on the Indian manufacturing industry [25], exploring the potential opportunities available in the integrated sustainable supply chain of the Internet of Things for Industry 4.0 transformation [26], and investigating the adoption of blockchain technology (a digital technology based on decentralized data storage) that ensures secure information storage and distribution in supply chain management [27].

Table 4 Top 10 most influential papers

Author and year	Area of focus of the publication	Number of citations
Frank et al. (2019)	Engineering; Operations Research and Management Science	834
Muller et al. (2018)	Business and economics; Government	437
Mitchell & Chen (2014)	Computer science	377
Leitao et al. (2016)	Computer science	358
Cai & Zheng (2020)	Engineering, Mathematics	347
Mittal et al. (2018)	Engineering; Operations Research and Management Science	342
Sanders et al. (2016)	Engineering	336
Luthra & Mangla (2018)	Engineering	332
Manavalan & Jayakrishna (2019)	Computer Science, Engineering	330
Kamble et al. (2019)	Engineering; Operations Research and Management Science	311

Source: own elaboration according to WoS (2023)

Collaboration is a fundamental aspect of research culture and provides a multidimensional perspective on scientific research and technological development [17]. To examine the relationships and interconnections between authors in the field of scientific publications focused on assessing readiness in the context of Industry 4.0, we used analytical software VOSviewer. The identification of the most contributing collaborations and active interactions between different authors in this area was achieved through co-authorship and co-citation mapping, as shown in Figures 9 and 10. We conducted a comprehensive analysis of the co-authorship network of 4,422 authors, resulting in the representation of the 14 authors with the most contributions and their collaboration over time. In this technique, the weight of the connection between two authors is determined by the number of citations between each author's publications. The more citations authors share, the stronger their connection. Additionally, the average number of citations to their publications is used to determine a score for each author. This score provides information about the overall quality of each author's research results, enabling the identification of the most influential authors in the research area. As shown in Figure 2, these 14 authors are divided into seven clusters with different numbers of co-authored works and citations. The group of authors, including Frank, Dalenogare, and Ayala, achieved the highest average co-citation score, reaching 1,158. This means that this group made the most significant contributions in the field of assessing enterprise readiness in the context of Industry 4.0.

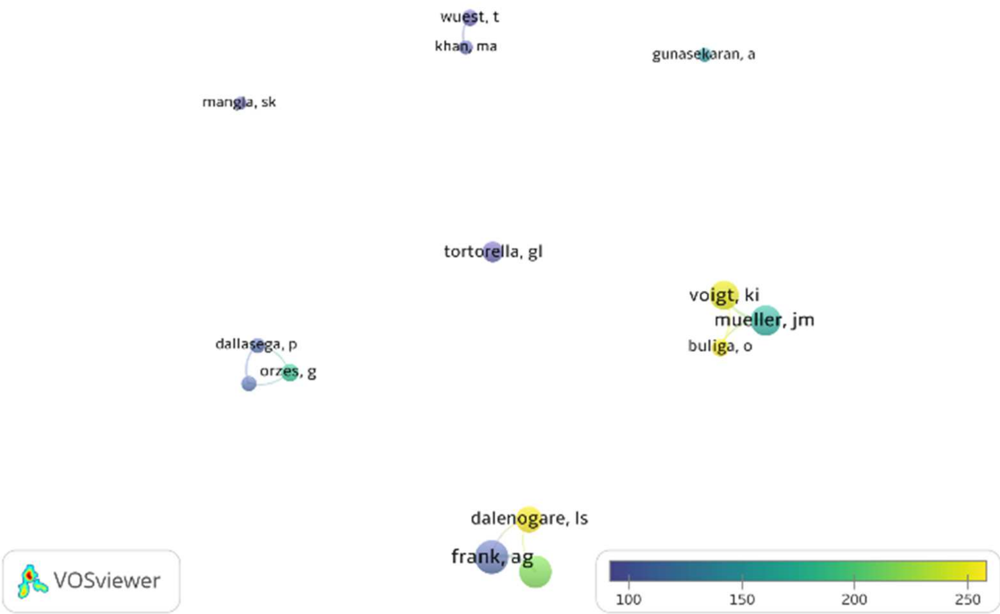

Figure 2 Collective authors´ citation
Source: own elaboration in VOSviewer

Co-citation mapping (Figure 3) focuses on the shared citations between two different documents in other publications. If two documents have a significant number of shared citations, they may be considered similar or

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related. VOSviewer represents such relationships as connections between documents. In this analysis, the minimum number of citations for an author was set at 130 to identify the most influential authors who have supported the development of this field. The results revealed the top 20 most influential authors and their co-citation networks. The authors in the network are divided into two groups, with the red part of the network dominated by author Schumacher and the green part of the network dominated by author Gobakhloo. This indicates that these authors frequently collaborated with other authors and their work was often cited by other authors in the network.

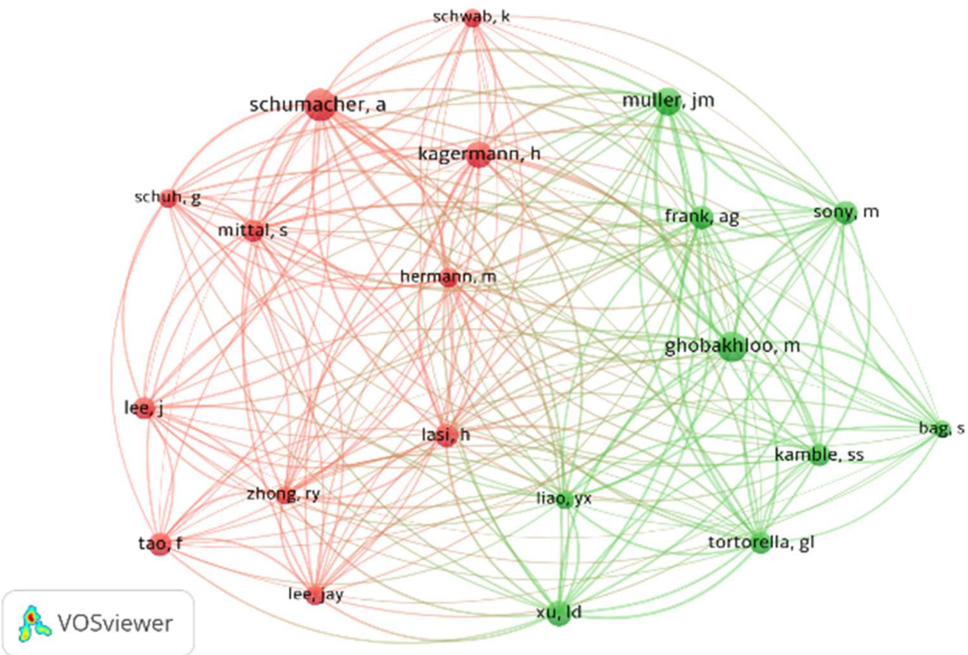

Figure 3 Authors´ interconnections in collaboration
Source: own elaboration in VOSviewer

In the ranking of countries contributing the most to addressing the issue of business readiness in the context of Industry 4.0 through their publications, China secured the top position with 191 publications (Table 5). This number represents more than 13% of the total published studies in this area. The total citations for these publications amounted to 4,108, and the achieved H-Index reached 34, which was the highest H-Index achieved among all countries. This means that at least 34 citations were received for 34 of the published papers. China is a country that has successfully incorporated ideas, technologies, and innovations ranging from computers to additive manufacturing [28]. China's prominent position in this field is not a matter of luck, as the country diligently pursues the goals of the "Made in China 2025" strategic plan, which focuses on modernization and raising the technological level in the context of Industry 4.0 [29]. The United States and India secured the second and third positions with an equal number of 139 publications, but the U.S. studies also had the highest number of citations (5,177). Following them, countries like Germany, Italy, the United Kingdom, Brazil, Australia, France, and, at the tenth position with 60 publications, Spain. Slovakia is an additional country mentioned in this ranking, ranking 21st with 31 publications.

Table 5 Top 10 most publishing countries

No.	Country	No. of publications	% of 1.425	No. of citations	H-Index
1.	China	191	13.40%	4108	34
2.	USA	139	9.75%	5177	33
3.	India	139	9.75%	3005	24
4.	Germany	116	8.14%	3746	26
5.	Italy	106	7.44%	3220	30
6.	UK	103	7.23%	3143	29
7.	Brazil	95	6.67%	2917	22
8.	Australia	65	4.56%	844	16
9.	France	61	4.28%	1915	18
10.	Spain	60	4.21%	1215	16
.					
21.	Slovakia	31	2.18%	284	10

Source: own elaboration according to WoS (2023)

To identify strong or weak connections between countries, we used a metric called "Cumulative Strength of Relations" (CSR), which expresses the strength of the connection between countries in a network of collaboration based on the weight values determined by the number of common publications among authors from those countries. Within the context of our search, we defined collaborative countries as those with at least 10 published papers, resulting in a total of 50 countries. Table 6 shows that the United States and China are the most collaborative countries, with CSR values of 141 and 138, respectively. They are followed by the United Kingdom, India and Germany.

Table 6 Top most collaborating countries

No	Country	CSR
1.	USA	141
2.	China	138
3.	United Kingdom	117
4.	India	103
5.	Germany	85

Source: own elaboration according to WoS (2023)

Figure 4 shows a graphical representation of these connections. In this image, we can observe not only the strength of connections between countries as a whole but also the placement of countries into various color-coded clusters. These clusters represent groups of countries that cooperate more with each other than with other countries. Clusters are formed based on the similarity in the number of common publications and often include countries with similar scientific profiles or geographic locations.

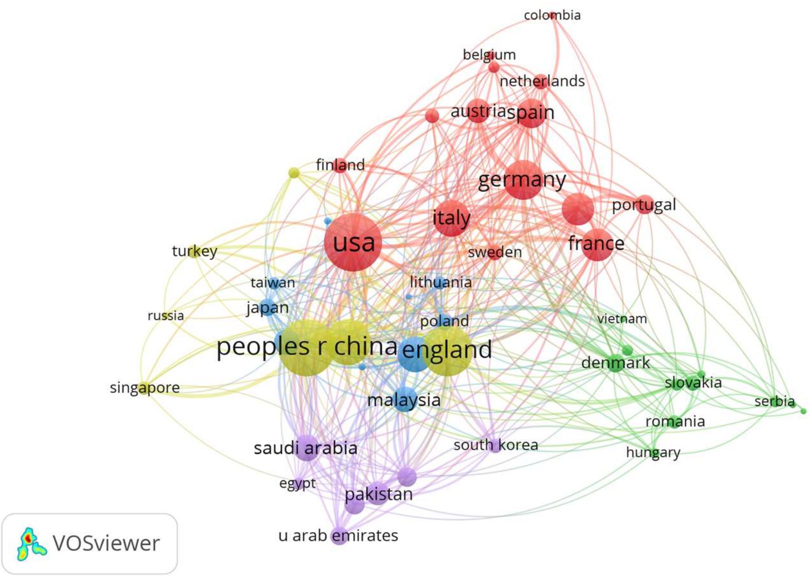

Figure 4 Co-authorship collaboration among countries
Source: own elaboration in VOSviewer

Table 7 displays the number of publications in areas related to the assessment of business readiness in the context of Industry 4.0. We can see that mechanical engineering had the highest number of publications, with 623, accounting for almost 44% of all published works. Business and economics followed with a representation of 23.79%, and computer science with 23.65%. These three areas have the largest share of the total number of publications. From this, we can infer that these areas are considered crucial for enterprise readiness in the context of Industry 4.0, and that's why scientists and researchers are most active in them. Science and technology constituted 10.39%, environmental science and ecology 8.91%. Operations research, telecommunications, materials science, and chemistry had a representation of less than 10% of all publications. Autonomous control systems had the smallest share at 4.70%.

Table 7 TOP 10 areas of investigation within the assessment of the company's readiness

Research area	No of publications	% of 1.425
Engineering	623	43.72%
Business and economics	339	23.79%
Computer sciences	337	23.65%
Science and Technology	148	10.39%
Environmental sciences and Ecology	127	8.91%
Operational Research Management Science	126	8.84%
Telecommunications	85	5.96%
Material Science	79	5.54%
Chemistry	76	5.33%
Autonomous control systems	67	4.70%

Source: own elaboration according to WoS (2023)

Table 8 lists the top 10 most popular journals in the field of assessing business readiness in the context of

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Industry 4.0. Together, they published a total of 322 articles, accounting for almost 23% of the total quantity. With 88 published works, Sustainability leads in the number of publications, representing over 6% of the total. Sustainability is an interdisciplinary journal primarily focused on theoretical advancements and practices in sustainable development and the circular economy (Sun et al., 2021). Other highly popular journals include Applied Sciences Basel, IEEE Access, Journal of Manufacturing Management, and Sensors, which published 40, 39, 28, and 25 articles, respectively. Among the top 10 journals, Sustainability, Applied Sciences Basel, IEEE Access, and Sensors have open access, while the others have partially open access, with some articles freely available but most requiring a subscription or payment for access. These 10 journals cover various topics such as sustainable development, manufacturing and economic aspects, engineering, computer and data sciences, process optimization, and the development of new technologies, highlighting the interdisciplinary nature of the field of assessing business readiness assessment in the context of Industry 4.0.

Table 8 TOP 10 most popular journals from an I4.0 readiness perspective

Journal	**No of publications**	**% of 1.425**
Sustainability	88	6.18%
Applied Sciences Basel	40	2.81%
IEEE Access	39	2.74%
Journal of Manufacturing Technology Management	28	1.96%
Sensors	25	1.75%
International Journal of Production Economics	24	1.68%
Technological Forecasting and Social Change	22	1.54%
International Journal of Production Research	20	1.40%
IEEE Transactions on Industrial Informatics	18	1.26%
International Journal of Advanced Manufacturing Technology	18	1.26%

Source: own elaboration according to WoS (2023)

Subsequently, we conducted a co-citation analysis to understand the interactions between the most influential journals in the field. The minimum number of citations for a journal was set to 600 using VOSviewer, resulting in 11 high-quality sources for co-citation analysis. The results are shown in Figure 5. Based on the co-citation activity, we identified three groups of journals. Group 1 collectively address issues related to manufacturing and production processes and related topics. Journals in Group 2 focus on innovations in IT but also provide theoretical and practical solutions for efficient management, production, distribution, and sustainability. Journals in Group 3 deal with topics related to production and the economy. Additionally, active interactions between Groups 1 and 3 and between Clusters 2 and 3 suggest that journals related to production and the economy serve as a bridge connecting issues of manufacturing and production process management with innovations in IT and the provision of theoretical and practical solutions for efficient management, production, distribution, and sustainability.

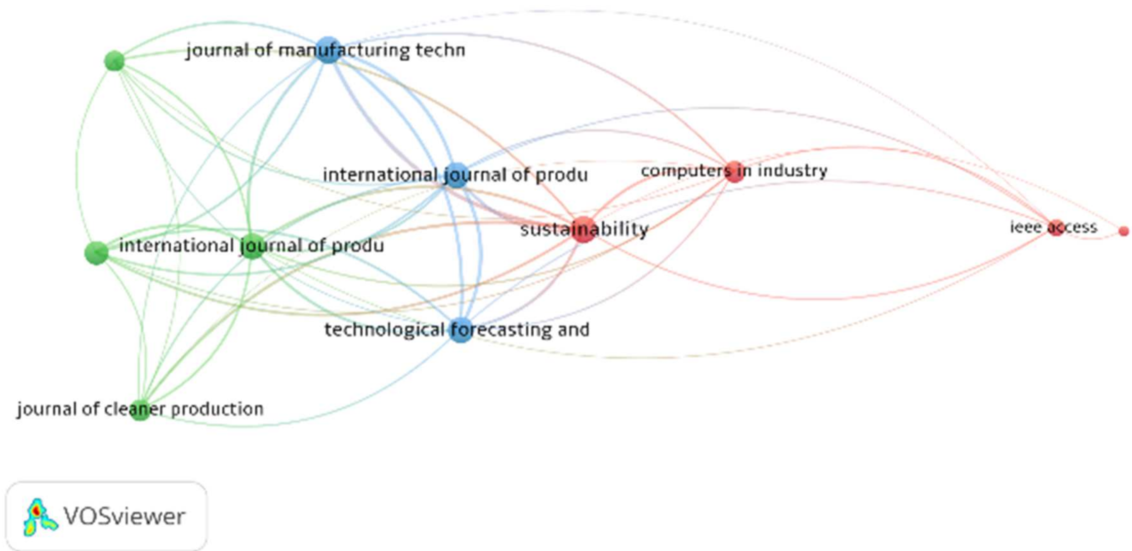

Figure 5 Most influential journal
Source: own elaboration in VOSviewer

To identify the most important and frequently occurring themes in the field of assessing business readiness in the context of Industry 4.0, we decided to analyse all the keywords that appeared in previous publications, including titles, abstracts, keywords, and author names. Figure 6 shows the mapping and interactions of the 30 most frequently occurring keywords out of a total of 5872 keywords. These keywords are grouped into three categories that can pinpoint the main research directions in the field of business readiness assessment in the context of Industry 4.0. Group 1 contains 14 keywords focused on digital transformation and innovation in the industry and management, specifically related to the concept of Industry 4.0. They are also focused on organizational preparedness and on concepts and technologies used to improve production and process management, including digitization, the implementation of new systems and technologies, and the creation of new models. In this group, the keyword "Industry 4.0" appeared most frequently, with 732 occurrences, and this keyword also showed the highest level of connectivity with other keywords. Group 2 contains 9 keywords related to information technologies, their use in the industry, and in optimizing production processes. It includes terms such as "Big Data," "Cyber-Physical Systems," "Internet of Things," "Smart Manufacturing," as well as various technological and design aspects. In this group, the keyword "Framework" appeared most frequently, with 168 occurrences, and this keyword also showed the highest level of connectivity with other keywords. Group 3 contains 7 keywords related to various factors and aspects of supply chain management and sustainability, as well as technological challenges and barriers that can influence a business's performance and success. In this group, the keyword "Performance" appeared most frequently, with 121 occurrences. The keyword "Challenges" showed the highest level of connectivity with other keywords.

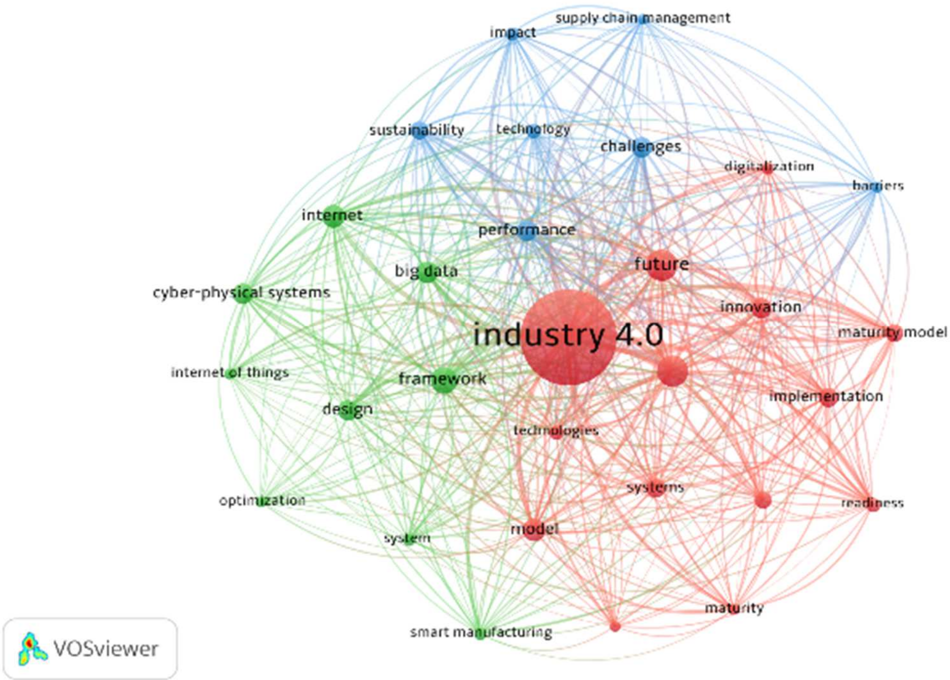

Figure 6 Most used keywords
Source: own elaboration in VOSviewer

4 Conclusions

The study has presented a detailed analysis of the state of readiness assessment for enterprises in the context of Industry 4.0, offering insights into the influential authors, countries, journals, and key research topics. China emerged as the leading contributor in terms of publication volume and citation impact, reflecting its strategic focus on technological advancement within Industry 4.0. The United States and India also play significant role in shaping this area of research.

Multidisciplinarity is a hallmark of this field, as demonstrated by the three distinct clusters of journals that span manufacturing, IT innovation, and economic aspects. Co-occurrence analysis of keywords revealed a focus on digital transformation, IT innovations, and performance.

This research serves as a valuable resource for academics, policymakers, and industry stakeholders, providing a comprehensive overview of the evolving landscape of assessing Industry 4.0 readiness. By identifying key players, trends and emerging areas, it informs future research directions and facilitates collaboration between stakeholders in this dynamic and evolving field. However, the authors are fully aware of the complexity of the topic and possibilities of expanding this research or narrowing its scope to one´s aims.

Acknowledgement
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Indicators of industry and their prediction abilities of German business cycle

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Keywords: industry, business cycle, prediction, cross-correlation, Germany.
Abstract: Industry forms an important part of the German economy and its development has a significant impact on the overall economic cycle of the country. The aim of the contribution is to identify industry indicators that would be able to predict the future development of the economic cycle in Germany. For the purposes of creating a composite indicator, the predictive capabilities of 170 indicators from various areas of industry for the quarters 2000-2022 from the European Commission database were examined. The leading capabilities of the indicators were investigated using methods such as the Hodrick-Prescot filter to select the cyclical component of the time series and cross-correlations using the Pearson coefficient to determine the relationship to the economic cycle of Germany. The industry indicators that have the highest level of predictive ability in relation to Germany's GDP include Employment expectations over the next 3 months, Assessment of the current level of stocks of finished products, Competitive position on foreign markets inside the EU over the past three months and an Industrial confidence indicator.

1 Introduction

Predicting the development of economic cycles is in the forefront of interest of many economists who are aware that it is a difficult path with an uncertain outcome. Predictions in general are associated with a high degree of uncertainty, which makes it impossible to create reliable models and procedures that would be valid over time. It is an ongoing process of searching for variables that can best predict the cyclical development of the economy at a given time. Industry indicators can be included among the groups of variables that are among the leading indicators of the economic cycle for a long time. It is the industry that forms the basis of many national economies, such as Germany, without a doubt and represents a high share of total production, employment and the creation of sustainable economic growth [1]. Industry is also a sector very sensitive to internal and external influences that can lead to fluctuations in the economic cycle. It is considered a sector that copies or even precedes the development of economic cycles. Cyclical fluctuations have a significant impact on decisions about production or reduction of activity in industrial enterprises.

Already the financial crisis in 2008 showed a strong degree of reaction of the industry to external changes which subsequently led to a drop in GDP in many countries of the world. Unexpected events such as the Covid 19 pandemic or the war in Ukraine also affected the development of industrial production. Germany has a special position in this system which results from its export-import relations with other European economies. For this reason, the development and prediction of the German business cycle is in the center of interest of many small and open economies, such as Slovakia.

Monitoring the cyclical development of industry indicators is, for example, a source of important information to support the development of future innovations, which is confirmed by studies conducted on data from Poland [2,3].

In addition to the business sector, information on cyclical development is also useful for the state in the process of preparing fiscal policy measures [4]. This issue is dealt with by several foreign studies such as Sala et al. or Buterin et al. [5,6].

Industry indicators can be found as components of composite leading indicators created by many economists as well as national and international institutions such as OECD or Eurostat. In the case of OECD, they are qualitative and quantitative industrial indicators that differ depending on the country [7]. In the case of Germany, industry is represented in the composite leading indicator by up to four indicators from the manufacturing sector, which confirms the strong position of this sector in predicting the economic cycle of Germany. Eurostat in the case of each country as well as Germany uses the Confidence indicator of industry as part of the composite indicator, which constitutes up to 40% of the total advance indicator Economic sentiment indicator [8].

Likewise, economists who deal with the creation of composite leading indicator at the national level confirm that specific industry indicators are suitable for predicting business cycles and are closely related to the industrial orientation of that country. In the case of the V4 countries, it is, for example, the study by Vraná [9]. Specifically for Poland, these are studies by Bandholz or Zalewski [10,11]. For Germany, industry indicators are found in the composite indicators constructed by Wirtschaftswoche, Obrex or Handbuch [12-14].

Most authors use industry indicators as components of composite indicators. Nasiri et al. proposed an entire composite leading indicator from industry components, declaring that this indicator has the ability to predict the business cycle at a maximum of 4 and at least 1 period ahead [15].

A prerequisite for knowing the important industry for the economic cycle of the selected country is an in-depth analysis of the cyclical behavior of industry indicators in relation to the cyclical component of the GDP of the given economy. This contribution focuses on the identification of industry initiators that have an early potential for the development of the strongest European economy, which is Germany.

2 Methodology

For the purposes of this study, 170 indicators presented by the European Commission for selected industrial categories were analyzed (Table 1). The period of 2000-2021 was selected and the data were processed with a quarterly periodicity, which ensured a sufficiently long time series to investigate the cyclical behavior of the indicators.

Table 1 List of monitored variables

Category	Type of indicators in category	Number of indicators
Business surveys		22
Production in industry: A: Total	Mining and quarrying Manufacturing Electricity, gas, steam and air conditioning supply Water collection, treatment and supply	22
Turnover in industry: A: Total B: Domestic market C: Non domestic market		34
Producer prices in industry: A: Domestic market B: Non domestic market		36
Import prices in industry		20
Labour input in industry A: Employment B: Volume of work done C: Gross wages and salaries		36
Total		170

Source: own processing.

Due to the need to identify the relationship between the components of the industrial and economic cycle of Germany, which represents the economic cycle, the following methods were used: Seasonal cleaning of time series (seasonal indices) - it is necessary to obtain cyclical components from the original data, and therefore we need to seasonally smooth the time series. We will use the method of smoothing through seasonal indices. Trend elimination (Hodrick-Prescott filter) - one of the reasons for choosing the HP filter was the fact that it can eliminate the trend component in one operation and at the same time smoothes the entire time series [16]. This allows us to obtain the cyclical components of time series, which are essential for the analysis of economic cycles.The disadvantage of the HP filter is a "problem of ends" that can be solved by predictions, for example, using the extrapolation method [17]. The filter is defined as the solution to the following optimisation problem [18]:

$$y_t = \tau_t + c_t \tag{1}$$

$$min_{\{\tau_t\}}\left\{\sum_{t=1}^{T}(y_t-\tau_t)^2+\lambda\sum_{t=2}^{T-1}[(\tau_{t+1}-\tau_t)-(\tau_t-\tau_{t-1}]^2\right\} \tag{2}$$

Where $\mathbf{y_t}$ is the original series, $\boldsymbol{\tau_t}$ is the trend component and $\mathbf{c_t}$ is the cyclical component. The method consists in minimising the deviation of the original series from the trend (the first term of the equation) as well as the curvature of the estimated trend (the second term). The trade-off between the two goals is governed by the smoothing parameter λ. The higher the value of λ, the smoother is the estimated trend.

To get optimal results for detrending, it has been suggested to choose λ=1600 for quarterly data and λ =14 400 for monthly data [16]. The advantage of the HP method is that no limitation is set on the length of the time series. However, there is a requirement that you should seasonally adjust each series before proceeding with the HP filter. The trend itself is not very interesting when analyzing cyclical behavior. Therefore, the rest of the study was done with the cyclic components of each series [19].

Cross correlation – enables the relationship between the reference series and the time series of the investigated cyclical indicators. Cross-correlations are performed with a five-period forward and backward lag using the Pearson correlation coefficient, which reflects the linear dependence between variables [20]. If this relationship is non-linear, which we find out with the help of the graph, we make it linear by transforming the variables (e.g. logarithm) and then calculate the new correlation. The relationship between industry indicators and the economic cycles of EU countries is determined based on the values of the mutual correlation of cyclical components. The monitored indicators can be considered as cyclical indicators if the second highest transition value in time t-5 to t+5 is greater than 0.55. These indicators show a cyclical relationship with the reference series, which is the cyclical component of GDP or the cyclical component of the Index of Industrial Production (IIP), which represent the business cycle of Germany.For cyclical indicators, it is possible to create three groups of indicators [21]:

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1. **Leading Cyclical Indicators -** The highest crossover value is achieved at time t-1 to t-5. These indicators evolve in advance of the development of the country's economic cycle and can be used to partially predict cycle development.
2. **Coincident Cyclical Indicators -** the highest crossover value is achieved at time t. This is a set of indicators that are evolving in line with the economic cycle of EU countries.
3. **Delayed (lagging) Cyclical Indicators -** the highest crossover value (The second highest cross-correlation value is tracked to confirm or displace the cyclical relationship. If only the highest value could be observed, it could only be a random high correlation at a given time without cyclic behaviour of the indicators) is reached at time t+1 to t+5. These indicators are developing late in the economic cycle, e.g. growth in employment and wages in the mining industry may be delayed by several quarters of GDP growth.
4. **Non-cyclical Indicators -** if the greatest cross-correlation value at t-5 to t+5 was less than 0.55. This set of indicators does not develop in any relation to the country's economic cycle. This means that growth, resp. the decline in the indicator develops independently of the evolution of the economic cycle, and so, the indicator is not sensitive to changes in the economic cycle. Due to the different units of the partial indicators, their normalised values obtained by using the standardization method are used in the composition of the composite leading indicator [22].

3 Results and discussion

3.1 Reference series representing the business cycle

When we want to monitore and predict economic cycles, it is important to choose a reference series that will appropriately copy the development of the German economy. In general, such an indicator is considered GDP or IIP. For this reason, the relationship between the cyclical components of GDP an and IIP is investigated using the Pearson coefficient.

Based on the significant position of industry in the economic cycle of Germany, it can be assumed that the IIP will behave as a concurrent indicator. This means that the highest value of the cross-correlation will be at time t. The probability of this result also increases due to the fact that we follow quarterly time series and not monthly. In the case of monthly data, there would be a greater probability of catching a lead, but this lead would be relatively short (1-2 months).

Table 2 presents the results of the cross-correlation of these indicators at time t-5 to t+5.

Table 2 The result of the cross-correlation between the cyclical component of GDP (Index, 2015=100) and cyclical component of IIP (Index, 2015=100) in the period Q1 2000- Q4 2022

Time	Cross correlation
t-5	-0,08
t-4	0,11
t-3	0,11
t-2	0,50
t-1	0,64
t	**0,92**
t+1	0,63
t+2	0,33
t+3	0,35
t+4	0,11
t+5	-0,08

Source: own elaboration.

The results from Table 2 show a strong correlation between GDP and IIP. This means that it is appropriate to use any of these time series for monitoring and forecasting the business cycle of Germany. Scientific studies more often work with GDP predictions. For this reason, we will also consider GDP as a reference serie in our contribution.

3.2 Industrial indicators used by Eurostat and OECD in forecasting the business cycle of Germany

It currently uses Eurostat and OECD industry indicators to predict the German business cycle at the international level. These selected industrial indicators have not changed over time for a long time and therefore it is important to know their predictive abilities in the present. Table 3 presents the results of cross-correlations for four industry indicators used by the OECD and the Industrial confidence indicator used by Eurostat.

Table 3 The result of the cross-correlation between the cyclical component of GDP and cyclical component of industry using by OECD and Eurostat in the period Q1 2000- Q4 2022

Indicators	**Leading period (correlation value)**
OECD indicators of industry (components of CLI)	
Manufacturong survey - export order books: level sa (% balance)	t (0.707)
Manufacturing survey - export order books: expectation (% balance)	t-1 (0.685)
Manufacturing survey - new orders	t (0.704)
Manufacturong survey - finished goods stocks: level (% balance) inverted	t-2 (0.72)
Eurostat: Industrial confidence indicator	t-2 (0.679)

Source: own calculation.

For the monitored period from Q1 2000 to Q4 2022, it was demonstrated that currently all investigated industry indicators can be considered cyclical as they show a significant relationship with the cyclical component of Germany's GDP. However, the nature of the cyclical behavior of the selected variables indicates that three indicators behave in relation to the cyclical component of Germany's GDP as concurrent indicators and also two variables have the nature of leading indicators. This means that two indicators used by the OECD can provide sufficiently high-quality information about the possible future development of the economic cycle of Germany, namely the Manufacturing survey - new orders and Manufacturing survey - export order books: expectation and the Industrial confidence indicator used by Eurostat for prediction. These indicators can provide the most accurate prediction approximately more than one quarter ahead. For this reason, it is possible to consider them as indicators that can tell us about the future direction of the economic cycle of Germany. The other two OECD Manufacturing indicators can be used to monitor, but not to predict, the German business cycle.

3.3 Industrial indicators showing a prediction before the economic cycle of Germany

In order to determine the cyclical behavior of individual industry indicators in relation to GDP, cyclical componentswere selected for all 170 indicators. These were indicators from the Business Survey category focused on the industry, where there were data of a qualitative and quantitative nature focused on expectations of new orders, competitive position or expectations of employment development. The second large group consisted of indicators focused on production in industry, turnover in industry, producer prices, import prices and labor input in industry in various categories of industry as manufacturing, mining and quarrying, electricity, gas, steam and air conditioning supply and water collection, treatment and supply. The cross-correlation results between the cyclical components of the variables indicated several significant findings. Most industry indicators showed a concurrent relationship with GDP. These were indicators from the turnover in industry and producer prices group. Labor market indicators were mostly lagged indicators. The largest group of leading indicators was in the Business Survey group.

Figures 1-4 illustrate the development of selected industry indicators and Germany's GDP. The Industrial confidence indicator is one of the components of the Economic sentiment indicator (ESI). The ESI is constructed by Eurostat on a monthly basis and is a composite indicator that captures the confidence of selectet economic subjects across sectors such as industry, construction, services and consumers.

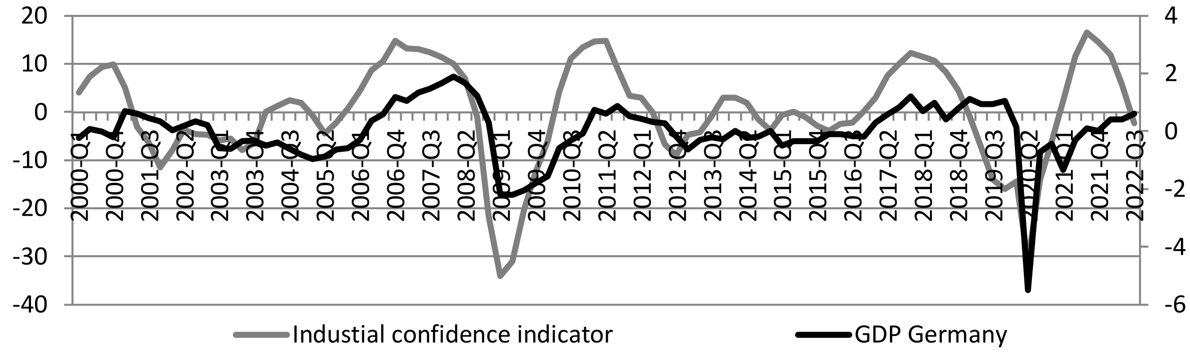

Figure 1 Development of the cyclical components of GDP (index, 2015=100) and Industrial confidence indicator for Germany
Note: All series have been seasonally adjusted, detrended and normalised.
Source: own calculation.

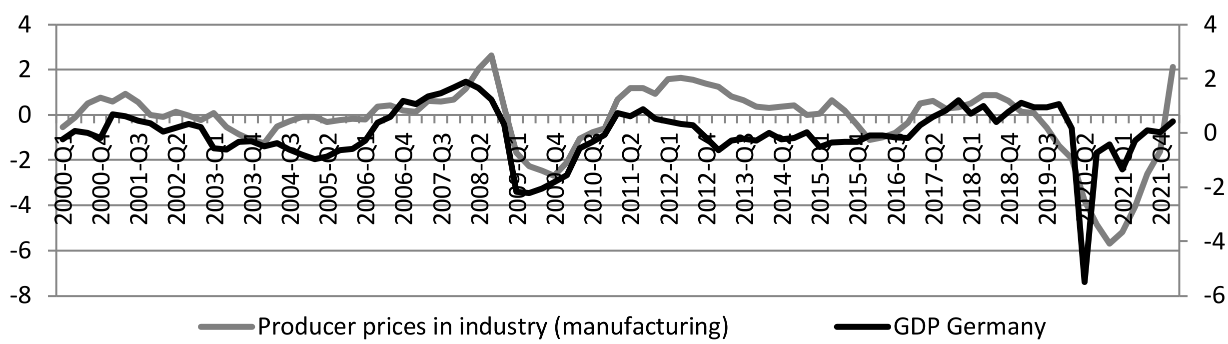

Figure 2 Development of the cyclical components of GDP (index, 2015=100) and Producer prices in manufacturing for Germany
Note: All series have been seasonally adjusted, detrended and normalised.
Source: own calculation.

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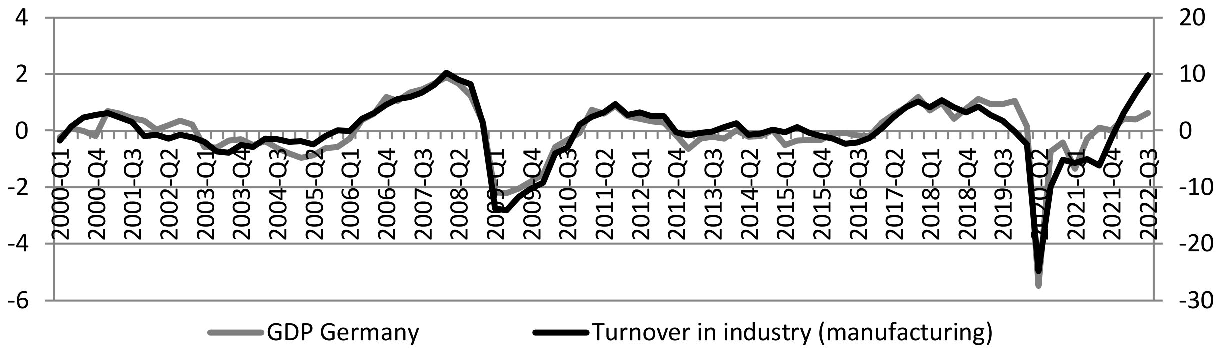

Figure 3. Development of the cyclical components of GDP (index, 2015=100) and Turnover in industry for Germany
Note: All series have been seasonally adjusted, detrended and normalised.
Source: own calculation.

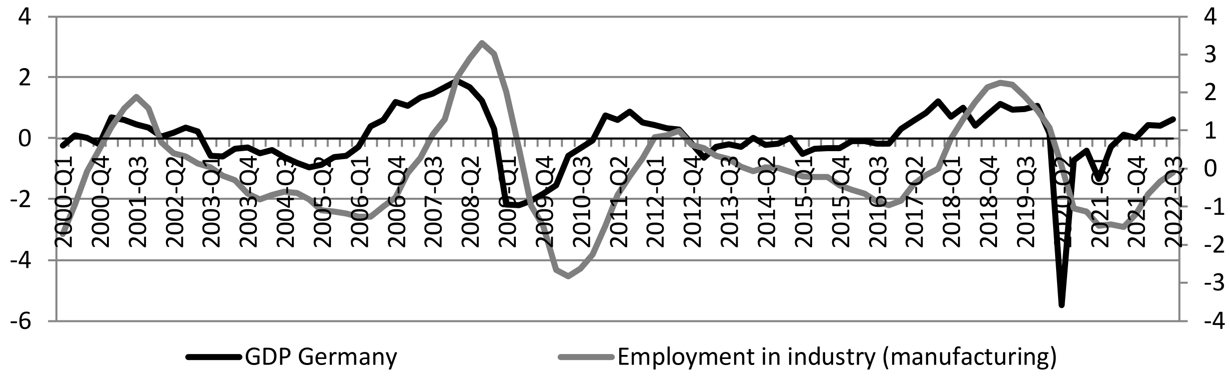

Figure 4. Development of the cyclical components of GDP (index, 2015=100) and Employment in industry for Germany
Note: All series have been seasonally adjusted, detrended and normalised.
Source: own calculation.

According to Figures 1-4, the Industrial confidence indicator is ahead of the development of Germany's GDP. This was also confirmed by the value of the cross-correlation, which was at the level of 0.687 at time t-2. The Turnover in industry indicator (manufacturing) showed a concurrence with GDP with a cross-correlation value of 0.85 at time t. Producer prices in industry (manufacturing) showed a lag for GDP at the level of 0.652 at time t+1. The development of the employment in industry indicator in the area of manufacturing was also delayed, where a delay of t+2 was recorded at the level of 0.689.

Table 4 shows the time of prediction in quarters for two groups of monitored indicators, where the advance behavior of selected indicators was recorded. This is the area of Business Survey and Manufacturing. The most lead indicators with a lead time of one to two quarters appeared in the Business Survey category.

Table 4 Results of the predictive capabilities of the Business Surveys Indicators from industry and chosen Indicators of production in industry

Business Survey indicators		**Indicators of production in industry**	
Indicator	**Time of prediction**	**Indicator**	**Time of prediction**
Production development observed over the past 3 months	**t-2**	Total (Mining and quarrying)	t
Employment expectations over the next 3 months	**t-1**	Mining of coal and lignite	x
Assessment of order-book levels	t	Extraction of crude petroleum and natural gas	n
Assessment of export order-book levels	t	Mining of metal ores	n

Assessment of the current level of stocks of finished products	**t-2**	Other mining and quarrying	**t-1**
Production expectations over the next 3 months	**t-2**	Total (Manufacturing)	t
Selling price expectations over the next 3 months	t	Manufacture of food products	t
Industrial confidence indicator	**t-2**	Manufacture of beverages	x
Assessment of current production capacity	t	Manufacture of tobacco products	x
Duration of production assured by current order-books, months	t	Manufacture of textiles	t
New orders in recent months	**-**	Manufacture of wearing apparel	x
Export expectations for the months ahead	**t-2**	Manufacture of leather and related products	t
Current level of capacity utilization (%)	t	Manufacture of wood, paper, printing and reproduction	t
Competitive position over the past 3 months: on the domestic market	**t-2**	Manufacture of paper and paper products	t
Competitive position on foreign markets inside the EU over the past three months	**t-2**	Printing and reproduction of recorded media	t
Competitive position on foreign markets outside the EU over the past three months	x	Manufacture of chemicals and chemical products	t
Factors limiting the production - None	t	Manufacture of basic pharmaceutical products and pharmaceutical preparations	x
Factors limiting the production - Insufficient demand	t	Manufacture of rubber and plastic products	t
Factors limiting the production - Labour	t	Manufacture of other non-metallic mineral products	t
Factors limiting the production - Equipment	x	Manufacture of basic metals	t
Factors limiting the production - Other	t	Manufacture of fabricated metal products, except machinery and equipment	t
Factors limiting the production - Financial constraints	n	Manufacture of computer, electronic and optical products	t

Note 1: t: concurrency, t-1, t-2, t-3: leading period length in quarters, x: indicators do not show cyclic relation, n: no data
Source: own calculation

Table 5 shows the results of cross-correlations and lead time for the six industry indicators that showed the best predictive abilities in the period under review. In the future, these indicators have the potential to form components of composite indicators designed to predict the economic cycle of Germany.

Table 5 Leading indicators of German business cycle

Indicators	Leading period (correlation value)
Industry, Employment expectations over the next 3 months, Balance	t-1 (0.703)
Industry, Assessment of the current level of stocks of finished products, Balance	t-2 (0.628)
Industrial confidence indicator, Index, 2015=100	t-2 (0.687)
Competitive position on foreign markets inside the EU over the past three months, Index, 2015=100	t-2 (0.602)
Manufacturing survey - export order books: expectation (% balance)	t-1 (0.685)
Manufacturing survey - finished goods stocks: level (% balance) inverted	t-2 (0.72)

Source: own calculation

4 Conclusions

Industry is still an integral part of the economy of many countries, among which Germany undoubtedly belongs, and plays a significant role in the creation of the country's GDP. From this point of view, it is important to know if there are sectoral indicators that could tell us about the possible future development of the country's business cycle. The aim of this contribution was to identify groups of indicators that have the ability to predict the development of the German economy. By analyzing 170 indicators, we came to the conclusion that indicators from the field of business research have the best predictive ability. These are primarily expectations of future orders or finished products, as well as expectations of employment in industry. The confidence indicator in industry was also significant. In the study, we also focused on monitoring the predictive capabilities of currently used industrial indicators used by the OECD and Eurostat.

Based on the analysis of these indicators we can claim that the Manufacturing survey indicator - new orders, Manufacturing survey indicator – expectation from OECD and the Industrial confidence indicator used by Eurostat are suitable for predicting the German business cycle. Other industrial indicators used by the OECD and Eurostat currently do not have the ability to predict the development of Germany's GDP. This means that there is an assumption that over time there is a change in the predictive abilities of industry indicators and for the needs of reliable prediction they must be changed in consideration of current developments.

The results of this study make it possible to create a composite indicator for the economic cycle of Germany in the future. However, for an overall view of the country's economy, it is necessary to supplement the analysis with other important sectors in addition to industry.

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The impact of intangible assets on market valuation: evidence from EURO STOXX 50 companies

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Keywords: intangible assets intensity, market valuation, profitability, cash holdings, panel regression.
Abstract: The impact of a company's intangible assets on its market value has been a topic of great interest. Many studies have focused on various factors, such as industry, size, age, indebtedness, and profitability of companies, which influence decisions regarding the disclosure of information about intangible assets. This study examines the role of intangible assets in the valuation of a company's market value and takes into account other firm-specific characteristics. Our analysis was conducted on a sample of 50 publicly traded companies that are part of the EURO STOXX 50 index and come from eight countries in the eurozone: Belgium, Finland, France, the Netherlands, Ireland, Germany, Spain, and Italy. The study covered a five-year period from 2018 to 2022.The results of our study indicate that intangible assets have a significant impact on a company's market value. In conclusion, our study highlights the growing importance of intangible assets in today's economy and their significant influence on a company's market value. Investors can benefit from a deeper understanding of these factors, aiding them in investment decisions. For companies, the strategic management of intellectual assets is essential for long-term success. As the importance of intangible assets continues to rise, further research in this area is necessary to gain deeper insights into their impact on the business world.

1 Introduction

The transition from industrial to knowledge-based economies has been a hallmark of economic evolution in recent decades. This shift has brought about substantial changes. not only in the way businesses operate but also in the way they create, manage, and protect their assets. At the forefront of this transformation is the increasing significance of intangible assets.

Intangibles, encompassing a wide range of assets like computerized data, economic expertise, intellectual property, and more have gained a new level of prominence. They are now considered critical drivers of a company's performance and success. In fact in some cases they are viewed as potentially more important than tangible assets [1,2]. This shift in perspective is not just a matter of academic debate; it has profound implications for the global and local economies.

At the macroeconomic level, investments in intangible capital have been growing at an unprecedented rate and are outpacing investments in tangible assets in many countries, as highlighted in the research by Dal Borgo et al. [3]. This trend suggests that nations are recognizing the need to foster innovation, knowledge creation. and intellectual property development as key drivers of economic growth.

On the microeconomic scale, it's becoming increasingly clear that effective management of intellectual property is central to a company's economic and financial success, essentially determining its survival [4]. In today's competitive and rapidly changing business environment. the strategic handling of intellectual assets has emerged as a make-or-break factor for companies.

However, despite the growing importance of intangible assets, there's a significant challenge in adequately representing their value in financial statements. The information disclosed in these statements often falls short in capturing the concealed or intrinsic value of a company's intangible assets. This limitation hinders the ability to accurately quantify the true worth of a company's intellectual capital and assess the advantages it brings to the firm [5].

Nevertheless. the importance of bridging this gap between intangible assets and financial reporting is undeniable. Understanding how investments in intangibles, as reported in financial statements, impact a company's market value can provide several benefits. It can empower potential investors to make more informed decisions, guide their investment strategies. and help them recognize the true value of the companies they're considering for investment. At the corporate level, this understanding can enhance the strategic management of intellectual assets, enabling companies to leverage their intangible resources more effectively and ultimately contribute to their long-term success.

In light of these considerations the aim of this article is to determine the impact of a company's intangible assets on its market valuation.

Theoretical background

Intangible assets do not have physical substance, and a significant number of them do not align with the conventional accounting standards for recognition nevertheless, they make a substantial contribution to the market value [6].

The motivation for a firm to invest in generating new knowledge has been a subject of extensive research in the realm of intellectual capital and intangible assets. A pivotal aspect influencing a company's commitment to increasing its intangible value is the industry in which it operates. Industry-specific attributes play a significant role in determining whether a company emphasizes building intangible assets over tangible ones. Moreover, sector-specific dynamics influence how companies acquire new knowledge and enhance their existing intangible asset base. It's important to note that there are differences in how service and non-service sectors acquire new knowledge [7]. For instance, manufacturing companies invest heavily in research and development (R&D) activities, while service sector firms often rely on external sources such as customer interactions and partnerships.

In addition to industry-related factors, the value of intangible assets is also influenced by firm-specific characteristics. Corporate governance policies play a significant role in a company's decision to disclose information about intangible assets and R&D investments. Transparent reporting of intangible assets can help reduce information asymmetry between the company and external stakeholders, leading to more favorable funding terms [8,9]. Profitable companies with consistent sales growth tend to have higher market values due to their increased intangible asset value [10].

Furthermore, companies achieving higher profitability should be encouraged to disclose information about their intangible assets in financial statements to attract potential investors. Other firm-specific factors like size, age, and debt load may also impact intangible asset disclosure. While larger companies tend to invest more in R&D, high levels of indebtedness can hinder R&D intensity [11].

The relationship between intangible assets, R&D intensity, and market value is complex and influenced by various industry and business-specific factors [12]. The disclosure of R&D expenditures in financial statements is a partial reflection of a company's innovation performance, but investors often consider this data when making investment decisions [13]. In summary, a company's market value is determined by a broad range of exogenous and endogenous factors beyond the total worth of its corporate assets [12].

2 Methodology

The objective of this study is to assess how intangible assets within a corporation influence the company's market valuation, which is estimated using Tobin's Q. The literature review reveals that a company's market value is influenced not only by the aggregate worth of its assets but also by a wide array of external and internal factors, extensively explored in empirical studies. In many cases, Tobin's Q has been frequently adopted as a proxy variable to assess a firm's value in research investigating the connection between intangible assets and the business's market worth. For example, Hall et al. [14] and Kohli et al. [15] firmly support Tobin's Q as the most suitable indicator of a company's market value, as it considers both the future potential value of the company and the expected growth stemming from R&D investments. When a company's Tobin's Q ratio exceeds one, it signifies that the market value of the company surpasses the book value of its assets. As noted by Rao at all. [16], this surplus value represents an unquantified source of worth associated with intangible assets. In line with this objective, the research hypothesis put forward is as follows: H1: The intensity of intangible assets has a statistically significant positive effect on the market valuation of companies.

We conducted data analysis pertaining to companies within the EURO STOXX 50 index, which is an equity index designed by STOXX. a Swiss index provider owned by the German company Deutsche Börse Group. This index includes the 50 largest and most liquid stock companies in Europe. specifically from eight countries in the eurozone: Belgium, Finland, France, the Netherlands, Ireland, Germany, Spain, and Italy. The companies included in this index collectively represent up to 60% of the market value of eurozone firms. making the EURO STOXX 50 a reliable indicator of eurozone development.

We worked with financial statement data from companies obtained from the Wall Street Journal database and data on firms' market capitalization available on the Companies Market Cap website. The analyzed time frame covered the years 2018 to 2022. It is important to note that we did not include data for the company Prosus from the Netherlands in our analyzed dataset. The reason for this exclusion is that Prosus was founded in 2019, and, therefore, it was not part of the analyzed period.

Significantly, companies from France, making up 32% of our sample (16 firms), and companies from Germany, comprising 28% (14 firms), are the most prominent in our dataset. Following are countries such as the Netherlands, with 12% representation (6 firms). Italy at 10% (5 firms), Spain at 8% (4 firms), Finland at 4% (2 firms), Belgium at 2% (1 firm), and Ireland at 2% (1 firm).

For the purpose of our research, we conducted a panel data regression analysis to determine the most suitable model for describing the relationship between independent and dependent variables. We used a standard methodology for estimating regression models for panel data. The estimates were performed using R Studio software and the plm package. We tested the estimated model to determine whether it is a model with significant time and individual effects or a fixed-effects model. We also examined whether the chosen econometric model satisfies the statistical assumptions.

In our regression analysis we used the following fixed effects model:

$$MV_{it} = \beta_0 + \beta_1 * IAI_{it} + \beta_2 * TAI_{it} + \beta_3 * CashHI_{it} + \beta_4 * Profit_{it} + \beta_5 * LEV_{it} + \alpha_i + \varepsilon_{it} \quad (1)$$

Where:

α_i **includes heterogeneity or individual effects, and it also contains a constant term along with a set of individual or group-specific variables, which may be observed or unobserved, but they are taken to beconstant over time t.**

Table1 Dependend and independent variables in model

Depended Variable	
Market Value	MV=Tobin's Q = market capitalization/book value of total assets.
Independed Variable	
Intangible Assets Intensity	IAI = book value of intangible assets/book value of total assets
Control Variables	
Tangible Assets Intensity	TAI = book value of tangible assets/book value of total assets
Cash Holdings Intensity	CashHI= book value of cash holdings/book value of total assets
Profitability	Profit = EBITDA/book value of total assets
Leverage	LEV = long-term debt/book value of total assets

Source: Own elaboration

In Table1 we cold see that the market value (MV) could be calculated as Tobin's Q, which is defined as the market capitalization divided by the book value of total assets.

The Intangible Assets Intensity (IAI) is determined by the ratio of the book value of intangible assets to the book value of total assets [17].

Tangible Assets Intensity (TAI) is determined as the ratio of the book value of tangible assets to the book value of total assets.

The Cash Holdings Intensity (CashHI) is calculated as the ratio of the book value of cash holdings to the book value of total assets [18].

Profitability (Profit). in this context, is computed as the ratio of EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) to the book value of total assets [19].

Leverage (LEV) is defined as the ratio of long-term debt to the book value of total assets [20].

We conducted the analysis for all companies in the index, as well as the technology sector, the energy sector, and the manufacturing sector. In energy sector, there were 4 companies from Italy, France, and Spain, specifically ENEL, Eni, Iberdrola, and TotalEnergies. In the manufacturing sector, there were 7 companies from the Netherlands, Germany, Italy, and France, specifically Airbus, BMW, Ferrari, Mercedes-Benz Group, Safran, Stellantis, and Volkswagen Group. In the technology sector, there were 6 companies from the Netherlands, Germany, Finland, and France, specifically ASML Holding, Infineon Technologies, Nokia, SAP, Schneider Electric, and Siemens.

3 Results and discussion

In order to provide an overview of the fundamental characteristics of the data utilized in our analysis, we have presented a summary of descriptive statistics in Table 2.

Table 2 Descriptive statistics

Variable	MV	IAI	TAI	CashHI	Profit	LEV
Average	0.63	0.24	0.08	0.10	0.11	0.19
Min	0.01	0.00	0.00	0.00	0.00	0.00
1Q	0.22	0.03	0.04	0.04	0.08	0.12
Median	0.65	0.18	0.06	0.07	0.09	0.20
3Q	1.57	0.37	0.17	0.13	0.13	0.26
Max	2.50	0.90	0.83	0.84	0.31	0.45

Source: Own elaboration

Considering that the average Q Ratio is approximately 0.63, it can be stated that companies in our sample have been relatively undervalued. This also suggests that market capitalization did not exceed the replacement cost of total assets for these companies on average during the period under consideration. The median for the leverage variable is approximately 20%. This means that half of the companies in the sample have a leverage value lower than 20%. while the other half has a leverage value higher than 20%. Regarding cash holdings intensity we can conclude that 75% of the companies in the sample maintain cash holdings at a level representing less than 13% of their total assets. The remaining 25% of the companies have a higher cash holdings intensity relative to their total assets. In other words, a significant portion of the companies tends to hold cash as a relatively smaller proportion of their assets indicating variability in cash holding practices among the companies in this sample. The average value of Intangible Assets Intensity is approximately 0.24. This suggests that, on average, intangible assets constitute about 24% of the total assets of the companies in the sample. It signifies the importance of intangible assets as a substantial component of these companies' total assets in this dataset.

Table 3 Descriptive statistics

	Complex	Technology	Energy	Manufacturing
IAI	1.943 **	2.179 **	0.401	-0.974
	(0.718)	(0.496)	(3.725)	(2.505)
TAI	0.95952	0.597	-10.191 **	-0.398
	(1.019)	(0.499)	(3.334)	(2.135)
CashHI	11.479 ***	-0.685	2.638	16.988 *
	(1.1780)	(0.875)	(3.764)	(6.951)
Profit	22.382 ***	0.630	25.563 ***	17.136 ***
	(2.790)	(0.770)	(6.679)	(2.790)
LEV	1.392	-1.186	8.224	-2.544
	(-1.869)	(1.270)	(4.542)	(3.855)

Source: Own elaboration

Note: Level of significance: P-value < 0.05 (*); p-value < 0.01 (**); p-value < 0.001 (***)

Our analysis aimed to understand the factors influencing Tobin's Q, which measures market value. We conducted the analysis (Table 3) for the "Complex" model and specific sectors, including "Technology," "Energy," and "Manufacturing." We found that the presence of intangible assets had a significant impact on market value. In the "Complex" model, an increase of one unit in Intangible Assets Intensity led to a substantial increase of 1.943 in market value. In the "Technology" sector, the effect was even more pronounced, with a one-unit increase in Intangible Assets Intensity resulting in a 2.179 increase in market value. However, we did not find a statistically significant impact in the "Energy" sector. In the "Manufacturing" sector, we observed a negative impact, with a one-unit increase in IAI leading to a decrease of 0.974, but this result was not statistically significant.

The "Complex" model and "Technology" sector did not show any statistically significant impact of Tangible Assets Intensity on market value. However, in the "Energy" sector, we observed a significant negative impact. An increase of one unit in Tangible Assets Intensity led to a significant decrease of 10.191 in market value. In the "Manufacturing" sector, we did not find a statistically significant impact.

The presence of cash holdings had a significant impact on market value. In the "Complex" model, an increase of one unit in Cash Holdings Intensity resulted in a significant increase of 11.479 in market value. This suggests that companies with higher cash holdings in their balance sheets tend to have significantly higher market value. In the "Manufacturing" sector, the effect was even more significant, with a one-unit increase in Cash Holdings Intensity leading to a substantial increase of 16.988 in market value.

In all sectors, we reliably found that higher profitability positively influences market value. In the "Complex" model, market value increased significantly by 22.382 for every one-unit increase in profit. The effect was even more pronounced in the "Technology" sector, where a one-unit increase in profit led to a 25.563 increase in market value. We also found a statistically significant impact of profitability on market value in the "Energy" and "Manufacturing" sectors.

Leverage had mixed impacts across sectors, indicating that different sectors have varying sensitivities to leverage. However, the estimates were not statistically significant.

4 Conclusions

The impact of a company's intangible assets on its market value has been a topic of great interest. Many studies have focused on various factors, such as industry, size, age, indebtedness, and profitability of companies, which influence decisions regarding the disclosure of information about intangible assets. This study examines the role of intangible assets in the valuation of a company's market value and considers other firm-specific characteristics.

Our analysis was conducted on a sample of 50 publicly traded companies that are part of the EURO STOXX 50 index and come from eight countries in the eurozone: Belgium, Finland, France, the Netherlands, Ireland, Germany, Spain, and Italy. The study covered a five-year period from 2018 to 2022.

The results of our study indicate that intangible assets have a significant impact on a company's market value.

Our study highlights the growing importance of intangible assets in today's economy and their significant influence on a company's market value. Investors can benefit from a deeper understanding of these factors, aiding them in investment decisions. For companies, the strategic management of intellectual assets is essential for long-term success. As the importance of intangible assets continues to rise, further research in this area is necessary to gain deeper insights into their impact on the business world.

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Industry 4.0 critics and comparative review – case study

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Keywords: Industry 4.0, Internet of Things, data analytics, automation systems, new age technologies.
Abstract: Advancements in analytics and IoT have enabled businesses to see more clearly throughout their supply chains. With this increased connectedness, supply chain management, wait times can be reduced, and logistics may be enhanced. Industry 4.0 has two effects on workers who are human. over the one hand, this enhances output and efficiency as machines take over tasks that humans can no longer accomplish. New skills and knowledge are nevertheless required as human tasks change. Regarding the need for new skills and knowledge, industry 4.0 is also having an impact on human labour. As a result of Industry 4.0, workplaces and the skills required for success are evolving. The main consequence is the need for new knowledge and abilities.

1 Introduction

The recognition of an innovation is contingent upon its potential for individual and social applications, which are multiplied and diverse due to their significance. It is also feasible to claim that true innovation consists of reshaping humanity's actual requirements by allowing the entirely unanticipated to become possible. These phrases clearly place the idea of Industry 4.0 in the innovative fields that are thought of as a theory ahead of actual practice, which is likely to create the connections between people and their societies with the future.

A sudden, drastic shift is indicated by the word "revolution." Throughout history, revolutionary shifts in social structures and economic systems have been brought about by new technology and fresh perspectives on the world.

However, the fourth industrial revolution is not limited to intelligent and networked systems and devices. Its reach is significantly wider. Concurrently, there are waves of new scientific breakthroughs in areas such as quantum computing, genome sequencing, nanotechnology, and renewable resources. Because of the confluence of these technologies and their interactions with the digital, biological, and physical worlds, the fourth industrial revolution is fundamentally different from previous revolutions.

Emerging technologies and broad-based innovation are spreading far more quickly and broadly in this revolution than in the others that are still happening in some regions of the world.

1.1 Characteristics of Industry 4.0

Characteristics of Industry 4.0:

- switch to robotronics from manual labor, ensuring that all production operations are automated.
- widespread deployment of unmanned vehicles has led to the modernization of transportation and logistical systems.
- The growth of physical system self-management and inter-machine connectivity is facilitated by the use of the Internet of Things.
- Implementation of self-learning initiatives to ensure ongoing production system development.

1.2 General views on Industry 4.0

A multifaceted concept, Industry 4.0 encompasses several aspects for diverse stakeholders. From our perspective, Industry 4.0 refers to a comprehensive set of cutting-edge technologies that assist industrial processes in becoming more dependable, efficient, productive, and customer-focused.

The change of manufacturing and other industries, driven by information, is known as Industry 4.0, among many other names. Connecting people, data, systems, services, and IoT-enabled industrial assets digitally between the physical and cyber realms is the aim of the Industry 4.0 environment. Acquiring, applying, and optimizing actionable information is the aim. Industry 4.0, according to some commentators, refers to a complete digitalization of the industrial process and a future stage of industry. Some perceive Industry 4.0 as an established concept that embodies enhanced production management and organization over complete value chains and product life cycles.

1.3 Foundational elements of the Industry 4.0 structure

Industry 4.0 frameworks are widely available. Every nation that is actively upgrading its manufacturing base has unique. Industry 4.0 is dependent on multiple cutting-edge technologies. While some are well-known, others have only recently been offered for sale.

The lists of technology used by various analysts vary slightly. (The Boston Consulting Group conducted a research in 2017 that inspired ours.) Nonetheless, Industry 4.0 frameworks typically highlight the following technologies:

Big data and advanced analytics: There are vast amounts of unanalyzed product and process data in the industrial environment. Its analysis and subsequent transformation into useful information can enhance services, optimize production quality, and facilitate quicker and more accurate decision-making.

Advanced robotics: Robots will interact with humans, collaborate with them safely, and eventually pick up knowledge from them as they develop in flexibility, cooperation, and autonomy. Industry 4.0 offers these opportunities within a production framework.

Advanced simulations: Pre-production testing and process optimization for products will be possible for operators in Industry 4.0 environments thanks to 3D simulation of product creation, material development, and manufacturing processes.

Artificial intelligence (AI) and cognitive computing: Cognitive manufacturing leverages the Internet of Things (IoT), sophisticated data analytics, and cognitive technologies like AI and machine learning. The quality, effectiveness, and dependability of industrial operations will all improve when these technologies are combined.

Industrial Internet of Things (IIoT): A growing number of products will include internet-connected components that communicate with one another via common protocols. With this manufacturing strategy, analytics and decision-making will be decentralized, allowing for real-time responses.

Additive manufacturing: In Industry 4.0 manufacturing settings, these technologies are the most effective option for creating high-performance, customized, small-batch goods.

Cloud-based service-enabling technologies: Compared to previous processes, Industry 4.0 manufacturing operations need a greater amount of data sharing between sites and businesses.

The creation of more industrial execution systems (MESs) that employ cloud-based machine data will be fueled by the move to cloud-based data management and storage.

Augmented reality (AR): AR allows real-world production views to be overlaid with virtual information to effectively portray manufacturing processes. The most likely use of AR in ASEAN nations is to teach technicians and future employees how production systems operate in real time.

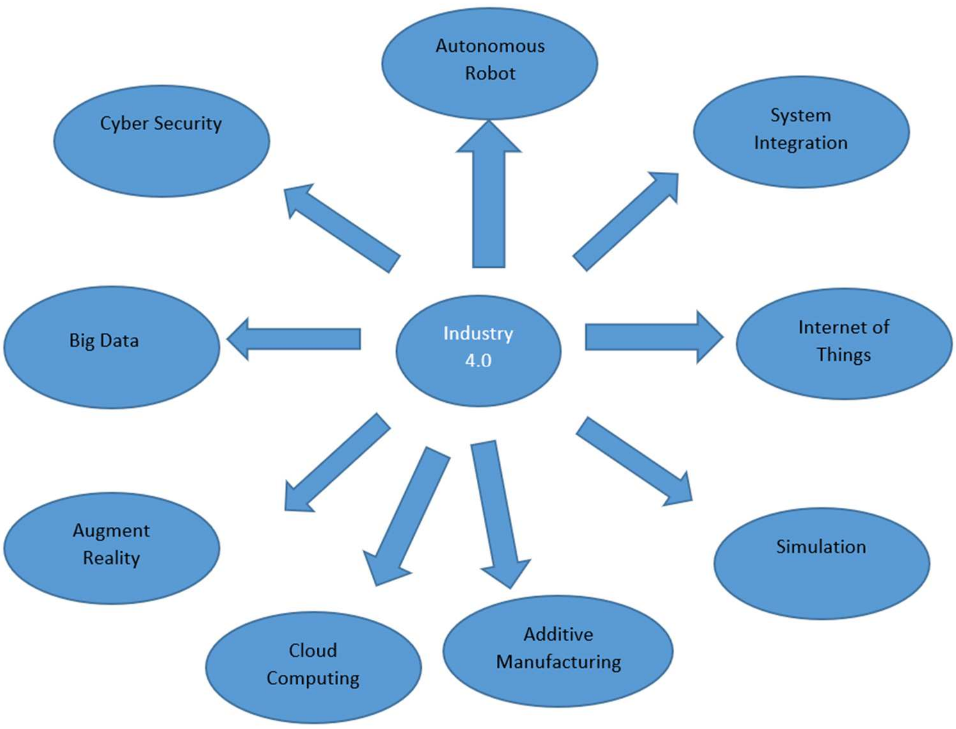

Figure 1 Industry 4.0 architecture

Figure 1 describes about the wide range of applications comprised Industry 4.0 are exemplified by Emerging Technologies. The technological world of Industry 4.0 is not one of solitary assembly lines or factories. Technologies interact with one another, with production hierarchies, with value chains, and with product life cycles in fully realized Industry 4.0 environments.

1.4 Network connectivity in Industry 4.0

Globally interconnected machinery, industrial products, internet-connected gadgets, virtual representations of these things, and people are all connected by data transmitted over digital networks. An important aspect of Industry 4.0 systems is how various degrees of human participation interact with networked machines. This ubiquitous connectivity has consequences for design and operations for Industry 4.0 manufacturing and systems engineers. Interoperability and connectivity are linked; shared communication protocols are not only becoming the standard. They are increasingly being included in the design of the production process. Cyber-physical systems the technologies that allow for the operation of smart factories are made possible by connectivity. Intelligent production objects are linked to embedded physical devices that have the ability to store and process data through cyber-physical systems.

1.5 Data integration in Industry 4.0 – overview

Throughout the product life cycle and at various levels of the production hierarchy, integration deals with the data flow between linked equipment and devices.

The term "horizontal integration" describes the linkage and data transfer between IT systems for all production and business planning procedures linked to manufacturing. Thus, digitizing supply chains and value chains as a whole is the goal of horizontal integration. End-to-end horizontal integration connects IT systems, information flows, big data, analytics, and IoT devices from supplier to customer. In conventional manufacturing thought, the steps that take place after components enter the factory floor and before they exit as a finished product were all considered to be part of the production process.

A broader viewpoint is necessary for Industry 4.0 concepts. Currently, the life cycle of a product starts with the first concepts for its development and goes horizontally through the stages of research, development, and manufacturing, ending with sales and potential recycling or disposal. The term "vertical integration" describes the connection of IT systems to equipment and machinery operating at various stages of the production hierarchy. These hierarchical tiers, to use conventional language, consist of:

- Field level: sensors translate ambient data into signals for analysis, and actuators translate signals into actions.
- At the control level, actuators are driven by controllers that collect process data from sensors.
- Production process level: wherein automated systems keep an eye on, manage, and modify particular operations inside production processes.
- The operations level is where things like quality control and production scheduling are done.
- Production planning and market analysis are made possible by the enterprise planning level, which oversees the entire production system.
- The connected global level is where production facilities are no longer isolated, expanding the traditional hierarchy. Data flow between production systems is supported and connected by network assets and procedures at this level. Industrial communications networks transfer data from one level of the hierarchy to the next, connecting all vertically integrated levels.
- We are conversant with topics like the product life cycle, manufacturing procedures, and production hierarchy. Early on in the development of Industry 4.0, the challenge was figuring out how to combine these ideas in a way that was simple to use and comprehend.

2 Literature review

Literature information focused on various review and critics on Industry 4.0 challenges and Impact in present and future.

V. Alcácer et al [1], the digital age is ushered in by Industry 4.0. Business models, surroundings, manufacturing systems, equipment, operators, goods, and services are all digital. Everything is linked together within the virtual scene and its matching virtual representation. Continuous mapping of the physical fluxes will take place on digital platforms. At an advanced stage of automation, numerous systems and software are facilitating factory communications with the newest developments in information and communication technologies, creating a state-of-the-art factory both inside and outside the plant, and completing every link in the value chain in real-time. All things are intelligent. The paradigm shift towards smart manufacturing will be made possible by this disruptive effect on manufacturing enterprises. The demise of traditional centralized applications is coming with Industry 4.0.

Jesús Hamilton Ortiz et al. [2], the concept of Industries 4.0, one of the major shifts that will define our way of life, is the main topic of this article. We want to talk about the fundamentals, process automation and enhancements, how to turn SMEs into Industry 4.0 companies, some financial and educational considerations, investment payback, and so on. Although there is much to say about this subject, our goal is to present both the industry's current state of affairs and its anticipated future developments for Industry 4.0. This chapter also outlines the transition from Industry 4.0 to Society 5.0, which in turn contains an upcoming version of Industry 5.0 that is anticipated to launch in 2020.

Yongxin Liao et al. [3], the fourth industrial revolution has garnered increasing global interest over the past few years. The state of the art for this next industrial revolution wave is still not thoroughly reviewed in the literature as it is now. By examining the scholarly advancements in Industry 4.0, this study seeks to close this gap. To analyze the scholarly articles on Industry 4.0 that were published online through the end of June 2016, a thorough assessment of the literature was conducted.

Shashank Kumar et al. [4], this paper's goal is to examine the body of material already written about

Industry 4.0 and look for new developments in this field. "-Using the inclusion and exclusion approach, research papers are chosen for the literature review. In addition, the literature is separated into three sections according to the study field and framework. The report focuses on a rapidly expanding topic of study. In addition, the several Industry 4.0 frameworks from the manufacturing, ergonomics, production, and environment domains are recognized to organize the upcoming studies.

Dan Li et al. [5], as the industrial sector grows more complicated in the context of Industry 4.0, mostly as a result of shifting consumer demands, humans become increasingly important. SMEs can gain a competitive edge by effectively handling the difficulties posed by growing complexity.

Enabling technologies that facilitate the burgeoning phenomena of Industry 4.0 may streamline knowledge and information exchange among employees, particularly for Operator 4.0. Few SMEs, nevertheless, have really used these technologies for this reason. Thus, by outlining the stages of Industry 4.0 development of SMEs in terms of their capabilities, this study seeks to increase understanding of the existing status and obstacles that need to be overcome as well as to offer some views on future prospects. This qualitative research of interviews focuses on the ways that office and assembly work are today supported by human-centered manufacturing processes. In the course of studying two Swedish SMEs, in-person interviews with nearly every member of the management team and operators were conducted to get their opinions on the companies' present capacities.

Moustafa Elnad et al. [6], one of the most discussed and popular subjects in the last few years is the idea of Industry 4.0. Over time, it has drawn interest from academics, professionals, and decision-makers all around the world. To accurately reflect the current status of this new paradigm, a more thorough evaluation of the studies in the literature is nonetheless required. In order to close this gap, a thorough analysis of prior research on Industry 4.0 will be conducted in order to determine its managerial, organizational, and technology enablers as well as its implementation benefits and obstacles. The study indicated that industry 4.0 is still an immature topic and applying this new paradigm is not a matter of technology alone. Organizational and managerial aspects should be taken into consideration. A systematic literature review was conducted, in which 244 peer-reviewed journal papers were analyzed in the Scopus database until the end of May 2022. Conference papers, book chapters, and journal papers not written in English were excluded from this study.

Dimitris Mourtzis et al. [7], by boosting operational efficiency and creating and implementing new services, products, and business models, Industry 4.0 changed manufacturing and production systems. Improving the sustainability and effectiveness of manufacturing systems was the specific benchmark for Industry 4.0. Consequently, the focus was on the digitization as well as the digitization of systems, leaving opportunity for additional development. But rather than being focused toward humans, the contemporary technological growth is primarily oriented toward systems and machines. Consequently, a number of nations have started coordinating efforts aimed at designing and developing the human-centered component of systems, services, and technologies—a concept known as Industry 5.0. Impacts from Industry 5.0 will also be felt throughout society, which will ultimately result in the creation of Society 5.0, a new society. The advances will center on the tools and technologies presented within the Industry 4.0 framework, with a particular emphasis on their social and human-centric aspects.

Wichmann et al [8], given the 21st century's digital firms' explosive growth, industrial manufacturing is predicted to be nearing the advent of Industry 4.0, the term for the fourth industrial revolution. Combining the digital and physical factories into one is the key technology that will propel this development. Experts in the field and business agree that there will be a fundamental paradigm change in the way products are created and produced. There is no consensus on how specific organizations may make use of these developments, despite widespread conviction that the future factory will have unparalleled ability to meet complicated client demands.

Marina Crnjac Zizic et al. [9], economic development is significantly influenced by the industry. But the advent of new technology and the growing intricacy of goods and manufacturing processes have a direct impact on workers and industrial businesses. The technocratic orientation of the Industry 4.0 paradigm and its emphasis on digitization were highlighted by its detractors. Consequently, the emergence of the new industrial paradigm, known as Industry 5.0, quickly set off a discussion on the purpose and justification for implementing the new paradigm. The focus on the worker, who plays a crucial part in the production process and whose function was highlighted during the COVID-19 outbreak, is what Industry 5.0 brings to the table to complement the current Industry 4.0 paradigm.

Yang lu [10], Industry 4.0, often known as the fourth industrial revolution, was first introduced in Germany and has garnered a lot of interest in recent literature. It has close ties to information and communications technology (ICT), enterprise architecture (EA), enterprise integration (EI), cyber physical systems (CPS), and the Internet of Things (IoT). Nevertheless, despite the dynamic nature of Industry 4.0 research, there hasn't been a comprehensive and methodical overview of recent studies on the topic. As a result, by looking through the body of literature in every Web of Science database, this paper undertakes a thorough analysis of Industry 4.0 and provides an overview of its findings, content, and scope. A total of 88 Industry 4.0-related articles are reviewed and categorized into five study areas.

Hamed Nayernia et al. [11], Industry 4.0 (I4.0) is a rapidly developing topic of study that combines expertise from several academic disciplines to produce innovative manufacturing solutions. The organizational aspect of implementing I4.0 has received relatively little study attention, despite the rising body of published work spanning a wide range of I4.0 subjects. This systematic review study employed quantitative analysis using text-mining 97 publications from 2015 to 2021 in order to close this gap. Eleven research streams were found by the investigation and categorized into five levels: supply chain, data, smart factories, industry and company, and human resources.

Amr Adel [12], the industry has been using industry 4.0 for the past ten years to address its inadequacies; now, industry 5.0 is finally ready. Industry 4.0 has restrictions because smart factories are raising corporate productivity. The industry 5.0 opportunities, constraints, and prospects for future research are all covered in this report. With its reduced focus on technology and assumption that human-machine cooperation is the foundation for success, Industry 5.0 is bringing about a paradigm shift and resolution. Personalized products are helping the industrial revolution increase customer happiness.

Fengwei Yang et al. [13], the ideas of Industry 4.0 were first introduced in 2011, and since then, the revolution has developed and moved beyond abstract ideas to practical implementations. Its application is widespread and has a wide range of effects on almost everyone. On a national and worldwide level, modifications are beginning to show while we adjust to new developments. It's becoming obvious that more than simply fresh ideas are at work; markets, governmental regulations, and technological developments are all interwoven like never before. Here, we provide a general explanation of Industry 4.0 concepts along with an explanation of some new terminology and problems related to completeness and clarity.

Michael Sony [14], academicians and practitioners worldwide are currently discussing Industry 4.0. Because they will enable organizations to make informed decisions about the implementation of Industry 4.0, the benefits and drawbacks of this technology are enormous. The academic literature that compiles and evaluates Industry 4.0's benefits and drawbacks is scarce, despite the fact that there are several research on the topic. This paper's goal is to examine, from an academic standpoint, the benefits and drawbacks of implementing Industry 4.0 in organizations. The early research on Industry 4.0 are the subject of a thorough and systematic review of the literature. On the remaining sixty-four articles in the sample, descriptive, category, keyword, and thematic analyses are performed. This report explains the future research areas and finds nine benefits and seven drawbacks of applying Industry 4.0 in enterprises.

Ercan Oztemel et al. [15], economic and societal advancement are significantly impacted by the manufacturing sector. Since "industry 4.0" is now a widely recognized name for research institutes and universities, the business and research communities have taken a keen interest in the project. While the concept is not new and has been discussed in academic research for many years with varying perspectives, the name "Industry 4.0" has recently been introduced and is somewhat accepted in both academic circles and the industrial society. In order to raise awareness of the greatest experiences, this report provides a review that highlights the progress. Its purpose is to offer a clear concept to anyone who want to create a roadmap for digitizing the corresponding production suits. The purpose of offering this evaluation is to give academics and industry practitioners access to a practical resource on Industry 4.0. To make sure that the evaluation procedure was reliable, the top 100 headings, abstracts, and key phrases (that is, 619 publications overall, regardless of type) for each search keyword were examined separately.

The literature review revealed that while industry 4.0 principles have the potential to progress manufacturing, they also appear to be a barrier for shop floor personnel. Information from literature addresses the historical, contemporary, and prospective conditions of industrial businesses.

3 Case study of Industry 4.0 implementation and its challenges – overview

In this section brief case study is carried out to analyze the significant importance of Industry 4.0 challenges in workplace. The analysis is carried out by survey technique through google forms. While constructing the survey the following questionnaire were listed here below:

Q1. Do you agree that the concept Industry 4.0 has more awareness towards staffs and expert members in organization?

Q2. How far Educational Institutions in India pay willingness in realizing Industry 4.0 concept in Core curriculum?

Q3. How do you rate and access the Internet speed for Industry 4.0 in Indian Educational Institutes?

Q4. Whether funded projects related to Industry 4.0 is Important?

Q5. Do you think multidisciplinary team is Important?

Q6. Do you agree the scope for increase in market growth if Industry 4.0 implemented in Indian organization?

Totally 16 responses collected from various members in different organizations like Industries, Educational Institutes etc.

The sample survey form is illustrated in table 1, as listed below.

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Table 1 Sample survey form

	B	C	D	E	F	G	H	I	J	
1	Name of the Employee	Name of the Organization	email ID of employee	Designati	Departme	Q1. Do yo	Q2. How f	Q3. How d	Q4. Wheth	C
2	Kishore Goud B	CTS	KishoreGoud.B@cognizant.com	Manager	Insurance	Yes I some	Yes I some	Better	strongly a	a
3	Bharathan	Dhaanish Ahmed college of Engineering	baskarbharath10@gmail.com	Assistant	Mechanic	Not agree	Neutral	poor	strongly a	s
4	Dr.C.Subramanian	Christ College of Engineering and Technology	csmanianmec@gmail.com	Professor	Mechanic	Yes I some	Neutral	Neutral	strongly a	a
5	Thamizhmaran.k	Christ college of engineering and technology	CCT 274	Senior ass	Mechanic	Yes I some	Yes I some	poor	agree	a
6	MD BAHAUDDIN	ISL ENGINEERING COLLEGE HYDERABAD	132	Assistant	MECHANI	strongly a	strongly a	strong	strongly a	s
7	Kannan GK	Chennai Institute of Technology	kannangk@citchennai.net	Assistant	Mechanic	strongly a	Yes I some	Better	strongly a	s
8	Rosi H	Manakula Vinayagar Institute of Technology	rosi.mphil@gmail.com	Assistant	Chemistry	strongly a	strongly a	strong	strongly a	s
9	Senthlmurugan	Yamaha	Senthilmurugan2001@yahoo.co.in	Incharge v	Vehicle as	Neutral	Neutral	Neutral	Neutral	a
10	P T RAJEENA MOL	Nehru College of Engineering and Research Centre	e 3499	Assistant	EEE	Not agree	Neutral	Better	agree	a
11	C V gowri Sankar	NIQR	cvgsankar@gmail.com	ECM	EC	strongly a	Neutral	Neutral	strongly a	s
12	Karthigayan K	Safe Infratech	879	Manager	Maintena	Neutral	Yes I some	Neutral	agree	s
13	Guru Prasath	Ccet	velayuthamb65@gmail.com	B.tech	Mechanic	Neutral	Neutral	Neutral	Neutral	N
14	Naresh	Tech Mahindra		Senior As	Technical	Neutral	Yes I some	Neutral	strongly a	s
15	Capt. I.V.S. Rama Krishna	AMET City College	captainindraganti@gmail.com	Principal	Nautical	Neutral	Not agree	poor	Neutral	s
16	K. Palani	Ashok Leyland	kpalani76india@gmail.com	Senior Ma	Safety	strongly a	strongly a	Better	agree	s
17	Padmanabhan Panchu K	Anna University	66809	Associate	Industrial	Yes I some	strongly a	Better	strongly a	a
18										
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27										

Table 1 indicates the basic information about the respondents and sharing of opinion given by the respondents are clearly indicated in the form as shown in table 1.

3.1 Observations from respondents

In the survey analysis there are totally 6 questions constructed. All questions are analyzed based on the inferences from various respondents.

Q1. It is observed that 31.3% of the employees given their opinion regarding the awareness of Industry 4.0 in workplace. Today Majority of the Organizations recognize the need of Industry 4.0.

Q2. Only 31.3% of the respondents have positively replied on Industry 4.0 concepts in the introduction of education Curriculum.

Q3. Just 12.5% of the employees given their positive opinion on network speed and access to Industry 4.0.

Q4. 56.3% of the respondents given the reply towards the financial support for carrying out projects on Industry 4.0 related work.

Q5. 56.3% of the employees accepted that cross functional team is necessary to work in Industry 4.0.

Q6. Only 50% of the employees shared their positive feelings towards market growth potential of Industry 4.0 In Indian Organization.

4 Conclusion and future scope

In this research work attempt has been made to preform detailed review and sensitivity study on Industry 4.0 with respect to Indian working climate. Case study was illustrated to analyze the potential challenges of Industry 4.0 in workplace organization through survey method. Nearly 16 responses recorded in the survey form. Based on the survey form data it is reported that most of the critical parameters like internet speed, self-readiness, Multidisciplinary approach, Market growth are some of the critical factors influences the success of Industry 4.0. Hence it is recommended to improve the infrastructure and other facilities like training, team projects etc. Management must take enough care to adopt the employees to accept the change by improving the method of work, culture etc.

4.1 Future scope

Industry 4.0 enhances the method of work apart from conventional work. It increases the productivity through smart automation method. At the outset the modern technology helps to keep the human stay strong and updated with all knowledge in recent trends of engineering and technology.

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