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ANALYZING THE ROLE OF COMPUTER SCIENCE IN SHAPING MODERN ECONOMIC AND MANAGEMENT PRACTICES. BIBLIOMETRIC ANALYSIS

Abstract:

The application of computer science in management and economics is a rapidly growing field that combines the analytical and technological capabilities of computer science with the strategic and operational needs of management and economics. The main aim of this research paper is to analyze the main academic contributors, sources, and international collaborations from 2014 to 2022 in computer science in the areas of management and economics, as well as to analyze the main subtopics developed over time. Bibliometric techniques were used to carry out the literature review, which allows an objective analysis of the academic literature through quantitative indicators. The results reveal a significant shift towards data-driven decision making in management, with artificial intelligence and machine learning improving predictive analytics, operational efficiency, and economic forecasting and modeling, highlighting the essential role of digital transformation in these disciplines, with significant implications for researchers, practitioners and decision-makers. It concludes that all stakeholders should work to develop a more informed and innovative approach to maximize the exploitation of the potential offered by computational sciences in different contexts. This includes the integration of advanced computational tools to improve decision making and operational efficiency, or the exploitation of computational models for more effective forecasting and policy decision making, as well as the continuous analysis of emerging areas in this field, being aware of the ethical, privacy and security challenges presented by these technologies, in order to ensure a responsible and equitable application.

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1. INTRODUCTION

In the dynamic and ever-progressing domain of technology, the confluence of computer science with management and economics has emerged as a cornerstone of modern organizational and economic strategies (Brauner et al., 2022; Sarker, 2022). The swift and relentless advancements in computational methods, data analytics, artificial intelligence, and machine learning have not merely altered the conventional methodologies in management and economics. They have been instrumental in the genesis of innovative paradigms and approaches that redefine how these fields operate (Milosz & Lukasik, 2015; Coccia et al., 2022; Sánchez-García et al., 2024).

The impact of computer science in the fields of management and economics extends beyond the initial layers of enhanced decision-making and data analysis, permeating deeper into the strategic fabric of these disciplines (Milosz & Milosz, 2014; Sarker, 2021; Weber et al., 2023). The introduction of advanced computational tools and algorithms in management has streamlined decision-making processes and redefined the scope and efficiency of organizational operations, facilitating a more agile and responsive management approach, capable of adapting to rapidly changing market conditions and consumer preferences (Aggarwal et al., 2022; Sharma et al., 2022), e.g., the use of artificial intelligence and machine learning in predictive analytics has enabled managers to anticipate market shifts, optimize resource allocation, and even predict consumer behavior with unprecedented accuracy.

This predictive capability especially useful in areas such as supply chain management, where AI-based forecasts can lead to more efficient inventory management and distribution strategies This significantly reduces costs and improves service levels, enabling a level of predictive analytics previously unattainable, and allowing managers to anticipate market trends, consumer behavior, and potential operational bottlenecks with greater accuracy. This is essential in processing vast amounts of data to unearth patterns and insights that inform managerial decisions (Ivanov & Dolgui, 2021; Lee et al., 2022). Moreover, the integration of big data analytics in management opened new avenues for customer relationship management and personalized marketing strategies. By analyzing vast datasets, managers can now understand customer preferences and behaviors at a granular level, allowing for more targeted and effective marketing campaigns, which optimizes marketing budgets, ensuring a higher return on investment, and may enhance customer satisfaction and loyalty (Karimjanova & Soliyeva, 2022; Manis & Madhavaram, 2023; Nojeem et al., 2023).

In connection with the above, computational advancements have revolutionized economic modeling and forecasting, since the ability to analyze large-scale economic data through advanced algorithms has facilitated more nuanced and comprehensive understandings of economic dynamics, influencing everything from monetary policy to market regulation, so that the influence of computational techniques extends to the core of economic theory and practice (Milosz & Kozhanova, 2016; Kalamara et al., 2022; Zhao et al., 2023a). In this regard, advanced computational models have enabled economists to simulate complex economic systems, providing insights into the potential impacts of various economic policies and market conditions, which is also relevant for policymakers, since these simulations can be utilized to forecast the outcomes of policy decisions, thereby making more informed and effective policy choices (Squazzoni et al., 2020; Katsamakas & Sanchez-Cartas, 2023). Furthermore, its ability to process and analyze large-scale economic

data has revolutionized the field of econometrics, enhanced the precision of economic forecasts, and enabled a more nuanced understanding of economic relationships and causality (Kar & Dwivedi, 2020; Ferguson-Cradler, 2023; Kuroki, 2023).

This integration has facilitated the exploration of new economic concepts and models, e.g., the analysis of network effects in digital economies, the dynamics of cryptocurrency markets, and the economic implications of digital platforms. They are all areas that have gained prominence due to the computational capabilities available to modern economists, which represent new frontiers in economic research and policymaking, offering insights into how digital transformation is reshaping economic landscapes (Monaghan et al., 2020; Gregory et al., 2021; Ni et al., 2023). Therefore, the relevance of computer science in management and economics is profound and far-reaching, and its integration has not only enhanced existing practices but also paved the way for innovative approaches and methodologies, so that as these fields continue to evolve in the digital age, the role of computer science as a key driver of change and innovation becomes increasingly apparent, promising further advancements and discoveries in the management and economic sciences (Khan et al., 2020; Brem et al., 2021; Abdurakhimovich, 2023; Schubert et al., 2023).

However, this integration is not without its challenges (Almeida et al., 2020; Sadeeq et al., 2021; Telukdarie et al., 2023), e.g., there are ethical, privacy, and security implications of deploying artificial intelligence and machine learning in sensitive economic and management contexts. Issues such as algorithmic transparency, data bias, and the digital divide pose significant challenges to the equitable and effective application of these technologies (Shin & Park, 2019; Akter et al., 2021; Nazer et al., 2023). Therefore, the need for this research arises from the profound and transformative impact of computer science on management and economics, since as these fields evolve with the digital age, the integration of computational methods, data analytics, artificial intelligence, and machine learning has enhanced traditional practices and introduced innovative paradigms and approaches that redefine operational and strategic decisions.

The main aim of this research is unveiling the main sources, contributors, and research subtopics in the field under study, as well as to provide a balanced perspective by acknowledging both the transformative potential of these technologies and the complexities they introduce into the fields of management and economics. Thus, we provide a holistic approach for understanding how these technologies are reshaping the current managerial and economic context, which is essential for scholars, practitioners, and policy makers to adequately interpret the profound impact of digital transformation on these vital areas of study and practice.

Bibliometric techniques allow the identification and comprehensive analysis of the most influential research papers and key trends, increasing the depth and breadth of literature reviews, and contributing significantly to the systematic and rigorous exploration of academic fields (Martínez-Falcó et al., 2023a; Montalvo-Falcón et al., 2023). In this regard, this methodology offers several advantages that enhance the quality and scope of traditional literature reviews, since they allow to cover a wide range of studies and perspectives, which is especially crucial in broad fields (Marco-Lajara et al., 2023a; Sánchez-García et al., 2023). Unlike traditional review methods, which can be influenced by the subjective biases of the researcher, bibliometric techniques rely on quantitative data, such as citation counts and keyword co-occurrence, to draw conclusions, thus bringing an objective perspective to the review process (Borgholthaus et al., 2023; García-Lillo et al., 2023).

It is worth mentioning that bibliometric analysis has the ability to identify current research trends and major hubs of activity through the examination of keywords and citation networks, providing guidance for future research (Martínez-Falcó et al., 2023b; Zhao et al., 2023b). In addition, bibliometric tools often incorporate advanced visualization techniques, such as mapping or network analysis, which transform complex data into more accessible and understandable formats, revealing patterns and relationships that might be obscured in traditional analyses, helping to interpret the data, and improving the communicative aspect of research results (Ellis et al., 2019; Marco-Lajara et al., 2023b).

In addition, bibliometric analysis is invaluable in assessing the impact and influence of specific research works or authors within a field, making possible to discern the most influential studies or researchers by scrutinizing citation patterns, thereby acknowledging significant contributions to the field, which is crucial in recognizing and understanding the pillars upon which current research stands (Ellegaard et al., 2015; Migliavacca et al., 2022). Furthermore, they provide a holistic view of research efforts and collaborations worldwide, an essential factor in today's increasingly interconnected academic context (Sezgin et al., 2022; Gupta et al., 2023).

This study is based on an extensive dataset that includes 3478 scholarly articles authored by 10,129 researchers from 102 different countries, from January 1, 2014, to December 31, 2022. Collectively, these publications have accumulated 26,537 citations and are underpinned by a substantial bibliographic base comprising 105,523 references. Following the initial introduction, the subsequent section of the paper delves into the research methodology employed. This is followed by a detailed examination and discussion of the findings. The paper concludes by summarizing the insights gained from the analysis, reflecting on potential limitations, and proposing directions for future research.

2. METHODOLOGY

For the compilation of academic papers, this study primarily utilized the Web of Science (WoS) database. The choice of WoS was influenced by its minimal redundancy and its advanced capabilities for conducting detailed temporal searches. Its reliability as a scholarly source is well-recognized, as noted in recent studies (Dima et al., 2022; Popescu et al., 2022). This research focused on analyzing the literature on the role played by computer science in the areas of management and economics. The search parameters were defined as: “TS = ("computer science*" OR "computer app*" OR "computer tech*") AND ("management" OR "economic*").

This approach was restricted to peer-reviewed articles published from January 1, 2014, to December 31, 2022, ultimately yielding a collection of 3478 documents. The main information of the database analyzed is displayed in Table 1. To refine the database, we have used the PRISMA statement, which is a key tool when conducting and reporting systematic reviews and meta-analyses, lying its primary importance in enhancing transparency, as it provides a detailed checklist and flow diagram, ensuring that every facet of the review process is clearly documented (Innocenti et al., 2022). The information in this respect is displayed in Figure 1.

This transparency is crucial for the replicability of studies and for their critical appraisal by peers and other stakeholders, since this technique standardizes the reporting of systematic

reviews, fostering consistency across studies, which is essential for comparing and synthesizing research findings effectively, so that by adhering to these guidelines, researchers can significantly improve the quality and credibility of their reviews, as it helps in identifying potential biases and ensures comprehensive coverage of relevant literature, guides the literature search process, a critical step in systematic reviews, influencing the scope and depth of findings (Ardern et al., 2022; Carbonell-Alcocer et al., 2023).

Tab. 1. Main information

Main information data	
Sources	2350
Documents	3478
Average age of documents	6.1
Average citations per document	7.63
References	105.523
Document contents	
Keywords Plus (ID)	3187
Author's Keywords (DE)	10151
Authorship	
Authors	10129
Authors of single-authored articles	683
Authors collaboration	
Single-authored articles	710
International co-authorships %	18.72

Source: Own elaboration.

Its endorsement by many academic journals underscores its role in facilitating the publication and dissemination of research, thus standing out as an indispensable guideline in academic research, ensuring the reliability and utility of systematic reviews and meta-analyses in contributing to the scientific community (Castro Arteaga et al., 2022; Boyadzhieva et al., 2023).

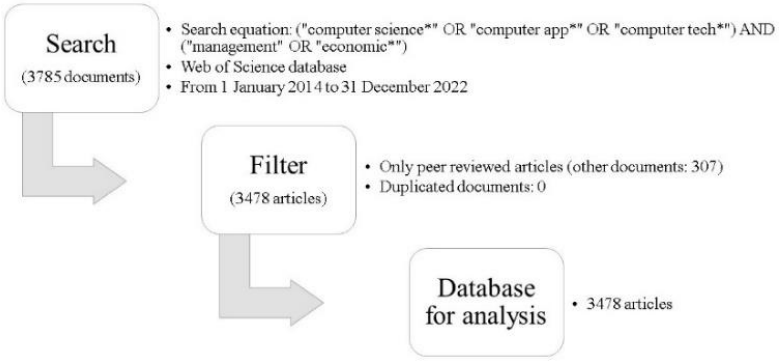

Fig. 1. PRISMA statement

Furthermore, as indicated in the introduction, bibliometric methods offer an objective, data-driven analysis of different academic fields, minimizing subjective biases through quantitative indicators such as citation counts, and improving literature reviews by providing a global view of research trends, seminal papers, and knowledge gaps. In this sense,

advanced bibliometrics visualization tools reveal complex patterns and relationships, help interpret data and identify research fundamentals, thus contributing to the understanding of the dynamics of scholarly research and providing guidance for future research.

3. RESULTS AND DISCUSSION

3.1. Academic literature on computer science in the areas of management and economics

An overview of the publication trends from 2014 to 2022 in the top ten leading journals focusing on computer science as applied to management and economics is presented in Table 2. A total of 199 articles were published across these journals during this period, accounting for approximately 5.40% of the publications in the field.

Tab. 2. Leading journals in the field under study

Year	IEEE	Scient	Sust.	CIN	Heliyo	MIS	IJET	IJCSN	AGI-	JIFS	Total
2014	0	2	0	0	0	0	0	1	0	0	3
2015	1	3	0	0	0	0	0	0	0	0	4
2016	0	3	0	0	1	0	0	1	0	1	6
2017	1	6	0	0	1	0	1	2	13	0	24
2018	3	1	1	0	0	0	3	0	0	1	9
2019	7	1	5	0	8	0	5	0	0	3	29
2020	11	3	3	0	7	0	2	2	0	3	31
2021	7	5	8	1	1	2	2	4	0	5	35
2022	7	3	6	17	0	15	2	4	0	0	58
Total	37	27	23	18	18	17	15	14	13	13	199
%	1.00	0.73%	0.62	0.49	0.49%	0.46	0.41%	0.38%	0.35	0.35	5.40

Source: Own elaboration. Note: Note: IEEE A.: IEEE Access; Scient.: Scientometrics; Sust.: Sustainability; CIN: Computational intelligence and neuroscience; MIS: Mobile information systems; IJETL: International journal of emerging technologies in learning; IJCSNS: International journal of computer science and network security; AGI-HT: Agri food industry hi-tech; JIFS: Journal of intelligent & fuzzy systems.

The data reflects an increasing trend in research publications in computer science applications in management and economics, highlighting the growing importance and interdisciplinary nature of this field. The diverse range of journals contributing to this body of work underscores the multifaceted approach researchers are taking to explore the intersection of these disciplines. In the initial years (2014-2016), the publication activity was relatively low, with only a handful of articles being published across these journals. For instance, in 2014, there were only 3 publications in total, with 'Scientometrics' contributing two articles and 'International Journal of Computer Science and Network Security' one. This trend saw a slight increase in 2015 and 2016, but the numbers remained modest.

However, there was a notable surge in publication activity from 2017 onwards. In 2017, the total number of publications jumped to 24, with a significant contribution from 'Agri Food Industry Hi-Tech'. This upward trend continued, with 2019 and 2020 witnessing 29 and 31 publications, respectively. Notably, 'IEEE Access' and 'Heliyon' showed a marked increase in their contributions during these years. The year 2021 marked another increase, with 35 publications in total. This year, 'Sustainability' led the way with 8 publications,

followed by 'IEEE Access' and 'Scientometrics'. The diversity in journal contributions indicates a broadening interest and research in the field. The most remarkable year in the dataset is 2022, which saw a significant leap to 58 publications. This year was marked by a substantial increase in articles from 'Computational Intelligence and Neuroscience' and 'Mobile Information Systems', indicating a growing interest in these areas within the context of management and economics.

3.2. Most relevant contributions on computer science in the areas of management and economics

The most prominent authors in computer science in the areas of management and economics are displayed in Table 3 using different indicators that, in addition to showing their prolific careers, expose the significant impact and quality of their research in shaping the field. When analysing them, there is a clear hierarchy of impact and contribution based on their presence in the various classifications.

Tab. 3. Leading authors

Rank	**Authors**	**A.P.**	**MLC authors**	**L.C.**
1	Zhang, Y.	15	Milosz. M.	15
2	Li, Y.	13	Milosz. E.	8
3	Zhang, J.	13	De La Sotta, C.	5
4	Milosz, M.	11	Merigó, J.M.	5
5	Wang, L.	10	Pedrycz, W.	5
6	Li, J.	9	Weber, R.	5
7	Liu, Y.	9	Aziz, H.	4
8	Wang, X.F.	8	Mackenzie, S.	4
9	Liu, H.	7	Bal, R.	3
10	Liu, L.	7	Barmasov, A.V.	3
Rank	**Authors**	**H-ind.**	**Authors**	**F.A.**
1	Zhang, J.	6	Zhang, J.	5.37
2	Milosz, M.	5	Milosz, M.	5.08
3	Chen, Y.	5	Zhang, Y.	4.57
4	Liu, H.	5	Li, Y.	4.19
5	Wang, H.	5	Chirila, C.B.	4
6	Wang, X.F.	5	Wang, L.	3.93
7	Zhang, Y.	5	Li, J.	3.86
8	Dickerson, J.P.	4	Liu, Y.	3.40
9	Li, Y.	4	Milosz, E.	3.33
10	Abad-Segura, E.	3	Ogiela, U.	3

Source: Own elaboration. Note: MLC = Most local cited; A.P. = Articles published; L.C.: Local citations; G.C.: H-ind = H-index; F.A.: Fractionalized articles.

It is worth noting that the Polish researcher of Lublin University of Technology, Marek Miłosz, is the only author ranked as top ten in all four rankings, being the most local cited author (15), ranking second per articles fractionalized (5.37) and H-index (5), and fourth per number of articles published (11). Regarding to the authors present in three of the four classifications, Zhang, Y. emerges as a prolific author, leading the pack with 15 published articles and securing a spot in the top ten for both H-index and fractionalized articles, although he does not appear in the category of most cited locally. Similarly, Li, Y. showcases

a strong publication record with 13 articles, complemented by notable rankings in the H-index and fractionalized articles categories, yet, like Zhang, Y., lacks presence in the most local cited list. Zhang, J. parallels this trend, tying for second in articles published, while leading the field with the highest H-index and topping the fractionalized articles ranking, again missing from the most local cited category. These authors, through their significant contributions to a number of indicators, demonstrate not only a high volume of research output, but also the impactful and influential nature of their work in this interdisciplinary domain.

For their part, there are several authors present in two of the four rankings, among whom it is worth noting Polish researcher Elżbieta Miłosz, who also belongs to Lublin University of Technology and ranks second in terms of local citations and ninth in terms of fractional articles. In the interdisciplinary field of computer science applied to management and economics, a selected group of authors have distinguished themselves by featuring in the top ten across two of the four key classifications: Articles Published, Most Local Cited, H-index, and Fractionalized Articles. Wang, X.F. and Liu, H. both demonstrated a strong combination of prolific output and research impact, with notable rankings in both Articles Published and H-index. Similarly, Liu Y. and Li J. exhibit their academic influence through a high number of articles published and significant presence in Fractionalized Articles, indicating both the quality and reach of their research. These authors, through their presence in two distinct categories, not only demonstrate a balance of quantity and quality in their research but also highlight the multifaceted nature of contributions in this evolving field.

Table 4 provides an overview of the impact and reach of the most relevant global and local papers.

Tab. 4. Most cited papers

Per global citations	**GC**	**GC per**	**Normalized GC**
Zheng, Y., 2014, Acm T Intel Syst Tec	729	72.90	48.58
Ceci, S.J., 2014, Psychol Sci Publ Int	517	51.70	34.45
Gupta, M., 2014, IEEE T Knowl Data En	503	50.30	33.52
Michie, S., 2017, J Med Internet Res	399	57.00	49.35
Wu, J., 2015, IEEE Network	314	34.89	41.08
Pizzi, G., 2016, Comp Mater Sci	309	38.63	39.60
Dorri, A., 2018, IEEE Access	266	44.33	27.79
Tan, G.W.H., 2014, Comput Hum Behav	258	25.80	17.19
Qiu, T., 2018, IEEE Commun Surv Tut	257	42.83	26.85
Donaldson, D., 2016, J Econ Perspect	229	28.63	29.35
Per local citations	**LC**	**LC/GC**	**NLC**
Merigó, J.M., 2018, Inform Sciences	5	2.86	90.45
Milosz, E., 2014, Iceri Proc	4	21.05	75.50
Dzienkowski, M., 2016, Inted Proc	3	33.33	40.24
Li, L.Y., 2017, Comput Educ	3	3.13	72.75
Yu, D.J., 2018, Knowl-Based Syst	3	3.45	54.27
Chyrun, L., 2019, Ceur Workshop Procee	3	17.65	52.57
Milosz, E., 2015, Edulearn Proc	2	200.00	50.43
Plechawska-Wojcik, M., 2015, Edulearn Proc	2	28.57	50.43
Milosz, M., 2015, Inted Proc	2	50.00	50.43
Stankova, E.N., 2016, Lect Notes Comput Sc	2	25.00	26.83

Source: Own elaboration. Note: LC = Local citations; GL = Global citations.

The metrics offer a multi-dimensional view of academic influence, encompassing both the breadth of global recognition and the depth of local relevance. Regarding to the top ten papers per global citations, leading this category is Zheng, Y.'s 2014 publication which got 729 citations, and a high normalized citation score of 48.58. This indicates not only the paper's immediate impact but also its enduring relevance in the field. This is followed by articles by Ceci, S.J., 2014 and Gupta, M., 2014, which also show a significant global citation count, reflecting their significant impact and ongoing relevance in the academic community.

For the most cited articles locally, in addition to the number of local citations, the LC / GC ratio and the normalised local citations are displayed. Here, Merigó, J.M.'s 2018 publication leads with 5 local citations, a high LC/GC ratio of 2.86, and an outstanding normalized local citation score of 90.45, indicating a strong local impact and relevance. Moreover, Milosz, E. features prominently with publications in 2014 and 2015, showing not only multiple local citations but also high LC/GC ratios and normalized scores, suggesting a significant local influence. Other notable mentions include Dzienkowski, M., Li, L.Y., and Yu, D.J., each contributing valuable research with a notable local impact, as evidenced by their local citation metrics.

Figure 2 underscores the diverse and international nature of research in computer science as it applies to management and economics, by presenting a compelling overview of the leading universities in terms of their contributions to the field of computer science as applied to management and economics. It highlights the institutions that have been most prolific in publishing articles in this interdisciplinary area.

At the forefront is the University of California System in the USA, with 51 articles, reflecting its significant role in advancing research at the intersection of computer science, management, and economics. Following closely is the University of London in the United Kingdom, contributing 43 articles, indicative of the UK's strong presence in this research domain. Purdue University, also in the USA, stands out with 33 publications, reflecting its robust research activities in these fields. The University College London and the University System of Georgia, each with 23 articles, further emphasize the UK and USA's dominance in this area of study. The Russian Academy of Sciences in Russia, with 22 publications, marks a significant contribution from Eastern Europe. Similarly, the Centre National De La Recherche Scientifique (CNRS) in France, the Chinese Academy of Sciences in China, and the Egyptian Knowledge Bank (EKB) in Egypt, each with 20 articles, demonstrate the global nature of research in this field.

The Georgia Institute of Technology in the USA, with 20 publications, adds to the USA's strong representation, and the University of Toronto in Canada, with 18 articles, shows North America's continued influence in this research area. Other notable institutions include the University of California Berkeley, Polytechnic University of Bucharest in Romania, Pennsylvania Commonwealth System of Higher Education, Universite Paris Cite in France, University of Florida, University of Michigan, Lublin University of Technology in Poland, and Harvard University, each contributing significantly to the body of research in this specialized field.

The volume of research output from various countries is exposed in Table 5, which sheds light on the nature of collaborations and the global impact of the research through citations, underscoring the diverse approaches to research collaboration and dissemination in the field.

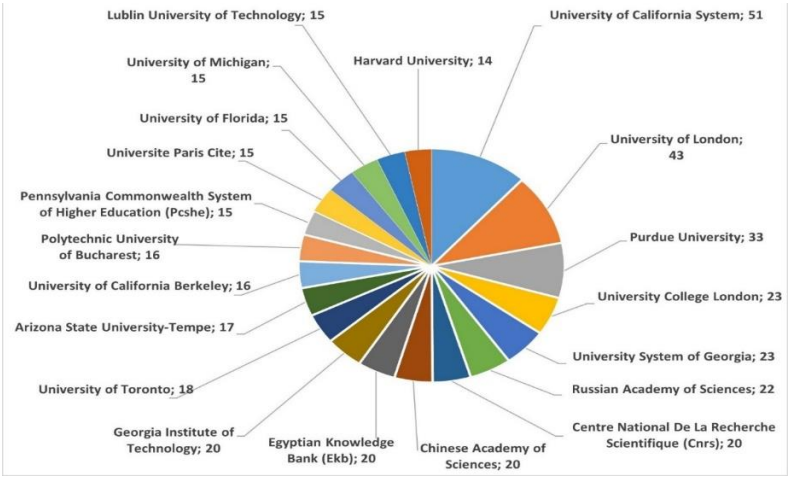

Figure 2. Leading universities

Some countries focusing more on domestic collaboration while others engage more actively in international partnerships, all contributing to the global knowledge pool in computer science applied to management and economics.

Tab. 5. Leading countries

Rank	Country		A.P.	SCP	MCP	MCP	Country	Cites	A.A.C.	A.P.
1	China		777	666	111	14.30%	U.S.A.	5909	12.70	465
2	U.S.A.		465	392	73	15.70%	China	4224	5.40	777
3	Russia		146	131	15	10.30%	United	1623	13.30	122
4	India		134	116	18	13.40%	Australia	1281	21.70	59
5	Spain		126	101	25	19.80%	Italy	1086	10.50	103
6	United		122	80	42	34.40%	India	1077	8.00	134
7	Germany		111	94	17	15.30%	Germany	927	8.40	111
8	Italy		103	85	18	17.50%	Canada	887	15.60	57
9	Poland		95	90	5	5.30%	Spain	801	6.40	126
10	Brazil		76	63	13	17.10%	Singapore	612	43.70	14
11	Romania		67	62	5	7.50%	Korea	573	17.40	33
12	France		65	38	27	4.15%	France	541	8.30	65
13	Ukraine		62	58	4	6.50%	Switzerland	481	28.30	17
14	Australia		59	31	28	4.75%	Turkey	465	11.60	40
15	Canada		57	42	15	2.63%	Netherlands	359	16.30	22
16	Indonesia		51	49	2	3.90%	Portugal	331	7.70	43
17	Portugal		43	31	12	2.79%	Poland	298	3.10	95
18	Turkey		40	38	2	5.00%	Saudi Arabia	267	8.30	32
19	Greece		36	28	8	2.22%	Sweden	254	14.90	17
20	Japan		34	25	9	2.65%	Japan	253	7.40	34
21	Korea		33	22	11	3.33%	Iran	231	7.20	32
22	Iran		32	29	3	9.40%	Chile	227	13.40	17
23	Pakistan		32	20	12	37.50%	Brazil	224	2.90	76
24	Saudi		32	25	7	21.90%	Russia	224	1.50	146
25	Czech		30	28	2	6.70%	Pakistan	208	6.50	32

Source: Own elaboration. Notes: A.P. = Articles published; SCP = Intra-country collaboration; MCP = Multi-country collaboration; AAC = Average article citations.

As can be seen, China leads in terms of articles published with 777, though its multi-country collaboration ratio is relatively modest at 14.30%., which suggests a strong domestic research environment with some international collaboration. For its part, the United States, ranking second per articles published (465), shows a slightly higher MCP ratio (15.70%) and leads in citations with a total of 5909, averaging 12.70 citations per article, reflecting a prolific output and a significant international impact and collaboration. Russia, with 146 articles, and India, with 134, are focused on domestic collaboration, as indicated by their lower MCP ratios. Spain, with a higher MCP ratio of 19.80%, suggests a more outward-looking research approach, engaging more in international collaborations.

The United Kingdom, though lower in article count (122), has a high MCP ratio (34.40%) and a significant number of citations (1623), indicating a strong international collaboration and impact. Similarly, Australia, with fewer articles (59), shows a remarkable average citation count of 21.70 per article. Countries like Italy, Germany, and Canada also demonstrate a balance between domestic and international collaborations, with their research receiving substantial citations. Poland, with 95 articles, has a low MCP ratio (5.30%), suggesting a focus on domestic collaboration, yet its average citations per article are relatively lower. In contrast, countries like Singapore, Korea, and Switzerland, with fewer articles, show exceptionally high average citations per article, indicating the significant impact of their research on a global scale.

The analysis of the most used keywords, exposed in Table 6, paints a picture of a field that is not only rich and diverse but also constantly evolving, with research spanning from foundational computer science principles to cutting-edge applications in artificial intelligence, big data, and beyond. The interplay between these topics reflects the dynamic nature of research in computer science as it intersects with management and economics, continually adapting to new technologies and societal needs. At the forefront is computer science, a term that unsurprisingly anchors the field (216 occurrences). This prevalence underscores the foundational role of computer science in shaping research across various domains, particularly in management and economics. Artificial intelligence and big data follow closely (88 and 84, respectively), reflecting their growing importance in transforming business practices, decision-making processes, and economic theories. The prominence of machine learning, with 83 occurrences, further emphasizes the shift towards automation and predictive analytics in various sectors.

The keyword education (76) highlights the significant intersection of computer science with educational methodologies and practices, particularly in the context of computer science education (61) and higher education (54). This suggests a keen interest in integrating computer science principles into educational curricula and exploring the impact of technology on learning environments. Computer technology and cloud computing, with 62 and 56 occurrences respectively, indicate a focus on the technological aspects of computer science and their applications in business and economics. This includes exploring cloud-based solutions for data storage, processing, and management.

The presence of information technology (53) and e-learning (48) points to the digital transformation of educational and business practices, while knowledge management (45) and internet of things (41) suggest a broader interest in managing and leveraging data from interconnected devices and systems. Deep learning and project management, each with 37 occurrences, reflect specialized areas of interest. Deep learning, a subset of machine learning, indicates a focus on more complex neural networks, while project management

highlights the application of computer science principles in organizing and executing projects. Innovation (36), software engineering (35), and computer applications (33) suggest a focus on the development of new technologies, methodologies, and applications in computer science. Finally, data science (30) encapsulates the interdisciplinary nature of the field, combining aspects of computer science, statistics, and domain knowledge to extract insights from data.

Therefore, the application of computer science into economics and management is representative of a broader trend towards digitization and data-driven decision making in modern societies, reflecting the evolving demands of the global economy and the increasing complexity of technological systems. The relevance of keywords such as artificial intelligence, big data and machine learning highlights a significant shift towards harnessing computational power to solve complex economic and management problems, making it possible to process and analyze vast data sets, uncovering patterns and insights that inform strategic decisions, optimize operations, and predict future trends with a level of accuracy previously unimaginable. The intersection with education, especially in computer science and higher education, indicates a recognition of the critical need to equip future professionals with the skills necessary to navigate and shape this evolving context, pointing to a deliberate effort to integrate advanced technological competencies into curricula, preparing students not only to use, but to innovate at the cutting edge of computing applications in business and economics.

Tab. 6. Most used keywords

Rank	Words	Ocur.	Rank	Words	Ocur.
1	Computer Science	216	11	Information Technology	53
2	Artificial Intelligence	88	12	E-Learning	48
3	Big Data	84	13	Knowledge Management	45
4	Machine Learning	83	14	Internet Of Things	41
5	Education	76	15	Deep Learning	37
6	Computer Technology	62	16	Project Management	37
7	Computer Science	61	17	Innovation	36
8	Cloud Computing	56	18	Software Engineering	35
9	Higher Education	54	19	Computer Applications	33
10	Data Mining	53	20	Data Science	30

Source: Own elaboration. Note: Occur.: Occurrences.

In connection with the above, keywords such as cloud computing and information technology highlight the infrastructure that enables this transformation, facilitating scalable and flexible solutions for data management and computation, essential for the dynamic environment of modern business and economics, and supporting the operational and strategic agility needed to respond to rapidly changing market and consumer behaviors. Moreover, allusions to e-learning and knowledge management reflect the growing importance of continuous and accessible learning and the strategic use of knowledge in organizations. Digital transformation, underscored by the integration of the Internet of Things, deep learning and project management, points to an ecosystem in which interconnected devices, advanced analytics and efficient project execution converge to create smarter, more responsive economic and management systems, revealing an environment in which the boundaries between computer science, economics and

management are merging and creating a new paradigm in which insights and technology-driven innovations are at the core of economic and management strategies. The emphasis on innovation, software engineering and computer applications further indicates a drive towards the development of new solutions and methodologies that harness the potential of computer science to address contemporary economic and management challenges.

Table 7 and Figure 3 show the most frequent international collaborations established between countries. At the top of the list is the collaboration between China and the USA, with 69 collaboration agreements, which underscores the significant academic and research synergy between these two global powers in advancing computer science applications in management and economics.

Tab. 7. International collaboration agreements

From	To	Frequen	From	To	Frequen
China	USA	69	United Kingdom	Australia	11
USA	United Kingdom	37	USA	France	11
USA	Canada	24	China	Pakistan	10
China	Australia	19	United Kingdom	Canada	10
Spain	Portugal	17	USA	Netherlands	10
USA	Australia	17	Canada	Australia	9
USA	Germany	16	India	Saudi Arabia	9
USA	Spain	16	Italy	France	9
China	Korea	15	Spain	Chile	9
China	United Kingdom	15	Spain	Italy	9
USA	Switzerland	15	United Kingdom	France	8
China	Canada	14	United Kingdom	Germany	8
United Kingdom	Italy	14	United Kingdom	Netherlands	8
USA	India	14	USA	Finland	8
China	Japan	13	USA	Singapore	8
USA	Russia	13	China	France	7
China	Singapore	12	China	Russia	7
Pakistan	Saudi Arabia	12	China	Saudi Arabia	7
USA	Korea	12	Germany	Australia	7
China	India	11	Spain	Colombia	7

Source: Own elaboration.

The USA's collaborations are widespread, as evidenced by its frequent partnerships with United Kingdom (37), Canada (24), Australia (17), Germany and Spain (16), Switzerland (15), and India (14). These collaborations reflect the USA's central role in global research networks and its commitment to fostering international academic exchanges. China's international collaborations are also notable, particularly with Australia (19 times), Korea (15 times), the United Kingdom (15), Canada (14), and Japan (13), which highlight China's growing influence and integration into the global research community.

The collaboration between Spain and Portugal (17) reflects a strong regional partnership, likely facilitated by cultural and linguistic similarities. Similarly, the United Kingdom's collaborations with Australia, Canada, Italy, France, Germany, and the Netherlands, ranging from 8 to 14 instances, demonstrate its extensive research connections within the Commonwealth and Europe. The collaborations between Pakistan and Saudi Arabia (12), and China with Singapore (12) and India (11 times), also highlight emerging research

partnerships in Asia. Finally, other collaborations involving countries like France, Chile, Colombia, Finland, and Singapore with various partners reflect the diverse and interconnected nature of the research community in this field.

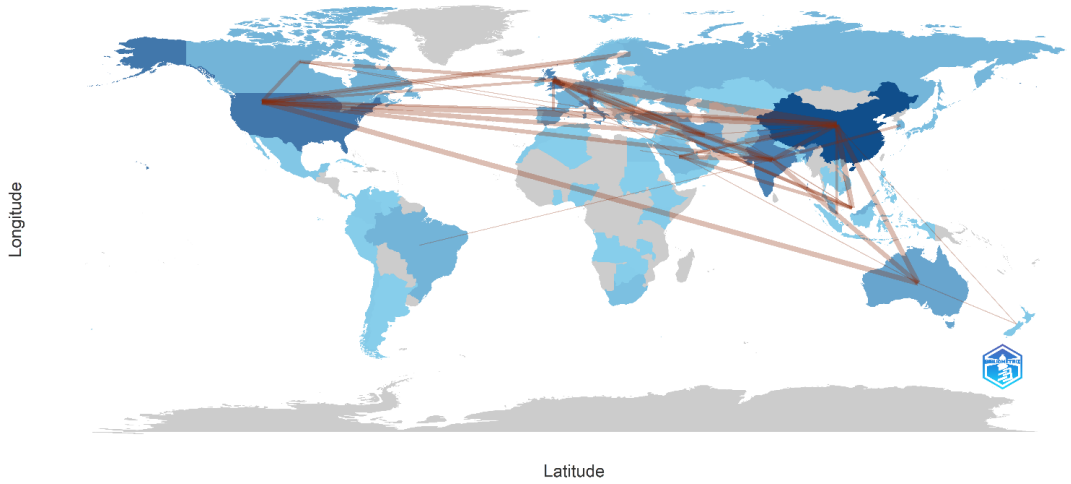

Figure 3. Collaboration world map

4. CONCLUSIONS

This bibliometric analysis in the field of computer science applied to management and economics has revealed several key insights, emphasizing the profound impact of computer science on these fields, and revealing the most influential contributors, sources, collaborations, and subtopics developed over time. The integration of computer science with economics and management is transforming the way businesses and economies operate. Among its most interesting applications, we can find data analytics, artificial intelligence, and machine learning, which are enabling the development of more efficient decision-making processes, the optimization of resource allocation, the enhancement of the overall economic productivity, and the introduction of advanced tools and methodologies. All this for better project management, operational efficiency, and strategic planning, e.g., the use of big data and analytics in management is not just improving existing processes but also paving the way for innovative business models and strategies.

With regard to economics, the influence of computer science is equally significant, becoming critical in understanding market dynamics, consumer behavior, and economic trends, as a result of its ability to analyze vast amounts of data with greater accuracy and speed is providing economists and policymakers with deeper insights, leading to more informed and effective economic policies and decisions. Moreover, the educational sector is also adapting to this integration, since universities are increasingly offering interdisciplinary programs that combine computer science with economics and management, preparing a new generation of professionals equipped to handle the complexities of the modern business and economic landscape.

In connection with the above, this analysis has revealed the important role played by key individuals and institutions, among which it is worth mentioning the efforts made by Marek Miłosz and Elżbieta Miłosz, both from Lublin University of Technology. Marek Miłosz emerges as a pivotal figure, uniquely positioned as the only researcher ranked in the top ten across all four key bibliometric indicators: articles published, most locally cited authors, H-index, and fractionalized articles, which underscores its prolific output and the significant impact and quality of his research, spanning its contributions various facets of computer science, influencing both theoretical and practical applications in management and economics. Similarly, Elżbieta Miłosz demonstrated considerable influence, particularly in terms of local citations and fractionalized articles. Her work, while perhaps more focused in scope, has nonetheless contributed significantly to the depth and diversity of research in this field, playing an important role in shaping specific research areas within the broader domain.

Their institution, Lublin University of Technology, is positioned among the most prolific universities in the world in computer science in the areas of management and economics, indicating a strong institutional focus on advancing this field of study. The university's support for researchers like Marek Miłosz and Elżbieta Miłosz exemplifies its commitment to nurturing talent and promoting high-quality research. The analysis also sheds light on the dynamic nature of research collaborations, with significant international partnerships driving the field forward. The frequent collaborations between countries like China, the USA, and the United Kingdom, among others, reflect a global research community that is interconnected and collaborative.

The bibliometric analysis conducted in this study has several practical implications. By integrating advanced computational techniques into managerial practices, the study highlights a significant shift towards more efficient and informed decision-making processes, which is exemplified in areas like supply chain management, where AI-driven analytics have revolutionized inventory and distribution strategies, leading to cost reductions and enhanced service levels. In economics, the use of sophisticated computational models for economic forecasting and modeling provides deeper insights into complex economic systems, aiding policymakers, and businesses in making more informed decisions, which demonstrates a pivotal shift from traditional methods to more dynamic, data-driven approaches.

Regarding the theoretical implications, this study underscores the evolving nature of management and economics in the digital era, since the integration of computer science into these fields has not only enhanced existing methodologies, but also introduced new paradigms and approaches, e.g., the use of big data analytics in management has opened new avenues for customer relationship management and personalized marketing strategies, allowing for a deeper understanding of consumer behavior. In economics, computational advancements have enabled more nuanced economic modeling and forecasting, influencing everything from monetary policy to market regulation, signifying a fundamental change in how these disciplines are approached and understood, highlighting the growing importance of computational methods in shaping modern economic and management theories.

In connection to the above, the study's findings have significant implications for policy formulation and implementation. The ability to accurately model and forecast economic conditions using advanced computational methods provides policymakers with a powerful tool for decision-making. That is particularly crucial in an era where economic contexts are increasingly complex and interconnected, so that the insights gained from this analysis can

guide policy formulation, ensuring that decisions are based on comprehensive and accurate data. In this vein, it is underscored the need for policies that address the ethical, privacy, and security implications of deploying artificial intelligence and machine learning in sensitive economic and management contexts, including considerations around algorithmic transparency, data bias, and the digital divide, which are essential for the equitable and effective application of these technologies. Therefore, this bibliometric analysis not only sheds light on the current state of research in these fields but also provides valuable insights for future policy and theoretical development.

Thus, the integration of computer science in management and economics is profound and far-reaching, having enhanced existing practices, as well as paved the way for innovative approaches and methodologies. As these fields continue to evolve in the digital age, the role of computer science as a key driver of change and innovation becomes increasingly relevant, promising further advancements and discoveries in the management and economic sciences. This holistic approach is essential for academics, practitioners, and policymakers to fully grasp the profound impact of digital transformation in these vital areas of study and practice.

Regarding the main limitations, in conducting our research on the application of computer science in management and economics, we employed targeted keywords to filter publications through the Web of Science database, which enabled us to capture a significant portion of the key literature in this domain, but given the vast scope of the field, it was inherently challenging to encompass every relevant publication. Looking ahead, it would be beneficial for further studies to delve deeper into new research trends by examining the latest publications through traditional literature reviews, as well as broadening the search to include other relevant databases.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

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