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Research Article

Entrepreneurship From the Perspective of Industry 4.0: Bibliometric Analysis

Endüstri 4.0 Perspektifinden Girişimcilik: Bibliyometrik Analiz

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Abstract

This study was conducted to determine the extent to which entrepreneurship issues have adapted to the transformation process experienced with Industry 4.0. In this context, the levels at which Industry 4.0 and entrepreneurship issues are addressed together in academic studies were evaluated. The studies that examined Industry 4.0 alongside entrepreneurship topics were obtained from the Web of Science database. The data obtained were analysed using bibliometric analysis methods with the VOSviewer program. As of June 29, 2025, a total of 26,121 studies related to Industry 4.0 were identified in the Web of Science database, and it was determined that only 224 (0.86%) of these addressed Industry 4.0 in conjunction with entrepreneurship topics. As a result of the literature review, it was concluded that Industry 4.0 is mostly addressed in terms of its technical dimensions, while entrepreneurship and, consequently, the human element remain secondary, and there is a mismatch between the pace of development of Industry 4.0 and the rate of increase in studies on entrepreneurship. In this context, recommendations have been made for future studies to examine Industry 4.0 and entrepreneurship topics together in greater detail.

Keywords: *Industry 4.0, Entrepreneurship, Management, Data, Bibliometric analysis.*

JEL Codes: *L2, M1, C8, O14, Y1*

Öz

Bu çalışma, Endüstri 4.0 ile yaşanan dönüşüm sürecine girişimcilik konularının ne ölçüde uyum sağladığını belirlemek amacıyla yapılmıştır. Bu bağlamda akademik çalışmalarda Endüstri 4.0 ve girişimcilik konularının birlikte ele alınma düzeyleri değerlendirilmiştir. Endüstri 4.0'ı girişimcilik konularıyla birlikte inceleyen çalışmalar Web of Science veri tabanından elde edilmiştir. Elde edilen veriler VOSviewer programı ile bibliyometrik analiz yöntemleri kullanılarak analiz edilmiştir. 29 Haziran 2025 tarihi itibariyle Web of Science veri tabanında Endüstri 4.0 ile ilgili toplam 26.121 çalışma tespit edilmiş olup, bunlardan yalnızca 224'ünün (%0,86) Endüstri 4.0'ı girişimcilik konularıyla birlikte ele aldığı belirlenmiştir. Yapılan literatür taraması sonucunda Endüstri 4.0'ın çoğunlukla teknik boyutlarıyla ele alındığı, girişimciliğin ve dolayısıyla insan unsurunun ikincil planda kaldığı, Endüstri 4.0'ın gelişim hızı ile girişimcilik üzerine yapılan çalışmaların artış hızı arasında uyumsuzluk olduğu sonucuna ulaşılmıştır. Bu bağlamda, gelecekte yapılacak çalışmalarda Endüstri 4.0 ve girişimcilik konularının birlikte daha detaylı incelenmesine yönelik önerilerde bulunulmuştur.

Anahtar Kelimeler: *Endüstri 4.0, Girişimcilik, Yönetim, Veri, Bibliyometrik analiz.*

JEL Kodları: *L2, M1, C8, O14, Y1*

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1. Introduction

The world is undergoing a process of continuous and rapid change in the economic, political, and technological spheres. There are various factors triggering this change, and these factors vary depending on the period and geography in which the change is taking place. In particular, changes and developments in the industrial sector are among the factors that have the greatest impact on transformations in other areas. Countries that are at the forefront of the industrial sector are guiding this change and development and maintaining their leadership (Yüksel & Genç, 2018). Entrepreneurship stands out as an important factor in increasing the dynamism of social and economic life in this transformation process. Considering the requirements of the age, the power of entrepreneurs lies in their ability to create innovation and transform this innovation into concrete commercial outputs. In this context, today's entrepreneurs are making efforts in their entrepreneurial activities from both economic and social perspectives (Marangoz, 2012). Entrepreneurs operating in a global competitive environment must make all their business processes more flexible to sustain their existence, increase their competitive strength, and enter new markets. The concept of a flexible business is defined as a business's ability to adapt to its environment with all its units and develop solutions appropriate to differences in consumer expectations (Tekin & Zerenler, 2007). If organizations value their employees' perspectives and guide them toward technological and skill development, employees will feel more motivated and committed to their work during the Industry 4.0 process (Molino, Cortese, & Ghislieri, 2020). Therefore, with the advancement of technology, the role of entrepreneurship within the scope of Industry 4.0 has significantly increased.

In this context, this study conducted a bibliometric analysis to reveal the importance of entrepreneurship from an Industry 4.0 perspective. With this analysis, the aim was to provide a general overview of the development of research conducted in the field of entrepreneurship in the context of Industry 4.0 from the past to the present and the trends for the future. To achieve this goal, the study addressed the following key research questions: How are studies examining entrepreneurship from an Industry 4.0 perspective distributed over the years? Which countries, authors, journals, and publications are leading in this field? What are the general research trends in entrepreneurship in the context of Industry 4.0?

To answer these questions, the current literature focusing on Industry 4.0 and entrepreneurship was reviewed, and the effects of Industry 4.0 on entrepreneurship were evaluated. Within this scope, a total of 224 studies indexed in the Web of Science database were analysed to map the research environment related to entrepreneurship practices from an Industry 4.0 perspective and to determine future research directions. Based on the findings, it is anticipated that this study will contribute to the identification of academic trends in related research areas and serve as a guide for social life, businesses, and policymakers. Additionally, it is expected that this study will contribute to the identification of gaps in the academic literature, the emergence of new research areas, and the illumination of future studies. The remaining sections of the study are structured as follows: First, a general literature review on the subject is presented, followed by an explanation of the methodology used, an analysis of the findings, and finally, a discussion of the study's results, limitations, and recommendations for future research.

Industry 4.0

The concept of Industry 4.0 was first introduced into the literature in a theoretical context by Kagermann, Lukas, & Wahlster in their 2011 paper titled “Industry 4.0: Toward the Fourth Industrial Revolution with the Internet of Things” (Kagermann et al., 2011). Industry 4.0 stands out as a concept defining the new industrial revolution and distinguishes itself from previous industrial revolutions with the introduction of production based on cyber-physical systems. The First Industrial Revolution was defined by the use of mechanical production facilities powered by water and steam at the end of the 18th century; the Second Industrial Revolution by the widespread adoption of mass production based on division of labour and electricity; and the Third Industrial Revolution by the integration of electronic and information technologies into manufacturing processes, advancing automation in production to new levels (Kılıç & Alkan, 2018). Industry 4.0, commonly referred to as the “fourth industrial revolution,” is explained by the integration of cyber-physical systems, the Internet of Things (IoT), cloud computing, and cognitive computing (Schwab, 2016). This transformation enables the creation of real-time, self-organizing value chains that are optimized according to criteria such as cost, resource utilization, and accessibility,

providing both higher quality standards and flexibility and resilience in engineering, planning, production, operational, and logistics processes (Soylu, 2018).

As one of the world's leading countries in heavy industry, Germany introduced the concept of Industry 4.0 to avoid the risk of falling behind in software technologies and aimed to transform its production processes with this approach. Although similar concepts have been developed in many countries, Germany's approach has focused on restructuring production processes and guiding these processes by retaining knowledge. However, this revolution has mostly been approached from a technical perspective; the human dimension has remained in the background in the evaluation of innovations. Although the challenges that could arise during the transformation process were anticipated, they were often overlooked due to the technical focus of the approach. This is because the primary objective of Industry 4.0 is to achieve smarter robots and faster, more efficient production, thereby pushing human emotions and social impacts to the background (Yüksel & Genç, 2018).

The increasing prominence of Industry 4.0 and its emergence as a new reality for industrial enterprises have made it imperative for unprepared businesses to redesign their business models accordingly. The goals of maintaining uninterrupted production, continuous improvement, and enhancing global competitiveness have transformed the industrial sector into a more dynamic structure. This transformation has been shaped by the contributions of entrepreneurs striving to advance by blending past experiences with innovative thinking (Saka, 2017). On the other hand, the integration of Industry 4.0 technologies also brings significant challenges. In particular, the digital divide observed in developing regions poses a serious obstacle to the adoption of technologies (Aladağ, 2024; Hilbert & López, 2011). In addition, concerns about data privacy and security are also a critical issue for women entrepreneurs who do not have sufficient cyber security resources. As businesses become more dependent on digital platforms, the risks of cyberattacks and data breaches also increase (Michota, 2013). In this process, increasing access to finance can facilitate the integration of Industry 4.0 technologies into businesses, particularly in terms of initial costs (Bosman, Hartman, & Sutherland, 2020).

Entrepreneurs and leaders who can think multidimensionally, have strategic vision and dreams, analyse competition correctly, and believe in innovation play a critical role in the implementation of strategic plans and the management of change processes in the new global order. The effective implementation of the Industry 4.0 revolution in organizations will be possible with a leadership and entrepreneurship approach that possesses these characteristics (Saka, 2017).

Entrepreneurship

Advances in computer and internet technologies have brought about significant changes and transformations in the conditions under which entrepreneurial activities take place. In the traditional understanding of entrepreneurship, three basic elements—land, capital, and labour—were considered indispensable elements independent of the entrepreneur's courage and skills. In other words, if an entrepreneur did not have access to these three basic resources, their courage and ability to evaluate opportunities alone were insufficient to create a meaningful business. However, the innovations brought about by the information age have created more favourable conditions for today's entrepreneurs. Over time, the importance of these traditional factors in large or small-scale ventures has diminished, replaced by “business ideas” and “entrepreneurial competencies” (Halıcı, 2018).

Developments in information and communication technologies have become an integral part of not only everyday life but also the business world, making it necessary for businesses to have certain characteristics in order to compete in constantly complex and uncertain environments, maintain success, and continue to exist. These characteristics necessitate that businesses act proactively, take risks, and adopt an innovative approach in terms of target markets, products, and technologies. In this context, entrepreneurship is of critical importance to businesses in terms of generating new ideas based on raw materials, services, products, processes, industries, markets, or combinations thereof, and creating value by putting these ideas into practice (Ağca & Kandemir, 2008; Altuntas & Donmez, 2010; Ferdousi, 2012).

Thanks to technological developments, individual entrepreneurs and businesses are moving away from traditional entrepreneurship and taking advantage of the opportunities offered by new or emerging

technologies; in this regard, they are restructuring their services, products, processes, organizational structures, strategies, business models, and human resources (Kişi, 2018); Zhao and Collier (2016) emphasize in their studies that businesses that use new technologies to improve their business processes achieve higher profitability than those that use these technologies to a limited extent. In recent years, developments in digital technologies such as mobile computing, cloud computing, social media, 3D printing, and data analytics have ushered in a new era of entrepreneurship and further increased the importance of the concept of entrepreneurship (Commission, Small, & Enterprises, 2018; Nambisan, 2017; Pathak & Muralidharan, 2020; Yaghoubi, Salehi, Eftekharian, & Samipourgiri, 2012).

These developments have transformed not only businesses but also consumer behaviour and expectations. Thanks to information technologies, customers now have the opportunity to access the products and services they need from a wider range of alternatives, at the quality, time, and conditions they desire. This situation necessitates that businesses shape their product and service offerings to meet customer expectations at the highest level. Today, digital technologies offer businesses significant advantages in adapting to changes in customer relations and establishing strong bonds with customers (Swift, 2001).

As a result, in the transition process from Industry 4.0, where cyber-physical systems are at the forefront, to Industry 5.0, where unmanned technologies are discussed, modern industries play a strategic role in the economic development of countries and regions. Therefore, it is of great importance for managers to support the development of advanced technology-focused entrepreneurial activities (Yalçınsoy, 2021).

This research article will contribute to the existing literature by answering the following research questions:

- How many scientists and/or scientific publishers have been willing to publish their work in the fields of Industry 4.0 and entrepreneurship over the years?
- How have scientific studies published on Industry 4.0 and entrepreneurship been distributed around the world?
- What are the most prominent keywords used in studies related to Industry 4.0 and entrepreneurship?
- To which research areas are the studies published on Industry 4.0 and entrepreneurship most commonly distributed?
- How are the indexes of scientific studies related to Industry 4.0 and entrepreneurship distributed?
- What is the distribution of the publishing institutions that publish scientific studies related to Industry 4.0 and entrepreneurship?

The paper is organized as follows: The “Methodology” section clearly presents the methodology, search criteria, data, and criteria information related to the research. The “Results” section presents the findings obtained through bibliometric analysis. The “Discussion” section compares and interprets the study's findings and addresses the scientific contributions and potential limitations of the research. The final section, “Conclusion”, summarizes the key findings of the research and highlights the overall contribution of the study.

2. Methodology

A comprehensive review was conducted to assess studies in the literature on Industry 4.0 and entrepreneurship. A search procedure was established to access studies in the literature. Table 2.1. shows the search procedure. In this article, the studies found in the Web of Science Core Collection database were narrowed down to those that fall within the relevant area using keywords, and a comprehensive analysis of the studies obtained was presented. The Web of Science and Scopus databases are widely used and popular databases in the scientific world, recognized and used by scientists in the fields of science and arts, and contain many peer-reviewed journals (Sahabuddin et al., 2023; Sakib, 2023). The information obtained from the database through the search process was analysed bibliometrically.

Many software packages with different functions such as Publish or Perish,4 HistCite,5 and BibExcel were used for bibliometric analysis. Today, however, software packages such as Gephi and VOSviewer are used to analyse, modify, and customize output files that come from many databases, including popular databases such as Web of Science and Scopus, which offer different capabilities of these programs modify and customize output files originating from various databases, including widely used sources such as the Web of Science and Scopus, thereby integrating the distinct capabilities of these platforms (Fahimnia, Sarkis, & Davarzani, 2015; Persson, Danell, & Schneider, 2009).

Table 2.1. Search protocol

Search Keywords	"Industry 4.0" And "Entrepreneurship"
Database	Web of Science
Publication Types	Article, Review Article, Book Chapters, Proceeding Paper, Early Access, Editorial Material
Search Period	From 1975 to 29 June 2025
Language	English, Russian, Bulgarian, French, Hungarian, Turkish, Portuguese, German, Spanish

Criteria

In this bibliometric analysis, studies in the literature representing the importance of Industry 4.0 for entrepreneurship in different frameworks were analysed. This study includes scientific publications published between 1975 and June 29, 2025.

Data

The data used in the study were obtained from the Web of Science database on June 29, 2025. The citations of the studies up to this date were included in the database. The following two keywords listed in Table ... were used to search the database: Industry 4.0 and entrepreneurship.

3. Results

In scientific research, a comprehensive review of the existing literature and careful evaluation of sources is an effective method for understanding the evolutionary process of the field and identifying potential research gaps that have not yet been addressed in this context. This approach allows researchers to discover areas where they can make innovative contributions from both a theoretical and methodological perspective.

Findings indicating the distribution of research by region in bibliometric analysis are an important indicator. This indicator reflects the activity and enthusiasm of researchers in the region regarding this research topic. Figure 3.1. shows the distribution according to the total number of publications in each region. At the national level, Russia ranks first in terms of the number of publications, followed by Italy, the USA, England and China.

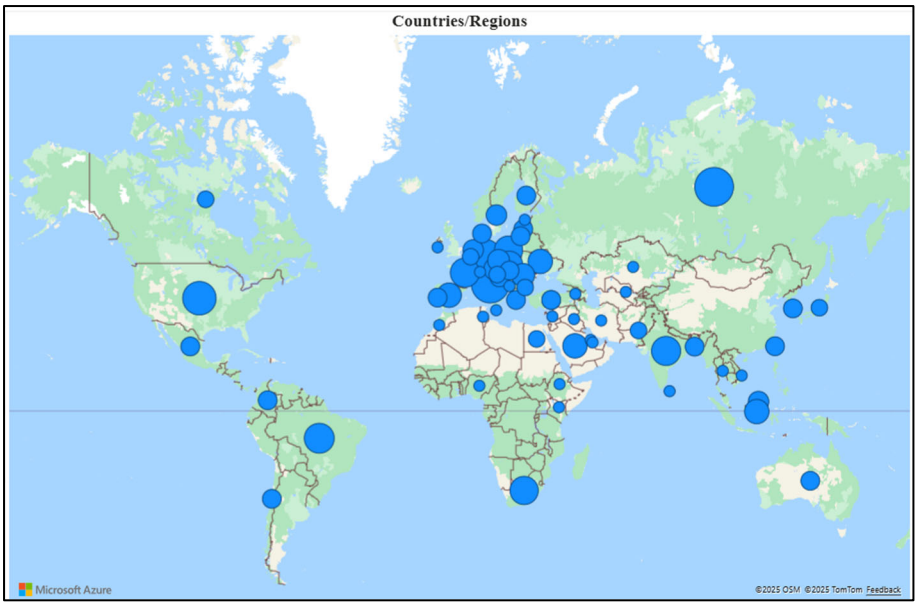

Figure 3.1. Country publication distribution.

As indicated in Table 3.1. articles constitute the bulk of fundamental academic contributions as the most intensive form of production in this field. This indicates that the research field is mature and active. Conference papers follow, which may indicate that the field is closely intertwined with current developments and that researchers dynamically share their findings with the academic community. Review studies, on the other hand, are conducted to synthesize the accumulated knowledge in the field, which may indicate that this field is subject to critical evaluation in the literature.

Table 3.1. Publication Count

Publication Types	Count
Article	150
Proceedings Paper	33
Review	22
Early Access	10
Book Chapter	5
Editorial Material	4

The treemap graph in Figure 3.2., which visualizes the number of publications by year, clearly shows the development dynamics of the relevant academic field. In particular, the intensification of publication activities in 2021 and 2024 indicates that interest in the field increased during these periods and that scientific production reached its peak. While 2020 and 2022 also stand out for their high production, 2025 has relatively lower numbers as it has not yet been completed. The limited number of publications in earlier years indicates that the research topic has gained relatively new momentum and that there has been significant academic growth over the past five years. These trends suggest that scientific interest in the field may have been shaped in parallel with social or environmental developments.

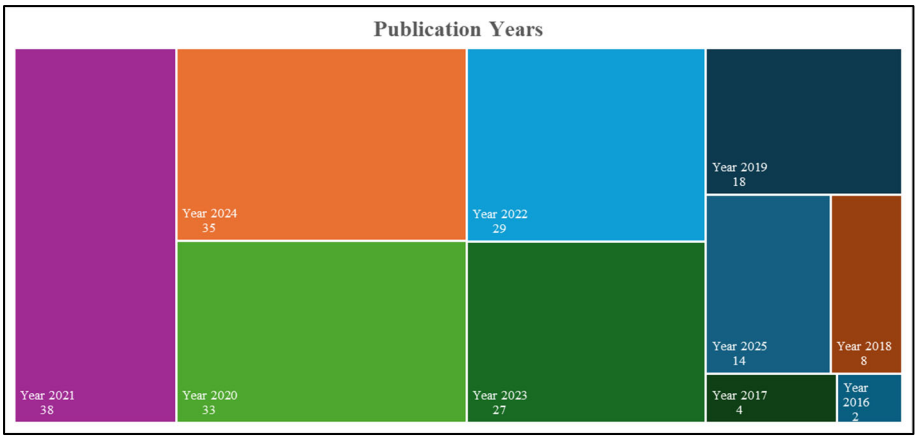

Figure 3.2. Treemap of Annual Publication Distribution

The graph in Figure 3.3. visualizes the contribution levels of different publishers to scientific publications in this field. MDPI leads the way with approximately 30 publications, followed by Springer Nature, IEEE, and Taylor & Francis. This distribution shows that academic output in the field is largely shaped by a few leading publishers. MDPI's clear dominance can be attributed to its fast and open-access publication policies, while organizations such as Springer Nature and IEEE stand out for their broad publication portfolios that support interdisciplinary research. The graph generally highlights the relationship between publisher preferences and academic production, providing insights into which platforms gain more visibility in the field.

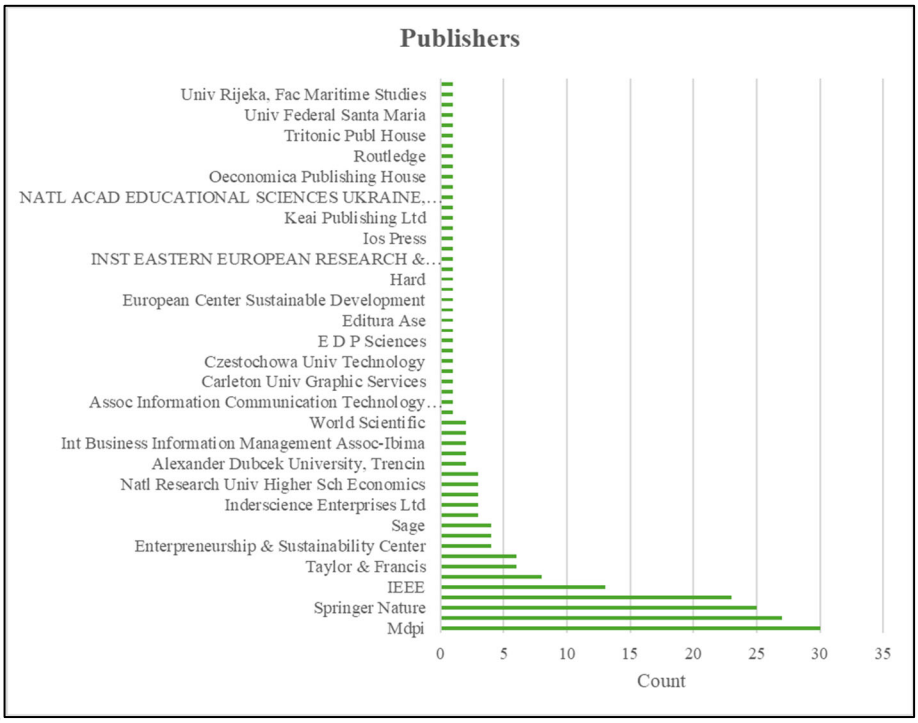

Figure 3.3. Publisher-Based Distribution of Scientific Publications

Figure 3.4. In the graph shown, MDPI stands out as the publisher with the highest contribution, while institutions such as Elsevier, Springer, IEEE and Taylor & Francis constitute the core publishers in this field. The fact that MDPI is ahead of Elsevier by 3 publications and approximately 10% suggests the impact of open access policies and publication speed on scientific visibility. Overall, the graph shows significant differences between publisher preferences and publication density; this situation may be closely related to researchers' access opportunities, disciplinary focuses, and publication strategies.

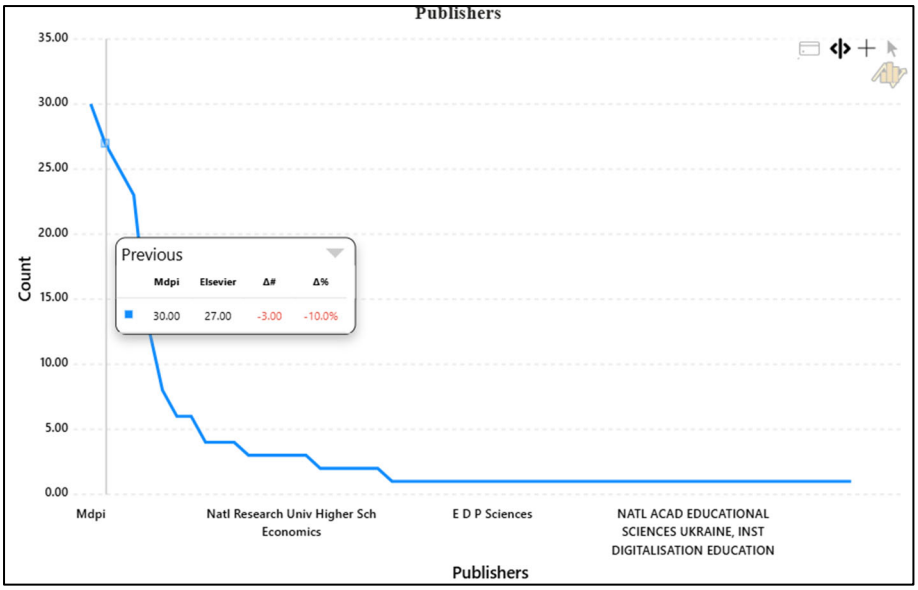

Figure 3.4. Publisher Contributions to Scientific Literature: A Comparative Overview

Figure 3.5. shows the classification of scientific publications based on Web of Science (WoS) indices, providing important data on the international visibility of the field. The SSCI (approximately 85 publications) and ESCI (approximately 75 publications) indexes, which have the highest number of publications, show that the field has a strong representation in the social sciences and emerging journals. The presence of the SCI index (approximately 45 publications) reveals that studies related to natural and technical sciences also hold an important place. The lower number of publications in other indexes (ISTP, ISSHP, BHCI, BSCI) reflects that the field is represented to a limited extent in indexes with a narrower or regional scope. Overall, the table shows that research outputs are largely represented in indices with high impact and access potential, and that the field exhibits a trend toward interdisciplinary expansion.

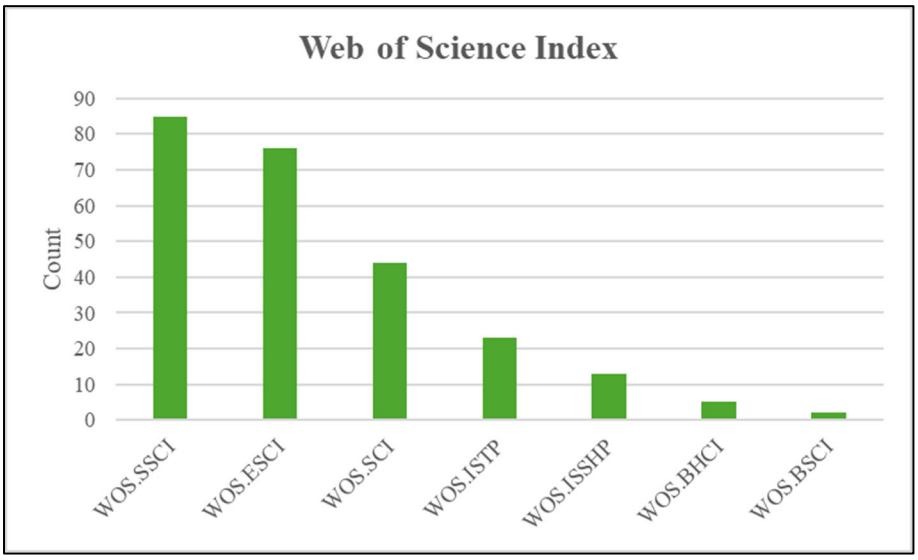

Figure 3.5. Index-Based Classification of Scientific Publications in Web of Science

The graph in Figure 3.6. visualizes the contribution of various research fields to scientific publications, with research fields on the horizontal axis and the number of articles published in these fields on the vertical axis. The highest number of publications belongs to the field of "BUSINESS ECONOMICS," which stands out with approximately 100 articles. This is followed by "ENGINEERING," "SCIENCE TECHNOLOGY," "ENVIRONMENTAL SCIENCE," and "COMPUTER SCIENCE." This distribution

indicates that research activities are largely concentrated in the social sciences and technology-focused fields. The graph also highlights potential research gaps for future studies by revealing that some disciplines have relatively lower academic output. Overall, this data reflects both interdisciplinary trends and sectoral priorities in scientific publications.

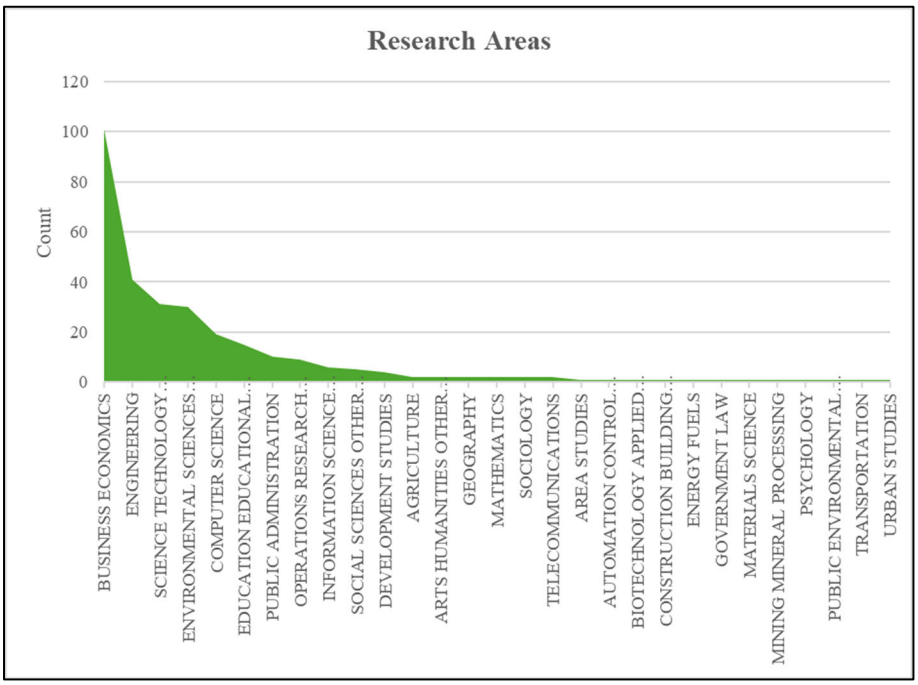

Figure 3.6. Disciplinary Distribution of Scientific Publications by Research Field

The graph shown in Figure 3.7. visualizes the number of publications in various academic fields within the scope of "Web of Science Categories" in terms of time and theme. The contours of the green area represent the density of the number of articles published in specific categories. The most significant contributions come from social science-based fields such as Business, Management, and Economics, indicating that environmental and social sustainability issues are being addressed from an economics-based perspective. The strong representation of environment-focused categories such as Environmental Sciences, Green Sustainable Science and Technology, and Environmental Studies highlights the increasing interdisciplinary interaction and the significant place sustainability studies occupy in the scientific agenda. The graph also reflects the contribution of applied fields such as engineering and computer science to scientific production, showing that research activities extend to both theoretical and practical dimensions. This diversity supports the cross-sectoral interaction of scientific studies and their socially beneficial orientation.

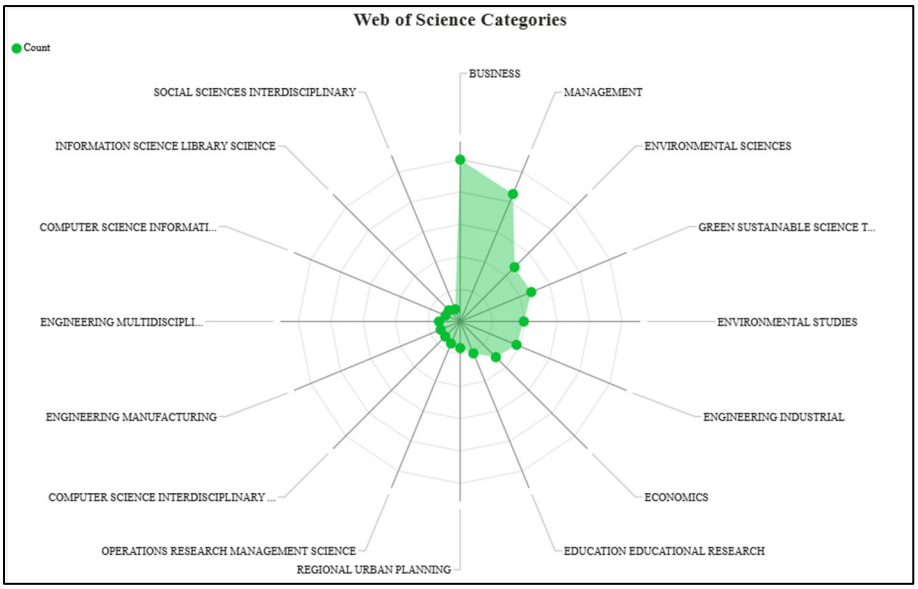

Figure 3.7. Area Chart Depicting Publication Trends Across Web of Science Categories

The bibliometric network analysis presented in Figure 3.8. visualizes the relationships between keywords and their frequency of co-occurrence. Prominent keywords such as “Industry 4.0,” “entrepreneurship,” “innovation,” and “digital transformation” form the core of thematic density in the relevant academic literature. The thickness of the connections between concepts reflects the level of co-occurrence, revealing the proximity of research fields to one another. Color-coded clusters classify sub-themes in the literature, showing interdisciplinary interaction and thematic diversity. This network structure provides the opportunity to systematically identify both current research trends and potential research gaps that could be focused on in future studies. Thus, the visual contributes to the structural analysis of the literature by creating a bibliometric map of the field.

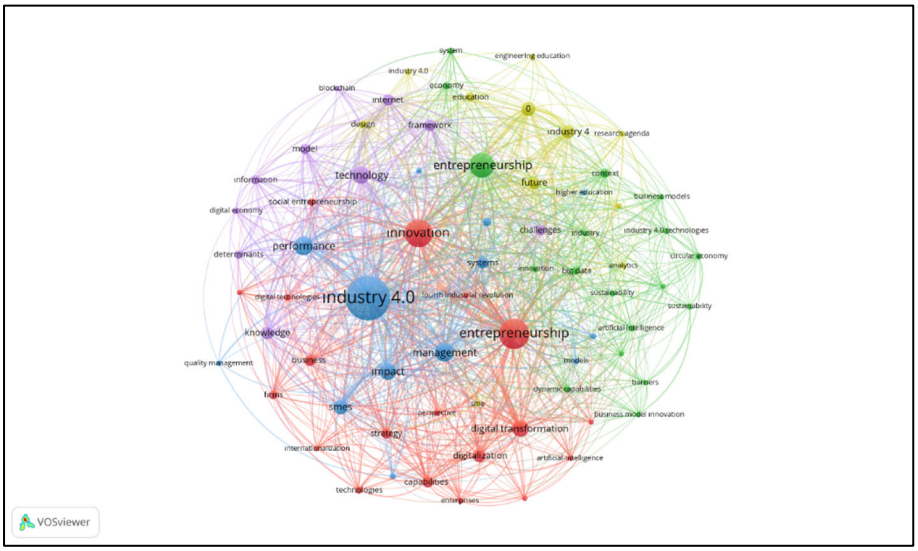

Figure 3.8. Co-occurrence Network of Keywords

Figure 3.9. visualizes the co-occurrence relationships of key terms that have emerged in the literature over the years using a bibliometric network map. In this structure, “Industry 4.0” and “entrepreneurship” are at the centre. These keywords exhibit strong relationships with concepts such as “innovation,” “technology,” and “management,” which have high connection frequencies. The size of the nodes reflects the weight of the relevant term in the literature, while the thickness of the connections reflects their common usage; the colour coding shows the thematic evolution according to publication years. Blue tones represent early-stage studies, while yellow tones represent current research, illustrating how themes have expanded and diversified over time. This visual provides important bibliometric insights

into the dynamic development of the knowledge structure related to Industry 4.0 and entrepreneurship, interdisciplinary interactions, and future research trends.

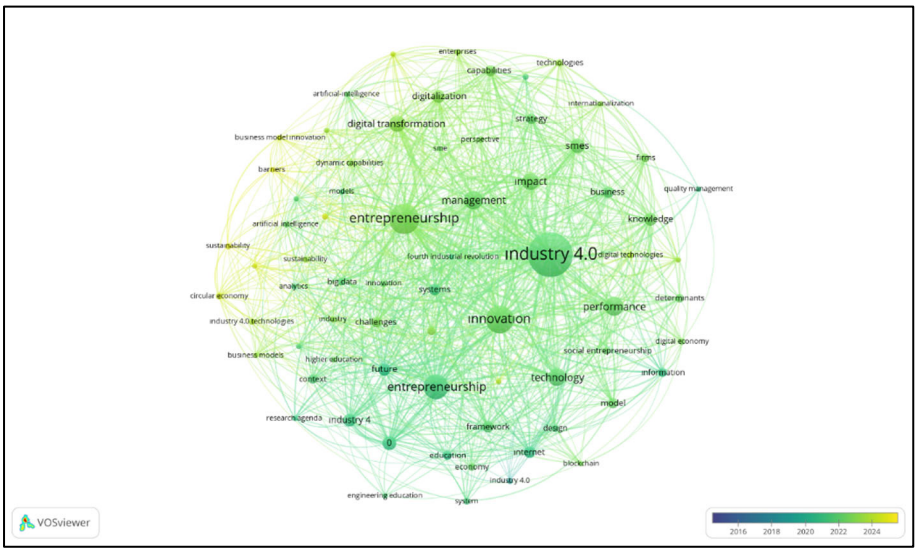

Figure 3.9. Temporal Co-occurrence Network of Keywords

The bibliometric table shown in table 3.2. presents quantitative data on the impact level of 224 scientific studies published between 1975 and 2025. A total of 4,005 different articles cited these publications, and 3,950 unique citations were recorded when self-citations were excluded. These publications have been cited a total of 4,357 times; when self-citations are excluded, this number drops to 4,287. The average number of citations per publication is 20.95, indicating that the literature in this field has significant visibility and impact. An H-index of 30 means that at least 30 studies have each been cited 30 or more times, indicating that the published research holds a strong position in the academic community in terms of both quantity and quality. Overall, the table shows that the analysed publication set has made a consistent contribution over many years and has demonstrated high performance in terms of scientific interaction.

Table 3.2. Scientific Impact Report Based on Citation Analytics

Publications	224
Year	From 1975 to 29 June 2025
Citing Articles	
Total	4005
Without self-citations	3950
Times Cited	
Total	4357
Without self-citations	4287
Average per item	20.95
H-Index	30

According to Table 3.3., the top 20 most cited studies in the relevant field stand out for their thematic diversity and academic impact. Studies such as Müller, Buliga, and Voigt (2018) and Li (2018) have become pioneers in the literature, with a total of more than 650 citations on topics such as business model innovation and national industrial strategies. Kraus et al. (2022), on the other hand, are among the most current and influential studies with a high annual citation average focused on digital transformation. Other notable publications include the perceived benefits of blockchain in banking

(Garg et al., 2021), the role of artificial intelligence in entrepreneurship (Giuggioli & Pellegrini, 2023), and the impact of digital transformation on SMEs (Garzoni, De Turi, Secundo, & Del Vecchio, 2020). These studies reveal the reflections of Industry 4.0 in a wide range of disciplines, from artificial intelligence to sustainability, digitalization to organizational culture, while also reflecting the dynamic development of the field in both its academic and applied aspects.

Table 3.3. High-Impact Articles: Citation-Based Ranking

Authors and Year	Title	Total Citations	Average per Year
Müller et al. (2018)	Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0	683	85.38
Li (2018)	China's manufacturing locus in 2025: With a comparison of Made-in-China 2025 and Industry 4.0	653	81.63
Kraus et al. (2022)	Digital transformation in business and management research: An overview of the current status quo	361	90.25
Garzoni et al. (2020)	Fostering digital transformation of SMEs: a four levels approach	173	28.83
Garg et al. (2021)	Measuring the perceived benefits of implementing blockchain technology in the banking sector	129	25.8
Popkova and Sergi (2020)	Human capital and AI in Industry 4.0. Convergence and divergence in social entrepreneurship in Russia	129	21.5
Giuggioli and Pellegrini (2023)	Artificial intelligence as an enabler for entrepreneurs: a systematic literature review and an agenda for future research	99	24.75
(2021)	The development of business model research: A bibliometric review	98	19.6
Mohelska and Sokolova (2018)	Management Approaches for Industry 4.0-The Organizational Culture Perspective	86	10.75
Calderon-Monge and Ribeiro-Soriano (2024)	The role of digitalization in business and management: a systematic literature review	77	25.67
Haefner and Sternberg (2020)	Spatial implications of digitization: State of the field and research agenda	71	11.83
Rane and Narvel (2021)	Re-designing the business organization using disruptive innovations based on blockchain-IoT integrated architecture for improving agility in future Industry 4.0	66	13.2
Cantú-Ortiz, Galeano Sánchez, Garrido, Terashima-Marin, and Brena (2020)	An artificial intelligence educational strategy for the digital transformation	58	9.67
Gerlitz (2016)	Design Management as A Domain Of Smart and Sustainable Enterprise: Business Modelling for Innovation and Smart Growth in Industry 4.0	54	5.4
Islam, Marinakis, Majadillas, Fink, and Walsh (2020)	Here there be dragons, a pre-roadmap construct for IoT service infrastructure	49	8.17
Oliva et al. (2022)	Risks and critical success factors in the internationalization of born global startups of industry 4.0: A social, environmental, economic, and institutional analysis	48	12

David and Grobler (2020)	Information and communication technology penetration level as an impetus for economic growth and development in Africa	47	7.83
Bartoloni et al. (2022)	Towards designing society 5.0 solutions: The new Quintuple Helix - Design Thinking approach to technology	46	11.5
Findik, Tirgil, and Özbuğday (2023)	Industry 4.0 as an enabler of circular economy practices: Evidence from European SMEs	44	14.67
Kruger and Steyn (2020)	Enhancing technology transfer through entrepreneurial development: practices from innovation spaces	43	6.14

The 15 journals listed in Table 3.4. and most frequently cited in the literature in the analysis play a decisive role in determining academic impact in terms of both their thematic scope and the publishers they are affiliated with. The journal with the highest number of citations, Technological Forecasting and Social Change, is published by Elsevier and stands out for its studies on future technological transformations. Similarly, the highly cited International Journal of Information Management is also published by Elsevier and follows a strong publication policy in the field of digitalization and information systems. Journals focused on sustainability, such as Sustainability, gain widespread visibility through support from open-access publishers like MDPI. Journals represented by publishers such as Springer, Emerald, and Taylor & Francis host studies based on management, entrepreneurship, and organization, increasing interdisciplinary publication diversity. In particular, the high citation rates of journals that host studies based on digitization, sustainability, and management indicate that these themes are in line with current research trends in the field.

Table 3.4. Top-Cited Journals: Publisher-Based Impact Analysis

Journal	Total Citations	Number of publications	Impact Factor (2024)	Cite Score (2024)
Technological Forecasting and Social Change	1617	7	13.3	26.3
International Journal of Information Management	361	1	27	54.9
Management Decision	190	2	5.9	8.4
Sustainability	186	7	3.6	5.8
Journal Of Intellectual Capital	150	2	8	13.9
Journal Of Business Research	129	2	9.8	25.3
Technological And Economic Development of Economy	106	2	5.9	7.1
Review Of Managerial Science	104	2	8.1	9.6
International Journal of Entrepreneurial Behavior & Research	99	1	6.1	9.3
Geography Compass	71	1	3.5	6.5
Benchmarking-An International Journal	66	1	5.1	11.5
International Journal of Interactive Design and Manufacturing - Ijidem	58	1	2.5	2.5
Entrepreneurship And Sustainability Issues	54	1	1.3	1.3
Economic Research-Ekonomska Istrazivanja	47	1	1.2	7.1
Technovation	46	1	10.9	19.5

4. Discussion

The bibliometric analysis of the study reveals that, despite the rapid technological expansion of Industry 4.0, there is relatively limited academic interest in entrepreneurship in this context. Although there are more than 26,000 publications that address Industry 4.0 in general, only 224 (~0.86%) deal directly with entrepreneurship themes, highlighting a notable gap in interdisciplinary integration. This finding supports the study's premise that while technical dimensions dominate the discourse, human-centred and entrepreneurship-related aspects are underrepresented.

Regional analysis positions Russia, Italy, the United States, the United Kingdom, and China as leading contributors to these academic studies, illustrating the convergence of various socio-economic and academic interests around technological innovation. The dominance of MDPI, IEEE, and other open-access publishers highlights the growing democratisation of knowledge dissemination and potentially catalyses further research in this underdeveloped thematic area.

The study's simultaneity analysis reveals key conceptual clusters such as 'Industry 4.0,' 'entrepreneurship,' 'digital transformation,' and 'innovation,' showing that academic interest is shifting toward multidimensional intersections that reflect emerging social and industrial demands. However, core contributions remain largely confined to the fields of business, management, and economics, with limited interdisciplinary interactions from education, public policy, or the humanities, resulting in limited holistic contextualisation.

Citation metrics, particularly those with an h-index above 30 and over 4,000 citations, confirm the visibility and impact of this emerging research stream. However, the modest number of publications compared to the broader Industry 4.0 literature suggests an opportunity for deeper theorisation, empirical examination, and methodological diversification. For example, the dominance of quantitative bibliometric approaches could be complemented by qualitative research to explore entrepreneurial behaviour, policy implications, or socio-cultural dynamics within digital transformation.

5. Conclusion

This study provides an important bibliometric overview of how entrepreneurship intersects with Industry 4.0, framing and analysing both the current state and emerging academic trends.

Key findings include:

- Research on entrepreneurship constitutes a small portion of the broader Industry 4.0 literature.
- Most studies emphasize technical and managerial perspectives.
- MDPI and other open access platforms play a critical role in disseminating relevant academic work.
- Core themes revolve around innovation, digital transformation, and business model evolution.
- Citation and index metrics confirm that academic impact and relevance in this area have significantly increased.

By highlighting intellectual structures and publication trends, the study makes a meaningful contribution to academia and policymaking. The study's insights provide a fertile ground for future interdisciplinary research and encourage academics to combine technological development with human creativity, inclusivity, and sustainability within the Industry 4.0 paradigm.

In recent years, concepts such as digitalization, corporate entrepreneurship, business models, and innovation management have indicated a shift in the literature towards a more strategic and theoretical orientation. Future studies are expected to benefit from addressing the concept of Industry 5.0 in the context of digitalization, innovation, sustainability, digital transformation, green resources, and artificial intelligence. These findings provide an important roadmap for future research and contribute to filling the existing gaps in the field. Furthermore, it is of great importance for policymakers to develop strategies that promote global collaborations and to support research in this domain. In addition, the role of entrepreneurship education in enhancing organizational performance underscores the need to revise educational programs and to implement entrepreneurship strategies more effectively.

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Araştırma Makalesi

Entrepreneurship From the Perspective of Industry 4.0: Bibliometric Analysis

Endüstri 4.0 Perspektifinden Girişimcilik: Bibliyometrik Analiz

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Genişletilmiş Özet

Bu çalışma, Endüstri 4.0 ile yaşanan teknolojik dönüşüm sürecinin girişimcilik alanıyla ne ölçüde örtüştüğünü analiz etmeyi amaçlamaktadır. Özellikle Endüstri 4.0'ın teknik boyutlarının ötesinde, insan merkezli dinamiklerin ve girişimci faaliyetlerin bu dijital devrimle ne düzeyde ilişkilendirildiği incelenmiştir. Söz konusu ilişkinin niceliksel ve niteliksel bir çerçevede anlaşılabilmesi için akademik literatürde Endüstri 4.0 ve girişimcilik konularının birlikte ele alınma oranı değerlendirilmiş, elde edilen veriler bibliyometrik analiz yöntemleriyle yorumlanmıştır.

Araştırma kapsamında, Endüstri 4.0 ve girişimcilik konularına odaklanan çalışmalar Web of Science (WoS) veri tabanından elde edilmiştir. Literatür taramasında, "Industry 4.0" ve "entrepreneurship" anahtar kelimeleri kullanılarak ilgili akademik yayınlar filtrelenmiş ve 29 Haziran 2025 tarihi itibariyle elde edilen veriler üzerinden analiz gerçekleştirilmiştir. Bu tarihte WoS veri tabanında Endüstri 4.0 ile ilgili toplam 26.121 çalışma tespit edilmiştir. Ancak bu çalışmaların yalnızca 224'ü (%0,86) aynı zamanda girişimcilik temasıyla ilişkilendirilmiş olup, bu oran konuya bütüncül bakışın oldukça sınırlı kaldığını ortaya koymaktadır.

Bibliyometrik analiz VOSviewer yazılımı kullanılarak gerçekleştirilmiş; özellikle anahtar kelime eşleşmeleri, ortak yazar ilişkileri, atıf ağları ve tematik kümelenme desenleri incelenmiştir. Elde edilen sonuçlar, Endüstri 4.0 literatürünün büyük ölçüde teknik bileşenlere—örneğin yapay zeka, nesnelerin interneti, siber fiziksel sistemler ve robotik otomasyon—odaklandığını göstermektedir. Bu bağlamda girişimcilik gibi sosyo-ekonomik dinamiklerin literatürde yeterince temsil edilmediği ve insan odaklı perspektifin geri planda kaldığı gözlemlenmiştir.

Girişimcilik temalı yayınların azlığı, Endüstri 4.0'ın sadece teknolojik bir paradigma olarak değil, aynı zamanda organizasyonel davranış, inovasyon kültürü ve yeni iş modelleri bağlamında değerlendirilmesi gerektiğini göstermektedir. İnsan unsuru, yeni teknolojileri kullanma kabiliyeti, risk alma eğilimi, fırsat algısı ve yaratıcılık gibi girişimcilik bileşenleriyle şekillenmektedir. Ancak mevcut literatür bu özelliklerin Endüstri 4.0 bağlamındaki rolünü büyük ölçüde ihmal etmiş görünmektedir.

Literatürdeki bu boşluk, Endüstri 4.0'ın gelişim hızına paralel bir şekilde girişimcilik araştırmalarında bir ivme kazanmadığına işaret etmektedir. Bu uyumsuzluk, akademik çalışmalarda dijital dönüşümün insan boyutuna yönelik analitik derinliğin artırılması gerekliliğini ortaya koymaktadır. Yeni teknolojilerin sadece sistemsel altyapıları değil, bu altyapıları işlevsel hale getiren insan faktörünü de içerdiği düşünüldüğünde, girişimcilik kavramının Endüstri 4.0 ile birlikte daha entegre biçimde ele alınması önem arz etmektedir.

Bu bağlamda, gelecekteki akademik araştırmaların aşağıdaki yönlerde genişletilmesi önerilmektedir:

- **Tematik Entegrasyon**: Endüstri 4.0 ile girişimcilik konularının birlikte ele alındığı disiplinler arası çalışmalar artırılmalı; mühendislik, işletme, sosyoloji ve bilişim alanlarının kesişim noktaları güçlendirilmelidir.
- **Kavramsal Derinlik**: Girişimcilik tanımı klasik ekonomik boyutların ötesine taşınmalı; dijital çağın ihtiyaçlarına uygun olarak yeniden yorumlanmalıdır. Özellikle dijital girişimcilik, sürdürülebilir inovasyon ve sosyal etki gibi temalar ön plana çıkarılmalıdır.
- **Politika ve Eğitim Önerileri**: Üniversiteler, teknoparklar ve girişimcilik destek programları Endüstri 4.0 çerçevesinde eğitim modelleri geliştirmeli; yeni nesil girişimcilerin dijital becerilerle donatılması teşvik edilmelidir.
- **Veri Odaklı Yaklaşımlar**: Büyük veri, makine öğrenmesi ve ağ analizi gibi yöntemlerle girişimcilik ekosistemlerinin yapısı daha detaylı biçimde incelenmeli; Endüstri 4.0 araçlarının bu süreçteki rolü istatistiksel ve görsel olarak değerlendirilmelidir.

Sonuç olarak, bu çalışmanın bulguları Endüstri 4.0 ve girişimcilik kavramlarının literatürde eşit düzeyde ele alınmadığını ve mevcut analizlerin çoğunlukla teknoloji merkezli kaldığını ortaya koymaktadır. Oysa dijital dönüşüm yalnızca teknolojik değil, aynı zamanda toplumsal bir dönüşümdür ve bu değişimin öncüleri girişimciler olacaktır. Bu nedenle akademik camiada insan merkezli perspektiflerin güçlendirilmesi ve girişimcilik konularının dijital devrim bağlamında daha görünür kılınması gerekmektedir.