

# Scientometric analysis of Industry 4.0, Engineer 4.0 and Manager 4.0 in Family Businesses

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## Abstract

The purpose of the research process was to assess the state of knowledge on the use of Industry 4.0 postulates in the context of Engineer 4.0 and Manager 4.0 competencies in family firms, identify research gaps and outline future research directions. We conducted a systematic literature review of 21 articles from the Scopus database that relate to the topic of Industry 4.0 and Engineer 4.0 and Manager 4.0 in family firms. To identify the state of the art, keyword co-occurrence analysis using VosViewer software was used as an analytical tool. We identified the most influential journals and subject areas. The study allowed us to identify consistent clusters that show a wide variety of topics in the discussion of the mentioned topic. The results showed a wide dispersion of research interests and the lack of a single, in-depth or dominant research area dealing with the phenomenon worldwide. We recommend further research on family businesses and Industry 4.0. In addition, the lack of comparative research on family and non-family businesses should be addressed. Contribution and added value: Our systematic literature review systematizes the existing literature on Industry 4.0 in family firms, isolates key research interests, identifies future research directions and provides important insights for researchers.

## Keywords

Industry 4.0, engineer 4.0, manager 4.0, family businesses, family firms.

## Introduction

The fourth industrial revolution, also known as Industry 4.0 – is having a significant impact on the functioning of companies, including family businesses. With the development of industry, there are changes in the area of technology, which, supported by the right skills and competencies of employees, provide the opportunity to fully exploit its potential (Nosalska, Gracel, 2019). The introduction of technological innovation is a key element in maintaining a competitive advantage in an evolving economic environment (Kazancoglu et al., 2021). It is important to understand that family businesses adapt to change differently than

other corporations. The business transformation can be considered both in negative and positive ways. This is predicated on the fact that in family businesses, the component most sensitive to the introduction of change is the family. The reason for this is its particular attachment to stability, which is dependent on the business performance of the company. Its resistance is caused by the fear of an unfavourable outcome of transformations (Więcek-Janka, 2013, p. 123). On the other hand, the use of family values and traditions in combination with a smooth succession can lead to the creation of a unique organisational culture that promotes innovation and the development of employees' competencies, thus ensuring the company's stability and growth (Mienkowski, 2022).

The general objective of the publication is to present the place of family firms in the literature related to engineering competencies used in Industry 4.0. The specific objective of the study is to present a bibliometric analysis using scientific publications from the Scopus database that combine Industry 4.0, family firms, and engineering competencies and skills.

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## Literature review

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When investigating the topic at hand, researchers identify significant divergences in both theoretical and practical areas. These differences manifest themselves both in the empirical data and in the concepts used to describe these data, such as concepts related to governance, family firms, boards, innovation or business models (Cucculelli et al., 2022; Cucculelli and Peruzzi, 2020; López-González et al., 2019). Despite the growing interest in the topic under discussion, it is necessary to continue research in this area. Further analysis of issues related to innovation, Industry 4.0 technologies and family businesses is recommended (Kazancoglu et al., 2021; Judit and Zsuzsanna, 2022; Wang and Li, 2023). There is a need for continued research in this area to better understand how these factors affect the functioning of family firms and the potential benefits and challenges of adapting Industry 4.0 technologies in this context.

Industry 4.0 is a set of advanced strategies and technologies associated with the next phase of industrial development. It is characterised by the intensive use of modern digital technologies and the automation of production processes. Industry 4.0 practices are set by principles of ethical behaviour and environmental management (Kazancoglu et al., 2021; Więcek-Janka et al., 2023).

In contrast, the concept of family business is related to the management, control, or ownership of one or more families. The family or families have an important influence on growth, personnel policy, investment, and innovation (Cucculelli and Peruzzi, 2020).

The study uses bibliometric and scientometric analysis in the area of family firms' use of engineering competencies specific to Industry 4.0 (Kazancoglu et al., 2021). The authors' interest in the presented issue is relevant for possible future research. This research can be used to further enhance and develop knowledge in the field and to identify areas that require more detailed analysis and research exploration. Bibliometric analysis is a research technique used to analyse scientific literature, scientific articles, journals or scientific publications. Bibliometric analysis of the topic in question allows the progress of research to be examined. It introduces the possibility of identifying key research trends and the evolution of the field of science, which can make a valuable contribution to knowledge development (Judit and Zsuzsanna, 2022). Furthermore, such analysis can support decision-making processes (Cucculelli and Peruzzi 2020) and the shaping of research priorities in the context of further research. Scientometric analysis is an important tool in science

management, focusing on monitoring scientific development (Judit and Zsuzsanna, 2022; Wang and Li, 2023) and assessing the outflow of science on the economy and society (López-González et al., 2019).

The Scopus database includes hundreds of information fields that vary according to the type of record and the type of information contained. This makes it possible to carry out in-depth analyses of articles in a given scientific field. In Scopus, it is possible to find metadata such as the title and authors of an article, abstracts, key words, source and year of publication, number of citations, indexes of publishing journals, language, and type of document or bibliographic references. This metadata allows researchers, scholars, and specialists in various fields to efficiently search, analyse, and evaluate scientific publications and research literature in Scopus. The data provided allow the identification of co-authorship patterns between researchers' articles and to perform demographic analysis (Pini, 2019). Specifically, they allow for the assessment and understanding of relationships between different countries participating in scientific collaborations and between scientific institutions or universities.

In the proposed literature review, we aim to verify whether the research carried out globally addresses the Industry 4.0 topic in the context of the engineer 4.0 and manager 4.0 competencies possessed and used in family firms and whether they coincide with those presented above. Furthermore, we will verify whether the findings presented in the global literature have been confirmed in research on Industry 4.0 in family businesses worldwide.

This will allow us to answer the following research questions:

RQ1: What are the most relevant research topics for the development towards Industry 4.0 in family firms?

RQ2: What links can be considered key to the development of this topic in research, considering: topic, authors, institutions, and countries.

RQ3: What research will be conducted in the future to add to the knowledge on this topic?

## Research methodology

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We conducted a systematic review of the literature complemented by bibliometric indicators. The use of both methods to analyse new areas of research provides a solid basis for identifying key aspects of the topic and speculating on new perspectives (Rialti et al., 2019). A systematic review of the literature provides qualitative insight into the topic and enhances academic discussion. Bibliometric analysis, in turn, identi-

fies and recognises potentially “hidden patterns” during the literature review process (Benavides-Velasco et al., 2013; Kraus et al., 2022). Our review aimed to establish a framework for new findings on the competencies of engineer 4.0 and manager 4.0 in family businesses and to link them to previous research (Więcek-Janka, et al., 2023).

Initially, a preliminary literature search revealed that to date no literature studies have been published on the development of engineering 4.0 and management 4.0 competencies in family firms. We developed a protocol that defined the parameters of the data search. We decided to use a database-based approach, which is most commonly used in management research (Hiebl, 2021). The search was carried out using the Scopus database. This database provides access to the highest quality publications (Caputo et al., 2019; Raghuram et al., 2019), which ensures compliance with standards and norms.

In order to develop the publication database, keywords had to be defined, a database selected, a database searched, and publication search filters applied. All selected articles met the basic requirements of theoretical and methodological rigour (Anessi-Pessina et al., 2016). This approach eliminates biases or omissions that may occur when considering specific journals (López-Fernández et al., 2016) and allows for replication of conducted study.

The selection of keywords consisted of identifying synonyms of terms or related terms and their plural for the following three areas: Industry 4.0, engineering competence, and family businesses. Thus, for “Industry 4.0” – “industrial revolution”, for “engineering competence” – “engineering competence”, “engineering skills” and “engineer”, “engineers”, “engineering”, for “family business” – “family companies”, “family business”, “family businesses”, “family enterprises”, “family businesses”, “family management”.

Table 1 provides a systematic overview of the search conditions, filtering, and the selected database.

The first step was to define keywords related to the area of study and to link them with relationships using “or” and “and” connectors. The appropriate combination of keywords made it possible to exclude publications that could relate to separate areas: engineering competence, industry, and family businesses. This resulted in 150 publications.

The second step was to determine the year of publication. The agreed time frame is between 2011 and 2023 due to the presence of the term Industry 4.0 in the keywords, which was first used at the international Hannover Messe in 2011. This resulted in 105 publications.

The third step was to define the document type as “article”, which excluded conference papers, conference

Table 1  
Systematic overview of the search conditions process

Keywords	<p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “Family business”.</p> <p>or</p> <p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “Family businesses”.</p> <p>or</p> <p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “Family firm”.</p> <p>or</p> <p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “family firms”.</p> <p>or</p> <p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “Family enterprise”.</p> <p>or</p> <p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “Family enterprises”.</p> <p>or</p> <p>“Industry 4.0” or “Engineering competence” or “Engineering skills” or “Engineer” or “Engineering skill” or “Engineering” or “Engineers” or “Industrial revolution” and “Family management”.</p>
Document Type	Article
Publication stage	final
Year of publication	2011–2023
Language	English
Database	Scopus

reviews, reviews, retracted publications, preliminary articles, short surveys, book chapters, and books from the search. The reason for using such a restriction is to make the articles easily accessible, which ensures that the categories of data used are standardised and that the study is carried out efficiently using bibliometric analysis. This resulted in 41 publications.

The fourth step was to define the stage of publication as “final”. This filter excluded unfinished articles from the search. This resulted in 40 publications.

The fifth step was to select articles written in English so that their content could be read. This resulted in 34 publications.

In the sixth step, we identified and evaluate studies. The search method for the selected articles followed a systematic review process (Pukall & Calabr, 2014; Goel & Jones III, 2016; Hernandez-Linares & Lopez-Fernandez, 2018; Fries et al., 2021). Regarding the language of publication, according to SLR best practices, only articles written in English were selected. The final step was to discard articles incompatible with the area of interest of the study, which was done by qualitative analysis of the title, abstract, and content. Articles with historical themes and referring to events before 2011 were excluded. This resulted in 21 publications (Figure 1).

Data synthesis is one of the most important stages of the study, as it requires analysis and comparison of the existing literature rather than a simple summary (Jones and Gatrell, 2014). As suggested by the author Kraus et al. (2022), the focus should be on concepts rather than authors. For this reason, the use of bibliometric analysis, in particular cooccurrence analysis. All articles in each cluster were analysed by the authors in order to identify their distinctive contribution to the description of the formation and development of engineer 4.0 and manager 4.0 competencies in operating family businesses.

## Results and Discussion

The analysis conducted allows us to conclude that articles on the concepts of Industry 4.0, Engineer 4.0 and Manager 4.0 were published between 2012 and 2022. There has been a noticeable increase in the number of articles in recent years, with the fewest articles published in the first years covered by the analysis and the most in 2022 (Figure 2). This increase indicates that the topic has become more popular in the past three years. To our knowledge, the

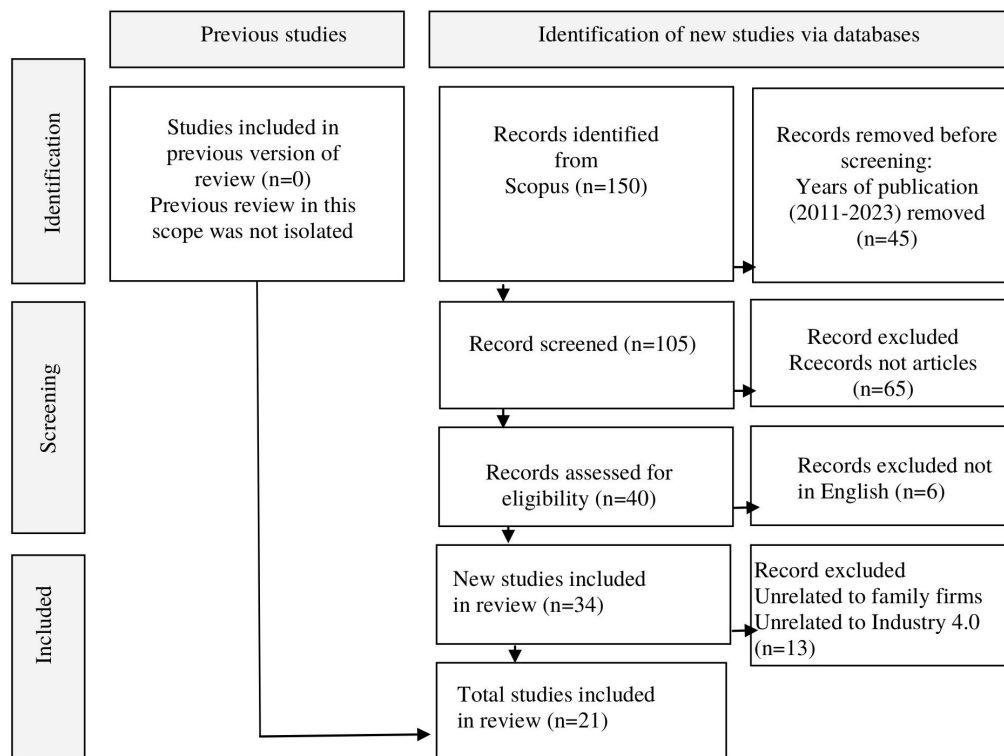


Fig. 1. Schema of article selection

analysis shows that research on the competences used in the Industry 4.0 concept, especially the distinction between the competencies of an engineer 4.0 and a manager 4.0, is a topic of research worldwide. The inclusion in this study of the combination of the Industry 4.0, Engineer 4.0 and Manager 4.0 competence area with the management of family businesses follows a similar trajectory, but occurs on a smaller scale (not included in the figure).

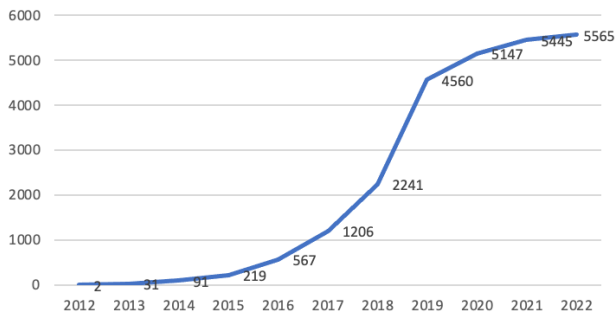


Fig. 2. The number of scientific articles relating to Industry 4.0 by year

To gain a better understanding of the themes of the selected 21 publications, a co-occurrence analysis of keywords was conducted to graphically represent the links between them (Domanska et al., 2023). The semantic maps generated denote clusters that group strongly related keywords, which were distinguished by colours. The co-occurrence of keywords is represented by linking them. The strength of the link is reflected by the distance of occurrence of the nodes from each other. The size of the node visualises the frequency of occurrence of the keyword in the selected publications.

Figures 3 and 4 show the generated semantic maps, where the minimum number of occurrences of a keyword was set to 1. All the keywords that occur are shown on the map.

The largest nodes are seen with the keywords family business, industry 4.0 and family firms. This is due to the highest number of occurrences in the selected publications and the greatest strength of connections to other keywords, as shown in Table 2.

Table 2  
Keyword counts

Keywords	occurrences	total link strength
family business.	8	72
industry 4.0	6	63
family firms	6	58

The cluster with the most used keywords is the purple cluster, with 15 results. The purple cluster mainly focusses on Industry 4.0, which is a keyword in articles that address issues such as employees, skills and digital work transformation (Grenčíková et al., 2020), emergency, environmental sustainability, prefabricated components in reinforced eps (Sferra, 2017) and servitization, networked innovation, push-pull strategies (Dressler & Paunovic, 2021).

The keywords family business and industry 4.0 are very much related to the visible red cluster in the bottom left corner containing 24 results, which deals with elements related to the fourth industrial revolution, running a company, its impact on the environment, as discussed by Kazancoglu, Sezer, Ozkan-Ozen, Mangla, Kumar (2021).

Closely related to family business is the small yellow cluster, consisting of four elements addressing the challenges of running a family business, namely challenges of family business, entry of next generation, conflict, and growth strategies (Panda et al., 2020).

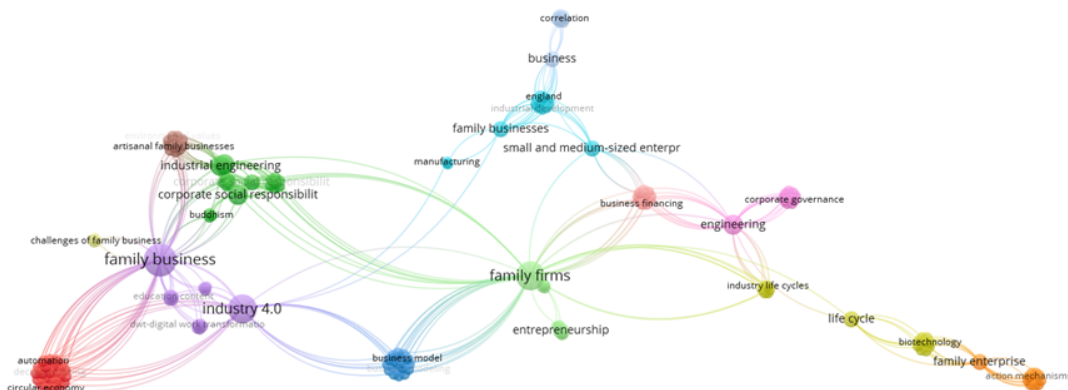


Fig. 3. Keyword association network



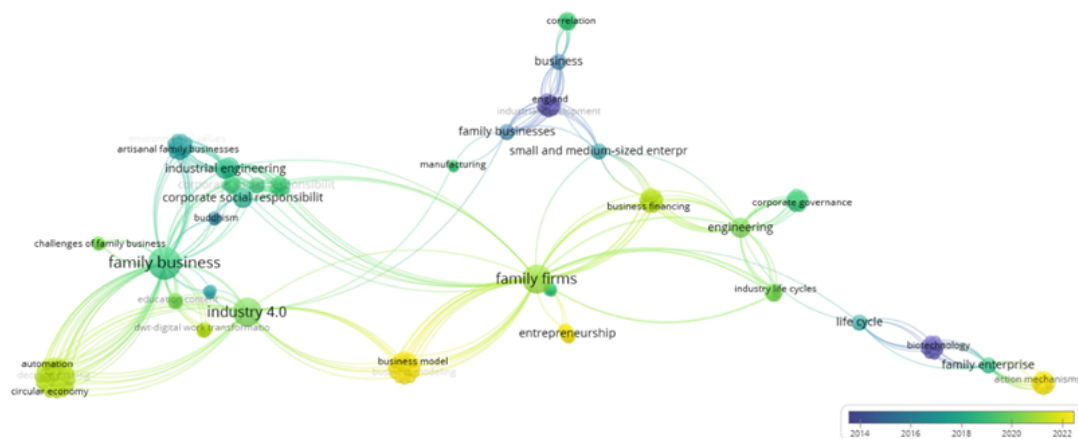


Fig. 4. Temporal graph of the keyword network

The green cluster contains 10 keywords and represents elements related to family firms that revolve around issues related to the approach to running a business, entrepreneurial skills, operating strategy (Truant et al., 2019), entrepreneurial attitude and character of young people (Judit & Zsuzsanna, 2022) and entrepreneurship or risk management (George et al., 2022).

Directly related to the green and purple cluster is the blue cluster (18 results), which centres around keywords derived from the Cucculelli, Dileo, and Pini (2022) publication, namely business model, public institution, manufacturing industry, manufacturing industries.

The most important keyword in the dark green cluster comprising 19 outcomes is corporate social responsibility, which is combined with industrial engineering, governance (López-González et al., 2019) or philanthropy (Campopiano et al., 2019). This cluster also incorporates key words such as Buddhism, karma, Thailand, as evidenced by research on Buddhist approaches to corporate social responsibility conducted with a small family business from Thailand (Chou, et al., 2016).

Strongly related to industrial engineering is the brown cluster, which contains 12 keywords. It targets quality standards and environmental impacts by using keywords such as iso certifications, quality practices, environmental values and environmental issues (Sánchez-Medina et al., 2017).

The keyword family businesses appears in the turquoise cluster, where it is found among keywords such as manufacturing (Pini, 2019) or small and medium-sized enterprises (Xiang et al., 2021). The most strongly related keywords in the cluster are those related to England, Manchester, Liverpool, and household structure (Barker & Ishizu, 2012).

The pale blue cluster, which includes nine outcomes and further discusses elements related to the functioning of business internationally such as diversification of

export territory, export, internationalisation, support of export, which are not related to the topic under study (Petrû et al., 2019), is linked to the English issues.

The next keyword defining family businesses, family enterprise, is found in the orange cluster, touching on industrial revolution and artificial intelligence (Wang & Li, 2023), which are strongly associated with the fourth industrial revolution. It also includes keywords such as economic, management style, and company performance (Wang & Li, 2023).

The yellow cluster of 18 keywords, which is strongly related to the orange cluster, focuses on topics related to development and life cycles: biotechnology, different stages, development stages (Shi et al., 2014) linked to the issues of family firms, industry life-cycle, ownership (Cucculelli & Peruzzi, 2020).

Strongly related to the engineering keyword pink cluster, which contains 12 results and refers to a publication by Cumming, Meoli, and Vismara (2019) on a study of the funding model of family businesses through crowdfunding platforms.

The pale red cluster (11 results) contains the keywords China, fintech, small and medium-sized enterprises (SMEs), state-owned enterprises (SOEs) mainly related to the article by Xiang, Zhang, Worthington (2021), which focusses on state-owned enterprises, family firms and firms under financial constraint in China, which relates to the topic under study.

Figure 4 shows a map related to publication time, showing the trend of keywords in publications between 2014 and 2022. A colour gradient from dark blue to yellow was used, where the darkest colour represents older publications, and the lightest colour represents the most recent publications. Keywords associated with the largest nodes were the most popular between 2018 and 2020.

The elements of the turquoise and yellow clusters are the darkest on the map with the timeline. The oldest listed publications on the generated map are characterised by strong connections between keywords.

Keywords used in recent publications appear in the orange, dark blue, and light green clusters. It is also worth noting two clusters associated with relatively new articles published in 2021, the red cluster and the pale blue cluster. As can be seen, over the years, publications related to family businesses and Industry 4.0 have started to focus on increasingly general issues related to the way the business is run, the impact of digitalisation, and entrepreneurship as a skill. The first publications surveyed covered narrow topics related to a very specific area of family businesses. Subsequent years covered topics related to family businesses, small and medium enterprises, or business in a general sense. Between 2018 and 2020, topics included challenges of family business, family firms, engineering, industry life cycles, corporate social responsibility, indicating the link between industry 4.0 and family firms, and the increasing longevity of such firms. More recent publications have addressed issues important to the operation of a business, such as financing, economy, business model, company management, and entrepreneurship, indicating that publications are increasingly focusing on the skills needed to manage a business.

The co-authorship analysis is based on the 54 authors shown on the map (Figure 5). The map is divided into 19 clusters. The lack of interaction between the clusters of researchers working on the topic of family firms signals a lack of world-class collaboration between different research centres. This indicates simultaneous research conducted independently by different institutions that do not share knowledge, which translates into a limited number of available publications in the field. The co-authorship analysis was based on the three largest clusters (Figure 5), as there is a perception that these clusters represent central and relevant entities in the context of the area under study. This method allows for a focus on the most important links between authors and a better understanding of mainstream research.

It can be noted that the largest of the clusters consists of 5 authors. This indicates a collaboration between them and an exploration of the topic under discussion. They focus on issues related to the words automation, business development, or decision making (Kazancoglu et al., 2021). These are areas of critical importance in today's dynamic business environment. It is linked to effective management or expansion into new markets.

Kazancoglu et al. (2021) has focused his research on areas related to sustainable quality management, operations management, and green logistics. In his research

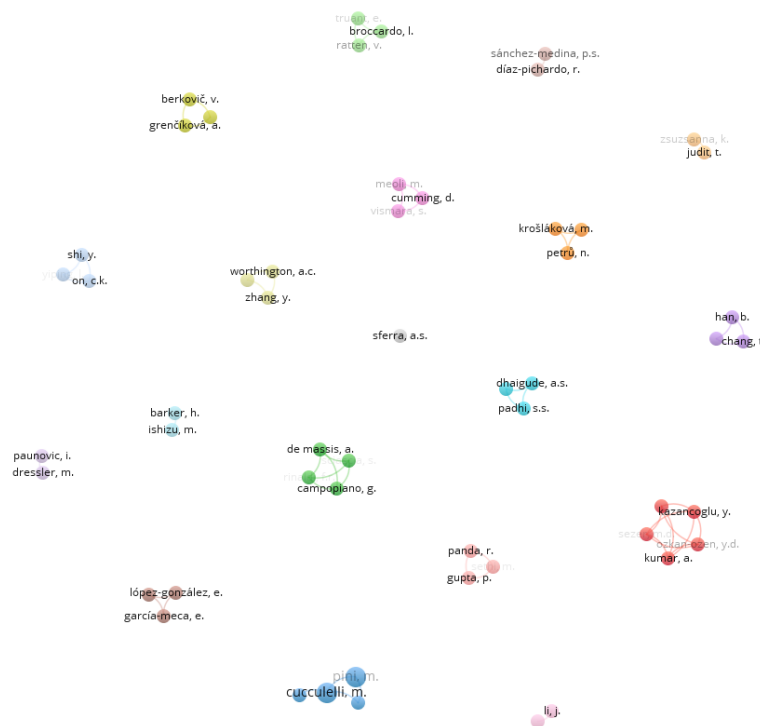


Fig. 5. Bibliometric map of co-authorship in publications on family firms 2014–2022

publications, Yeşim Deniz Özkan Özen (Kazancoglu et al., 2021) looks in detail at issues related to sustainable supply chains, logistics centres, or operational management. Sezer (Kazancoglu et al., 2021), on the other hand, focused on research in sustainable purchasing, two-way sourcing, and reverse logistics. Kumar (Kazancoglu et al., 2021) also conducted research on supply chain disruption, focussing on similar issues. In the area of business intelligence and supply chain management, Mangla (Kazancoglu et al., 2021) conducted research. The collaboration of these authors resulted in the article Industry 4.0 impacts on responsible environmental and social management in the family business, the topic of which focuses on the impact of technological innovations of Industry 4.0 on environmental and social management as a family business. The results show that this development contributes to improving corporate social responsibility and environmental management systems. It is worth mentioning that the results of this collaboration may prove useful in analysing environmental sustainability for family businesses.

The second largest collaborative authors were Campopiano, De Massis, Rinaldi, Sciascia (2019). They were created on the themes of industrial engineering and corporate social responsibility. This approach is particularly relevant as it brings together two key aspects of today's business and industrial world. It gives a holistic approach to business that takes into account both profit and social objectives, which is increasingly expected in today's society and business.

An Italian-Swiss collaboration (Campopiano et al., 2019) resulted in the article Family and non-family women on the board of directors: Effects on Corporate Citizenship Behaviour in Family-Controlled Fashion Firms, Based on the Topic of Women's Engagement in Family Firms Positively Influencing Corporate Social Responsibility. Campopiano (2019) based her research publications on the themes of innovation, social entrepreneurship, and mergers and acquisitions. Rinaldi (Campopiano et al., 2019) also addressed similar issues, focussing on innovation, sustainability, and industrial symbiosis. Different topics related to corporate social responsibility, innovation, or global reporting initiatives were addressed by Sciascia (Campopiano et al., 2019). In contrast, De Massis's academic work was based on issues of open innovation, corporate governance, and companies.

The analysis of the third largest collaboration points to the themes of business model, family management, or product design. Authors Cucculelli, Dileo, Peruzzi, and Pini (2022) focused on an area of unique importance and impact on the functioning of companies and their success.

Cucculelli's (2022) research papers were created by focussing on competitiveness, business model innovation, and family businesses, which together allowed him to produce more than 50 articles. Dileo (Cucculelli et al., 2022), like the earlier author, was based on the topics of innovation and family businesses, but also described the issues of ethnic businesses, small and medium enterprises, and self-employment. In addition to the topics mentioned above, Peruzzi (Cucculelli et al., 2021) examined the topic of credit and credit rationing in detail. Pini (Cucculelli et al., 2022), on the other hand, focused his research work on supply chain disruptions, eco-innovation, and family businesses.

An Italian collaboration resulted in an article that considered the impact of company ownership on innovation during the product life cycle. The final conclusion was that family management favours risk avoidance (Cucculelli & Peruzzi, 2020). However, 2 years later, the likelihood of innovation in the business model of family firms toward Industry 4.0 was considered, while the results showed a negative impact on the adoption of Industry 4.0 business models only in the context of family ownership (Cucculelli et al., 2022).

Figure 6 shows a hit map showing the time trend of the emergence of author collaborations between 2011 and 2023. The first collaborations were undertaken by Barker and Ishizu (2012). Focussing on a topic related to correlation and business, business models, family management, or product design. Focussing on a research area with a major revolution in today's business and scientific environment. A paper based on the Li, Wang (2023) collaboration was recently published. The themes of the publication were based on the importance of artificial intelligence as a tool to support the acquisition of economic advantage in the context of family businesses.

It should be noted that the highest number of author collaborations took shape between 2019 and 2020. During that period, the topic became increasingly popular, as demonstrated by the increase in the number of publications compared to previous years.

In summary, the authors who collaborated mainly focus on issues related to family businesses, the development of employee competences, and the qualities of a leader. However, the number of these authors is limited because the topic discussed is not very popular in academic research.

The publications studied amount to 21 articles published between 2011 and 2023. However, 17 citations from these publications were analysed in detail.

The first of these appeared in the international journal Business History (Barker & Ishizu, 2012). It was quoted 15 times in the years analysed. As the blue cluster shows, they wrote about business models and



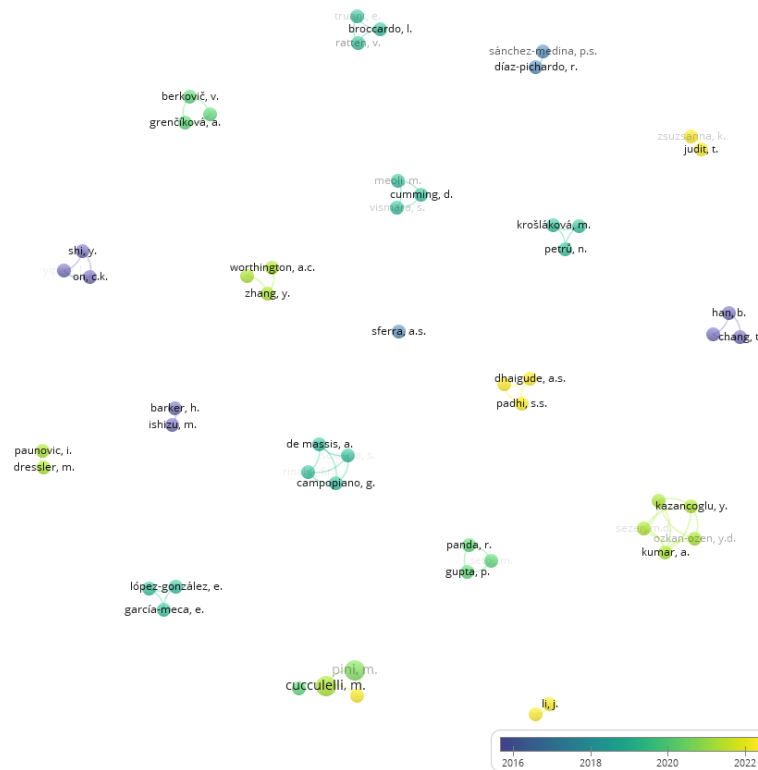


Fig. 6. Time graph of the co-authored network

family businesses. The most recent publication (Cucculelli et al., 2022) that was cited is published in “The Journal of Technology Transfer” and focusses on the issue of action mechanisms and family-owned business (orange cluster, Figure 2).

The most influential article was published in October 2019 and has been cited 98 times to date (Cumming, Meoli, and Vismara, 2019). Focussing on the topic of corporate governance and engineering (pink cluster, Figure 2). The second article in terms of citations was published in February 2019 in the Journal of Cleaner Production (López-González et al., 2019), focusing on the topic of industry life cycles and its maturation (yellow cluster, Figure 2). The citations are numbered 46 times. The third result in terms of citations is shaping up 42 times (Campopiano et al., 2019). Published in March 2019, this article was based on issues related to Industry 4.0.

Published articles have been cited a total of 355 times. There are also 4 papers representing 19% of the total that have never been cited. It is worth mentioning that the majority of articles are not cited to a significant extent, but achieve results that range from 1–7 times (Fig. 7).

Demographic analysis shows that 17 countries have published at least one article related to Industry 4.0

and family businesses. Italy is one of the main leaders, as publications originating from this country represent more than 20% of the total, and the number of citations is at the highest level of all countries at 186.

Figure 8 shows the network of co-authorship between countries. Of the 17 countries, there remain 9 countries with a link between them, which are the largest group that forms a network of links. These countries are divided into 3 clusters: red (containing the citation leader and the most influential country), green, and blue (Tab. 3). Between one of the main leaders, Italy, there are links with Germany, the United Kingdom, Belgium, the United States, and Australia. These links imply an international collaboration between the authors, who not only focus on the situation of family businesses in Europe, but also seek information in far-flung corners of the world. Australia cooperates with China, which, in turn, cooperates with Malaysia. Similarly, co-authorship is taking shape in the United States collaborating with the Old Continent and Taiwan.

The first publication related to the topic was produced in Malaysia in 2014, and is also the only publication originating from that country that has never been cited. This was followed by one publication in Taiwan and three in the UK in 2016. In mid-2017, two publications were published in the United States.

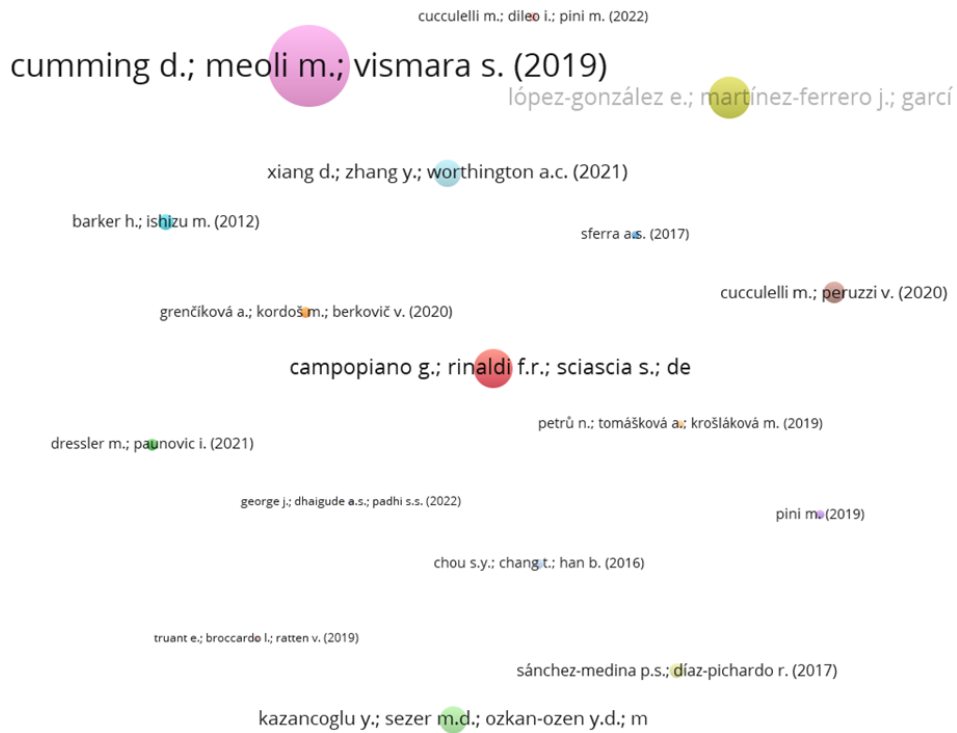


Fig. 7. Citation of authors from 2011 to 2020



Fig. 8. Co-authorship network between countries

Table 3  
Description of the contents of the clusters shown in Figure 8

Cluster 1 – red	Cluster 2-green	Cluster 3 – blue
Belgium	Australia	Taiwan
Germany	China	United States
Italy	Malaysia	
United Kingdom		

No publication was published in 2018. The year 2019 was fruitful in publications related to the topic. Belgium produced one publication and Italy, the most influential country, produced seven publications. In addition, three publications were published in China. In 2020, Germany and Australia each produced two publications related to the theme, they are the latest publications compared to other countries and years of analysis (Figure 9).

The published documents analysed are related to 50 institutions, among which 6 participated in mutual cooperation. These are presented in Table 4. The analysis of cooperation between institutions indicates a relatively low level of cooperation in the context of the topic under discussion.

The phenomenon is characterised by limited exchange of information between research units and a low degree of interaction. Limited collaboration can be the



Fig. 9. Co-authorship between countries 2014–2020

Table 4  
Cooperating institutions

Institutions					
Witten Institute for Family Business, Berlin, Germany	IULM University, Milan, Italy	Free University of Bozen-Bolzano and Lancaster University	LIUC Università Cattaneo, Cattaneo, Italy	Lancaster University Management School	Bocconi University, Milan, Italy

result of lack of access to resources or ignorance of the topic. Institutions may focus on their own research and distinctions, which may inhibit collaboration.

It should be emphasised that the research topic in question is relatively new and has not been fully explored by scientific research units. Continued research to better understand the phenomenon will influence the development and increase the number of collaborations between institutions within the new research area.

## Discussion

The fourth industrial revolution involves major changes that companies must undergo in order to adapt to an intensely evolving market. The emergence of new technologies and solutions brings with it new challenges. One of them is to educate the workforce with the set of skills needed to run a company in the digital age. The bibliographic analysis carried out presents publications from the last 12 years that show how family businesses are dealing with such a challenge and what engineer 4.0 competencies are used in running them.

The results of the bibliometric study carried out show the link between family business and industry 4.0 in the selected publications (Figure 2). Divided into 13 clusters, the semantic map shows the topics in which family business and industry 4.0 are linked. It turns out that during the study period, the topics of the publications changed from narrow issues to broader considerations. Older publications addressed issues such as the succession of small family businesses during the early industrial revolution in the UK (Barker & Ishizu, 2021) and about the Buddhist application of corporate social responsibility (Chou, Chang, Han,

2016). With the proliferation of Industry 4.0, more and more publications directly linked engineering issues to family businesses. Such a trend can be seen throughout the period under study. Grenčíková, Kordoš, Berkovič (2020) write about the impact of the industrial revolution on jobs in Slovakia, also considering the impact on family firms. Dressler and Paunovic (2021) explore strategies for implementing digital grape harvesting technology in small and medium-sized family vineyards. The last three years, on the other hand, have seen the most publications related to entrepreneurship, business knowledge, automation, and technological advances. The impact of the fourth industrial revolution on management in family firms has been written about by Kazancoglu, Sezer, Ozkan-Ozen, Mangla, and Kumar (2021). In their publication, Panda, Gupta, and Sethi (2020) address the challenges of the second generation entering the enterprise. Cucculelli, Dileo, Pini (2022) write about the changes in the business model of family firms within Industry 4.0. This means that issues related to the impact of the fourth industrial revolution on family firms are popular and increasingly being considered.

When analysing the publications surveyed, there is a trend related to considering the competencies needed to work in a fast-paced technological enterprise. Such issues have been written about by, among others, Judith and Zsuzsanna (2022) considering entrepreneurship among students and George, Dhaigude and Padhi (2022) who examined decision-making skills, risk recognition and the ability to assess excellent value based on a case overview. However, despite addressing the topic and exploring the desirable competencies of employees in family businesses during Industry 4.0, none of the publications exhaust the topic and analyse the whole issue.

The co-authorship analysis was performed and indicates little collaboration between the authors. As noted in the analysis performed, the number of co-author collaborations increased 2 years 2019–2022, indicating an increase in the popularity of topics related to family businesses and Industry 4.0. An increase in co-authorship could influence the possibility of data extraction, e.g. between institutions or countries, and the expansion of knowledge in the topic under study.

The Scopus database used in the study for the selected keywords, i.e. industry 4.0 and family businesses, and the selected time constraint (2011–2023) finds 105 articles. This shows that issues arising from the impact of the fourth industrial revolution on family businesses are being researched and considered in publications. The bibliometric analysis conducted indicates a research gap in considerations related to the desirable competencies of engineer 4.0 in family businesses.

## Summary

The issue of how family firms operate in the context of Industry 4.0 has started to emerge relatively recently. In this article, a bibliometric and scientometric analysis of scientific publications on engineering competencies specific to Industry 4.0 used in family firms was carried out, which led to the conclusion that this topic has not been studied in detail so far and therefore requires further research to be undertaken. Three research questions were posed and answered during the implementation of the research and the analysis of the findings.

The most relevant research topics for the development of Industry 4.0 in family businesses (RQ1) include the topic whose article “Investors’ choices between cash and voting rights: Evidence from dual-class equity crowdfunding.” (2019) received 98 citations are Douglas Cumming, Michele Meoli and Silvio Vismara. The most collaborations between authors (Yigit Kazancoglu; M’ur’uvvet Deniz Sezer; Yesim Deniz Ozkan-Ozen; Sachin Kumar Mangla; Ajay Kumar) were for the article “Industry 4.0 impacts on responsible environmental and societal management in the family business.” The network between the authors of the publication has not yet developed, which may be due to simultaneous research on a new and continuously evolving topic (RQ2). The keywords that occurred in the publications with the highest intensity were “family business”, “family firms”, and “industry 4.0”. To date, six scientific institutions have collaborated in the study area. Witten Institute for Family Business, Germany; IULM University, Italy; Free Uni-

versity of Bozen-’Bolzano and Lancaster University; LIUC Università Cattaneo, Italy; Lancaster University Management School; Bocconi University, Milan, Italy. In the survey carried out, Italy showed the most links with other countries in terms of co-authorship (5 countries).

Therefore, it should be recognised that the research area is a developmental one and it is worthwhile to continue scientometric analysis with extension to other scientific databases, e.g. WEB of Science, Ebsco, and then to carry out qualitative primary research that can help explore the relevance of the development of the 4.0 and 4.0 competencies in the context of family entrepreneurship.

It is certainly difficult to assess the state-of-the-art in the area under study, as some items are not represented in our sample. However, the above shortcomings do not significantly affect the quality of our study.

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