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Review

Insights from 20 Years (2004–2023) of Supply Chain Disruption Research: Trends and Future Directions Based on a Bibliometric Analysis

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Abstract: This paper explores the research trends in the literature about supply chain disruptions published over the last 20 years through a comprehensive review and keyword-based analysis. A sample of 4239 papers retrieved from Scopus was analyzed to identify the key themes covered and the shifts in time of those themes. The results highlight a significant rise in the number of publications on supply chain disruptions since 2021, reflecting the dynamic nature of supply chains and the need to adapt them to increasingly complex scenarios. The findings point out the importance of resilience and risk management but also the progressive shift toward technological innovations and digital tools, as a means to enhance supply chain robustness and sustainability in response to recent global disruptions (e.g., the COVID-19 pandemic, the Russia–Ukraine conflict, and the climate change). From the analyses carried out, interesting opportunities for future research directions are delineated. This study represents a unicum in the scientific literature in terms of the number of articles analyzed, the timespan, as well as the scientometric approach adopted. Finally, the paper highlights the main trends in the field of supply chain disruptions, providing valuable insights for future research activities.

Keywords: supply chain; disruption; bibliometric analysis; COVID-19; Industry 4.0; digitalization

Citation: Solari, F.; Lysova, N.; Romagnoli, G.; Montanari, R.; Bottani, E. Insights from 20 Years (2004–2023) of Supply Chain Disruption Research: Trends and Future Directions Based on a Bibliometric Analysis. *Sustainability* **2024**, *16*, 7530. https://doi.org/10.3390/su16177530

Academic Editor: GuoJun Ji

Received: 25 July 2024
Revised: 27 August 2024
Accepted: 28 August 2024
Published: 30 August 2024

1. Introduction

The term supply chain refers to a series of activities, materials, people, equipment, information, and resources required to define, produce, transform, assemble, and, finally, deliver a product or service from the producer to the customer. In that system, three major phases can be identified, which can, in turn, be divided into smaller processes: procurement, i.e., how, where, and when to source the raw materials, resources, components, products, etc., required for the production; operations, i.e., the actual manufacturing activity where the final product is made; and distribution, i.e., all the activities resulting in the delivery of a specific commodity to the customer.

Supply chains should not be considered as a simple product and/or service transfer from the producer to the consumer, but rather as an essential factor in generating value for the product itself. Indeed, the concept of supply chain is often associated with that of value chain [1]: the product and/or service, when flowing through the various stages of the supply chain, acquires value. It follows that topics regarding the supply chain are well-established and widely discussed in the scientific literature, with the first available studies dating back to the early 1970s [2,3].

One of the core aspects of supply chain studies is related to supply chain management [4], i.e., the optimization of supply chain operations and coordination of all its components to ensure efficiency and cost-effectiveness. Another aspect that many studies focus on is logistics [5], which is the planning, implementation, and control of the flows of goods

and services, referring mainly to transportation management, inventory management, and warehousing. A further well-debated topic concerns procurement strategies and processes to acquire items, assets, and services from external suppliers to have them available when needed [6,7]. This topic is obviously related to demand and market trend forecasting [8]. In recent years, information technology and data analysis have attracted great interest as tools to improve supply chain performance, identify inefficiencies, and improve decision making [9]. Furthermore, the increasing awareness that citizens and politicians have on climate change is driving an increasing focus on the economic, social, and environmental sustainability aspects of the supply chain [10].

Within this scenario, in the late 1990s, the topic of disruptions began to appear in supply chain studies. In the first studies, the focus was on the so-called millennium bug, or Y2K, whose effects could have had significant impacts on the supply chain. Mcgaughey and Gunasekaran [11] have comprehensively mapped the possible impact of the millennium bug on the supply of materials, components, and services crucial for manufacturing operations. Their analysis highlighted the urgency for manufacturers to evaluate the vulnerability of their supply chains to Y2K issues and to develop robust contingency plans to mitigate potential operational risks. In 2004, the focus shifted toward the war in Iraq and the SARS epidemic in Southeast Asia. Overby et al. [12] have analyzed the latter topic, highlighting the severe economic disruptions SARS caused in various business sectors of Southeast Asia, such as travel, manufacturing, and public health, both locally and globally. Between 2017 and 2023, many studies focused on Brexit, an event that disrupted both political and trade balances within the European Union and globally. Hendry et al. [13] have analyzed the resilience of local food supply chains in the UK, emphasizing the importance of vertical and horizontal collaboration among supply chain actors to anticipate and mitigate the impact of Brexit. In the last decade, several studies have addressed migration flows, while recently, the attention of researchers has shifted toward the COVID-19 pandemic. Wang [14] has delved into the economic consequences of the COVID-19 pandemic on global supply chains, with a specific focus on the challenges faced by Chinese migrant workers in low-wage employment sectors. The author outlined the precarious situations of these workers, in terms of job insecurity, reduced incomes, and increased exploitation, in view of business strategies to sustain profitability. In the last two years, much attention has been placed on the conflict between Russia and Ukraine, which resulted in a great disruption both in terms of trade relations among global players and raw materials and energy resources supply [15]. Rose et al. [16] have presented a detailed analysis of the economic impacts of grain export disruptions caused by the Russia–Ukraine war, revealing significant economic effects not only on the country directly involved in the conflict, but also across various global regions, thus highlighting the far-reaching consequences of disruptions in commodity supply chains [17]. Technological innovations, such as the advent of the fourth industrial revolution (Industry 4.0), could also be seen as disruptive events, as they force both companies and academia to change their approach to supply chain to adapt to a new context, so as to take the greatest possible advantage from technological innovations. In this respect, Abdirad and Krishnan [18] have reviewed the integration of Industry 4.0 technologies into supply chain and logistics management, highlighting the transformative impact of Industry 4.0 on the supply chain in terms of efficiency, transparency, and responsiveness.

This context of frequent disruptions and great uncertainty can have massive impacts on supply chains, as systems in which the failure of one element can cause the failure of the entire chain (ripple effect) [19]. As a consequence, risk management, i.e., risk identification, management, and mitigation, became even more important [20,21]. Fagundes et al. [22] have performed a bibliometric analysis to map the literature on decision-making models and support systems for supply chain risk management, emphasizing the integration of supply chain risk management with big data and Industry 4.0 technologies as a promising future research area.

From the set of considerations above, supply chains emerge as dynamic systems that must continuously adapt to the real-world context by gradually managing increasing levels

of complexity and various sources of disruptions [23]. Hence, the purpose of this study is to determine how the trends of scientific literature in the area of supply chain disruptions have changed over the past 20 years. This goal is achieved by carrying out an extensive literature review, supported by some typical scientometric/bibliometric tools, such as co-authors mapping and keyword-based analyses. Scopus was chosen as the reference database to obtain the sample of studies to be analyzed.

The remainder of the paper is organized as follows. Section 2 reviews the literature relevant to the present study. Because this study is organized in the form of a literature review, that section focuses primarily on the existing review papers on the topic of supply chain disruptions, to clearly show the contribution of this scientometric review. Section 3 details the methodology applied for carrying out the analyses proposed in this study, followed by the corresponding results presented in Section 4. A discussion of the key results and of the advancement compared to the available knowledge is proposed in Section 5. Section 6 concludes by commenting on the outcomes obtained and their implications, highlighting the contribution of this study compared to the available literature, and suggesting future research directions.

2. Literature Review

To highlight the contribution of the present study, a dedicated analysis of the existing reviews about supply chain disruptions was carried out to categorize the main topics analyzed by the researchers. To this end, some of the most relevant systematic literature reviews on the subject (resulting after launching the query described in Section 3) were screened before proceeding to the keyword-based bibliometric analysis to determine the general topic, the number of years covered by the review, and the number of papers analyzed. By "relevant", it is meant that the review must have a clear definition of the period and of the number of the papers analyzed (which is a requirement for being "systematic"—cf. Section 3), a high number of citations, and a clear relationship with the topic of the present paper. A sample of 40 reviews was selected to be compared to the present study, consisting of the reviews published in 2023, with the highest number of citations at the time of writing and the most cited reviews in the period 2018–2022 (Table 1).

Table 1. Overview of the relevant literature reviews.

Reference	Number of Papers	Period	Main Topic
[24]	101	2006–2019	Supply chain resilience in Small and Medium-sized Enterprises (SME)
[25]	46	2012–2022	Supply chain resilience in SMEs in the context of the COVID-19 pandemic
[26]	517	2020–2022	Trends in sustainability during and post the COVID-19 pandemic
[27]	151	2004–2021	Coordination issues in the return supply chain
[28]	40	2002–2021	Identification of key drivers for supply chain digitalization readiness
[29]	35	2020–2022	Resilience strategies for disruption management in healthcare supply chains during the COVID-19 pandemic
[30]	191	2019–2021	Effects of COVID-19 on the supply chain management
[31]	52	2017–2022	Resilience practices in healthcare supply chain management, with a focus on purchasing challenges during the COVID-19 pandemic
[32]	68	2009–2020	Artificial Intelligence and Big Data Analytics in Supply Chain Risk Management
[33]	50	2011–2020	Ripple effect in supply chains

Table 1. *Cont.*

Reference	Number of Papers	Period	Main Topic
[34]	50	2020–2021	Supply chains under disruptions due to COVID-19 pandemic, with a focus on the production and distribution of COVID-19 vaccine
[35]	135	2011–2021	Practice and research gaps related to supply chains, and what characteristics should a supply chain have to be survivable
[36]	33	2011–2020	Contribution of Industry 4.0 integration into supply chains to the enhancement of resilience
[37]	469	2020–2021	Potential disruption-management strategies during the COVID-19 pandemic
[38]	87	2006–2021	Impacts of additive manufacturing on the structure and dynamics of supply chains
[39]	173	2009–2021	Main impacts of pandemics and epidemics on food supply chains and policies that can minimize these impacts
[40]	147	2019–2021	How smart city solutions and technologies have contributed to enhancing resilience in cities during the COVID-19 pandemic
[41]	68	2019–2021	COVID-19 impact on livestock systems and food security in developing countries
[42]	62	2020	Delays and disruptions to cancer health care services due to COVID-19 pandemic
[43]	112	2020–2021	How technology has tackled food supply chain challenges related to quality, safety, and sustainability
[44]	192	2017–2020	Potential of blockchain for privacy and security challenges related to supply chain disruptions
[45]	32	2010–2020	Impacts on the business environment of supply chains of previous epidemic outbreaks
[46]	455	2010–2019	Supply chain risk management: review of the existing literature and exploration of risk factors
[47]	53	2000–2020	Integration of lean and resilience paradigms
[48]	306	n.d.–2020	Inventory models with multiple sourcing options
[49]	2402	2008–2020	Integration of sustainable supply chain management with organizational ambidexterity to manage disruptions effectively
[50]	77	2004–2018	Review of the methods that are currently used for mitigating supply chain disruptions
[51]	1310	1999–2019	Disruption risks in supply chain management
[52]	55	2004–2018	Use of information technology in supply chain risk management
[53]	157	2000–2019	How collaborations help supply chains respond and recover from a disruption
[54]	93	2008–2015	Review of simulation methods that deal with risks in supply chain and types of data integration employed
[55]	27	2009–2020	Psychological causes of panic buying
[56]	94	2017–2019	Resilience analytics in supply chain management and modeling of the supply chain network dependence on other networks
[57]	77	2010–2019	Use of machine learning algorithms for demand forecasting
[58]	1625	2009–2018	Analysis of the most adopted theories in supply chain management, marketing and management
[59]	200	n.d.–2017	Multidisciplinary review about the concepts of agility and resilience
[60]	54	2000–2018	Analysis of resilience focusing on upstream disruptions in agricultural value chains

Table 1. *Cont.*

Reference	Number of Papers	Period	Main Topic
[61]	27	2008–2018	Use of blockchain in supply chain management context
[62]	41	1997–2017	Cyber risk management in supply chain contexts
[63]	689	2010–2018	Research themes on IoT and big data analytics in the field of supply chain management
This study	*4239*	*2004–2023*	*Supply chain disruptions*

Most studies have focused on determining the characteristics that a supply chain must have in order to survive disruptions. The major disruption addressed in the articles was, as expected, related to the COVID-19 pandemic, which greatly impacted the supply chains worldwide [25,26,29–31,34,35,37,40–42,45,56]. On a general level, a key aspect that could support supply chains in reacting to and recovering from disruptions has been found to be digitalization, with the crucial role of IT infrastructures and cybersecurity for the efficiency of information sharing and safety of critical data [28,31,52,62]. Moreover, simulation and modeling tools and methodologies resulted in being fundamental in optimizing supply chain management [27,32,33,48,54,56]. Overall, Industry 4.0 technologies have been identified as potential means to increase supply chain visibility and resilience [25,28,29,31,38,40,43–45,52,57,62,63]. The resilience itself, intended as the ability to anticipate, prepare for, respond to, and rapidly recover from disruptions, was as expected a key topic addressed in the literature reviews of the latest years [24,25,29,31,35–37,40,44,47,49,51,59,60]. A high level of resilience is often linked with collaboration [24,30,49,53] and visibility [31,44,53,61]. Several authors, indeed, agree on the potential of Blockchain technology to greatly enhance supply chain visibility and information sharing, thus making supply chain management more efficient and increasing the collaboration and trust between supply chain actors [29,31,37,40,44,51,61,62]. Finally, great importance has been given to the aspect of sustainability, both environmental [35,37,43,44,49,50,52,61] and social [26,27,35,52,61].

From Table 1, it is also evident that the present study exhibits evident differences compared to the available reviews. In particular, it analyses a significantly greater number of papers and covers a wider timespan. Also, the scientometric approach adopted contributes to better delineating the main research trends in the field of supply chain disruptions.

3. Materials and Methods

3.1. Sample Creation

A systematic review of the literature is a structured process for retrieving the papers of interest within the scope of a scientific study, to clarify the state of the art in a field of research and the implications that can be drawn from that, as well as to answer a research question [64]. For the purpose of this study, a single query was made on the Scopus database in January 2024, targeting papers relating to supply chain disruptions and published in the last 20 years (2004–2023). The selected timespan is in line with the typical number of years of a scientometric study and is large enough to appreciate changed trends or evolutions in the selected field of research on a grand scale [65]. The string used for the query was "TITLE-ABS-KEY ("supply chain" AND disruption) AND PUBYEAR > 2003 AND PUBYEAR < 2024". Moreover, the following inclusion criteria were applied:

- Only papers published in international journals were retrieved, while other types of publications were not considered;
- Similarly, only papers written in English were considered.

Within this setting, 4555 papers were obtained, for which some relevant pieces of information were extracted using the "export" function available on Scopus and imported

on Microsoft Excel™ for further elaborations. In particular, the data extracted referred to the following:

- The paper's metadata: authors, journal, bibliographic data, publication year, document title, and document type (article vs. review);
- The authors' keywords;
- The publication option (traditional vs. open access);
- Funding information.

The Microsoft Excel™ database was subject to a preliminary manual check of the papers' data, which led to removing documents without authors. Indeed, these documents typically do not fall into the category of scientific papers; rather, they could be documents published in magazines or preface to conferences. Moreover, despite the query settings, one paper was found to be published in 2024 and was removed as well from the database. The final sample of documents, available as Supplementary Material at https://doi.org/10.17632/stbpjgsv5y.1 [66], consists of 4239 papers.

In addition to the data extracted from Scopus, a label was assigned to each paper by dividing the timespan into shorter (five-year) periods, as follows: period 1: 2004–2008; period 2: 2009–2013; period 3: 2014–2018; and period 4: 2019–2023.

3.2. Descriptive Analyses

Some preliminary statistical analyses were made on the sample of papers, to depict the trend in time of the literature relating to supply chain disruptions, in terms of papers per year, document type, publication option, availability of funding, journals in which the papers retrieved were published, and author-related statistics. Some elaborations were supported by specific software packages, such as VOSviewer v.1.6.20 and the Statistical Package for the Social Science (SPSS v.29). The related results are presented in Section 4.1.

3.3. Keyword Analysis and Trend

Keywords are essential tools that help researchers have access to papers, books, and works related to their field of expertise [67]. Although different logics might exist for selecting the keywords of a research paper [68], typically, these terms express the main topics of a paper; as such, in scientometrics, author keywords and their analysis are recognized as effective tools to reflect map the topics covered in a scientific field. Indeed, keywords represent the 'unique' topic of a document inside a wider research area [69].

In line with these considerations, a keyword analysis was made for mapping the topics covered by the articles retrieved. The analysis obviously excluded papers that lack the keywords, i.e., 356 documents. For carrying out an effective analysis, the keywords typically need to be screened and checked for consistency, on the basis of the following considerations:

- Authors often use slightly different terms to express the same concept. This is the case for singular or plural forms, British or American spelling of words, usage of capital letters/lower case letters, usage of hyphenation, or abbreviations (e.g., COVID vs. Coronavirus);
- Acronyms can sometimes be used as keywords instead of the full text.

Hence, the keywords used in the sample of papers were listed in a separate sheet and checked accurately to create a consistent set of terms. After checking the keywords, a list of 8226 single terms was obtained; that list excluded 59 terms that turned out not to express keywords, either because they were not single terms but sentences, or because they referred to some codified classifications of the paper. Nonetheless, the resulting sample of keywords appears to be well representative of the topics covered in the period of analysis.

For the single terms, following the procedure described by Fadlalla and Amani [70], the frequency and persistency were evaluated. The frequency is simply related to the number of occurrences of a keyword, while the persistency reflects the continuity of a

given concept over time and is measured as the number of years since a concept was first introduced as a keyword [71]. Based on these parameters, the topics were classified as

- Well-established ('core'), with high frequency and high persistence. They are expected to denote themes that have long been studied by many authors in the field;
- Intermittent, with low frequency and high persistence. Terms in this category denote themes that have been known for many years, but have been studied with low continuity;
- Phantom/emerging, with low frequency and low persistence. These topics could be relatively new to the research field or could describe themes that have progressively disappeared;
- Trendy, with high frequency and low persistence. These topics are relatively new but have already attracted the attention of many researchers.

The classification of the keywords was made with respect to the four periods of analysis (i.e., from 2004–2008 to 2019–2023), to highlight the evolution of the topics across the years.

Wang and Chai [72] have recently introduced some specific analyses that can be made on keywords, whose general aim is to quantitatively trace the developments of a discipline. In line with the approach proposed by the authors, the trend in the keyword categories was mapped using Sankey graphs, built with the open-source tool Sankey Matic (https://sankeymatic.com/, accessed on 25 July 2024). The same analysis was made on the keywords observed in all periods of analysis. Finally, to capture some specific facets of the topic under examination, some focused analyses were made on smaller sets of keywords, namely the following:

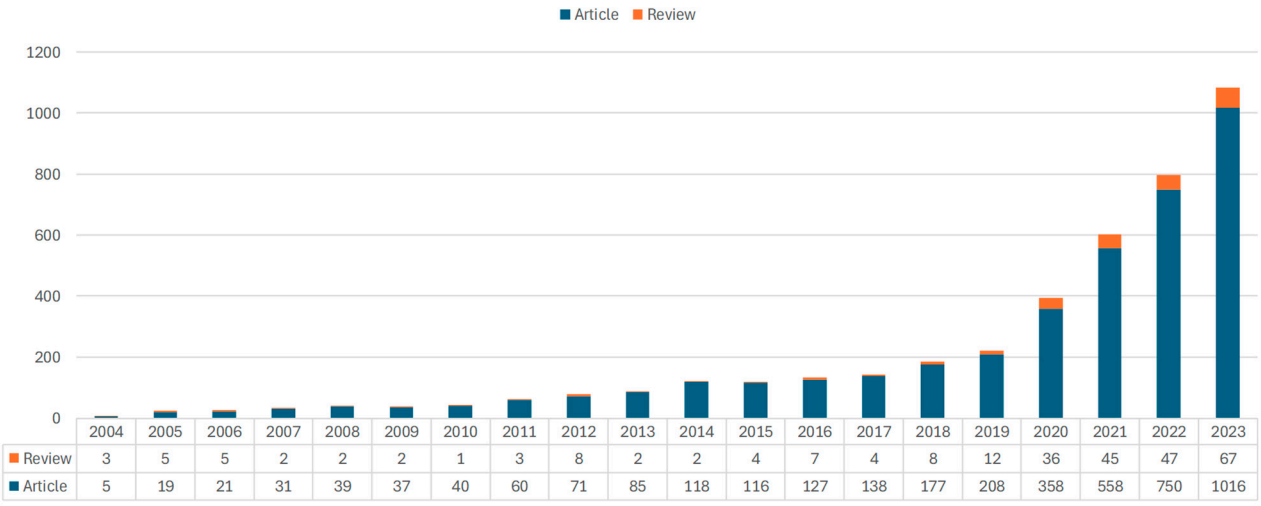
- The subset of keywords that were observed in all periods of analysis, as these terms are expected to reflect relevant themes to the selected field of research. For those terms, their classification across the four periods was mapped, so as to delineate a trend in the interest toward the specific theme;
- The subset of keywords with a minimum frequency of 30, thus indicating a high recurrence of the related topics in the targeted field of research. These keywords were first grouped by macro-areas; then, their trend in time was evaluated jointly with that of some core topics of the targeted field of research to identify possible correlations.

The results are presented and discussed in Section 4.2.

4. Results

4.1. Descriptive Analyses

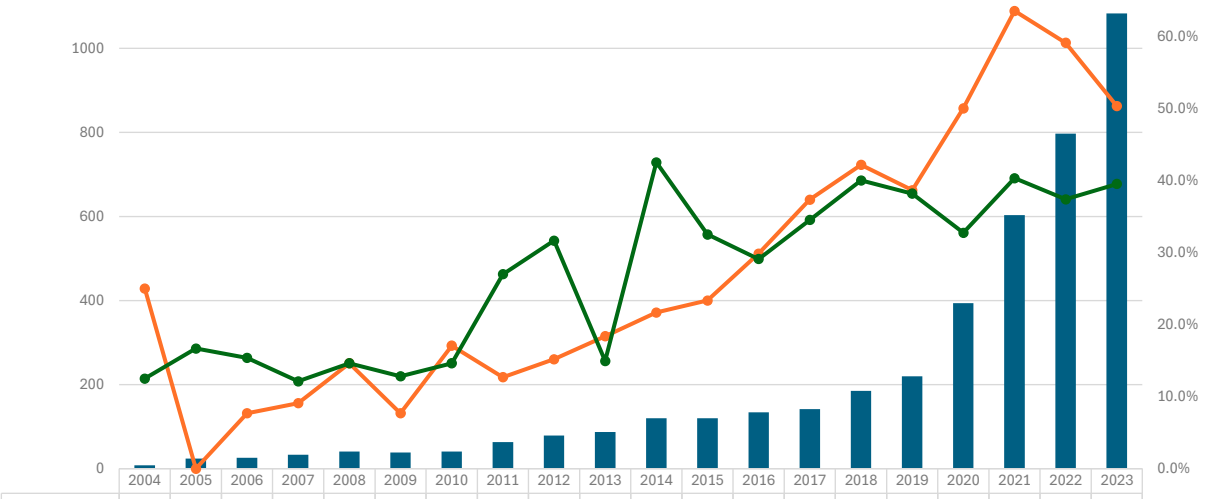
Figure 1 shows the trend in time of the number of papers published in the field of supply chain disruptions. It is evident that the topic has received increasing attention across the years, with a substantial growth in the number of publications starting from 2021. COVID-19, as a special case of supply chain disruption [73], has certainly contributed to the increased interest in this topic, taking into account its effect on logistics and supply chain processes [74]. It is also interesting to note that the peak in the number of publications was reached in 2023, which signifies that the research in this field is still very active and far from declining. Also, at present, a relevant number of review papers (265, 6.3% of the sample) has been published on the topic. Again, the number of reviews has increased significantly from 2021 onward, as a result of the growing number of publications on the theme, which form the necessary basis for developing review studies.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Review	3	5	5	2	2	2	1	3	8	2	2	4	7	4	8	12	36	45	47	67
Article	5	19	21	31	39	37	40	60	71	85	118	116	127	138	177	208	358	558	750	1016

Figure 1. Trend in time of the number of publications (articles and reviews).

The trend in time of the percentage of open access (OA) documents and funded research is shown in Figure 2. It is easy to see that overall, approximately half of the papers in the sample (46.4%) were published in OA mode and that the quota of OA papers, which was initially almost null, has experienced a substantial increase from 2020 onward. In the last few years, the annual number of OA papers has been higher than the number of traditional publications. The OA publication mode does not necessarily imply the presence of funding, as external funding is just one of the possible ways in which authors can cover the publication fees. This is reflected by the fact that the quota of funded research is not exactly the same as that of OA documents; rather, it is slightly lower (≈36% overall). Nonetheless, it is also true that if a research activity has been funded, results are likely to be published in the OA mode, as various funding sources (e.g., the European Commission) impose the OA publication mode; hence, the presence of a relevant quota of OA papers is somehow likely to also denote the availability of funding sources awarded to researchers for carrying out research activities on the topic of supply chain disruptions [75]. In fact, the trend of the funding sources turns out to be quite similar to that of OA papers, with a quota of funded research particularly relevant (≈40%) in the latest years.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
No_papers	8	24	26	33	41	39	41	63	79	87	120	120	134	142	185	220	394	603	797	1083
%OA	25.0%	0.0%	7.7%	9.1%	14.6%	7.7%	17.1%	12.7%	15.2%	18.4%	21.7%	23.3%	29.9%	37.3%	42.2%	38.6%	50.0%	63.5%	59.1%	50.3%
%funded	12.5%	16.7%	15.4%	12.1%	14.6%	12.8%	14.6%	27.0%	31.6%	14.9%	42.5%	32.5%	29.1%	34.5%	40.0%	38.2%	32.7%	40.3%	37.4%	39.5%

Figure 2. Trend in time of the number of open access papers and funded research.

The papers in the sample were published in more than 1350 different sources, with an average of 3.12 papers per journal. However, most of the journals (864, 63.58% of the total) have published one paper only, and a further relevant quota of journals (218, 16.04%) has published two papers. The maximum number of papers published by the same journal is 182 (4.29% of the sample) by the International Journal of Production Research, followed by *Sustainability* with 138 papers (3.26%). Figure 3 shows an extract of the distribution of the papers across the journals found in the sample; to make the representation more effective (and feasible in a graph), the extract is limited to those journals that published at least 10 papers in the last 20 years. Those journals cover 46.85% of the papers in the sample. In Figure 3, the number of papers published in each five-year period of the timespan was evaluated and journals were ranked in descending order of the number of papers published in 2019–2023 to highlight those journals with the highest growth in the latest years. The results indicate that certain journals, such as *Sustainability* and *Annals of Operational Research*, have notably risen in prominence in recent years, reflecting a growing interest in supply chain disruptions, also from publications that usually concentrate on different core subjects, like sustainability or operations research and decision-making tools. Reversing this line of reasoning, this result could also indicate that sustainability topics or operation research tools have started being related to the area of supply chain disruptions.

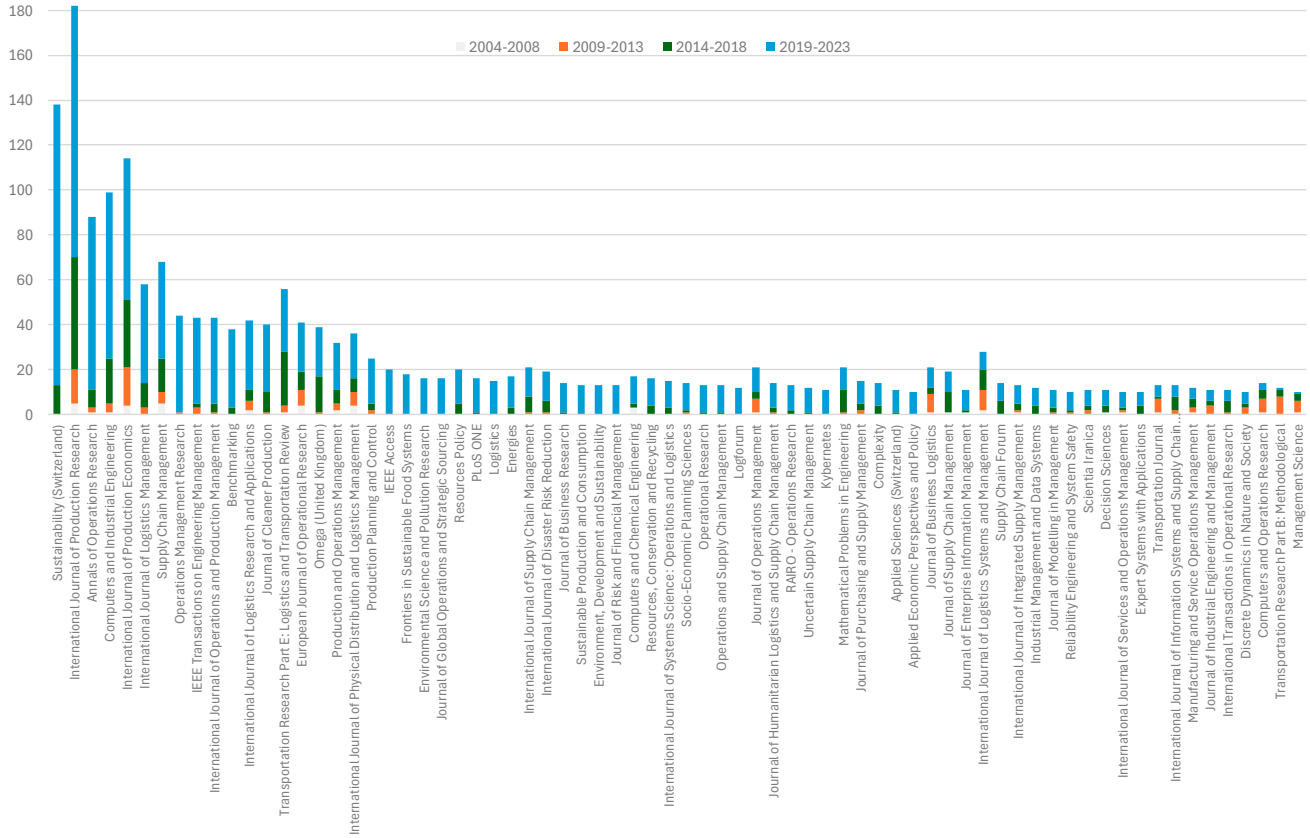
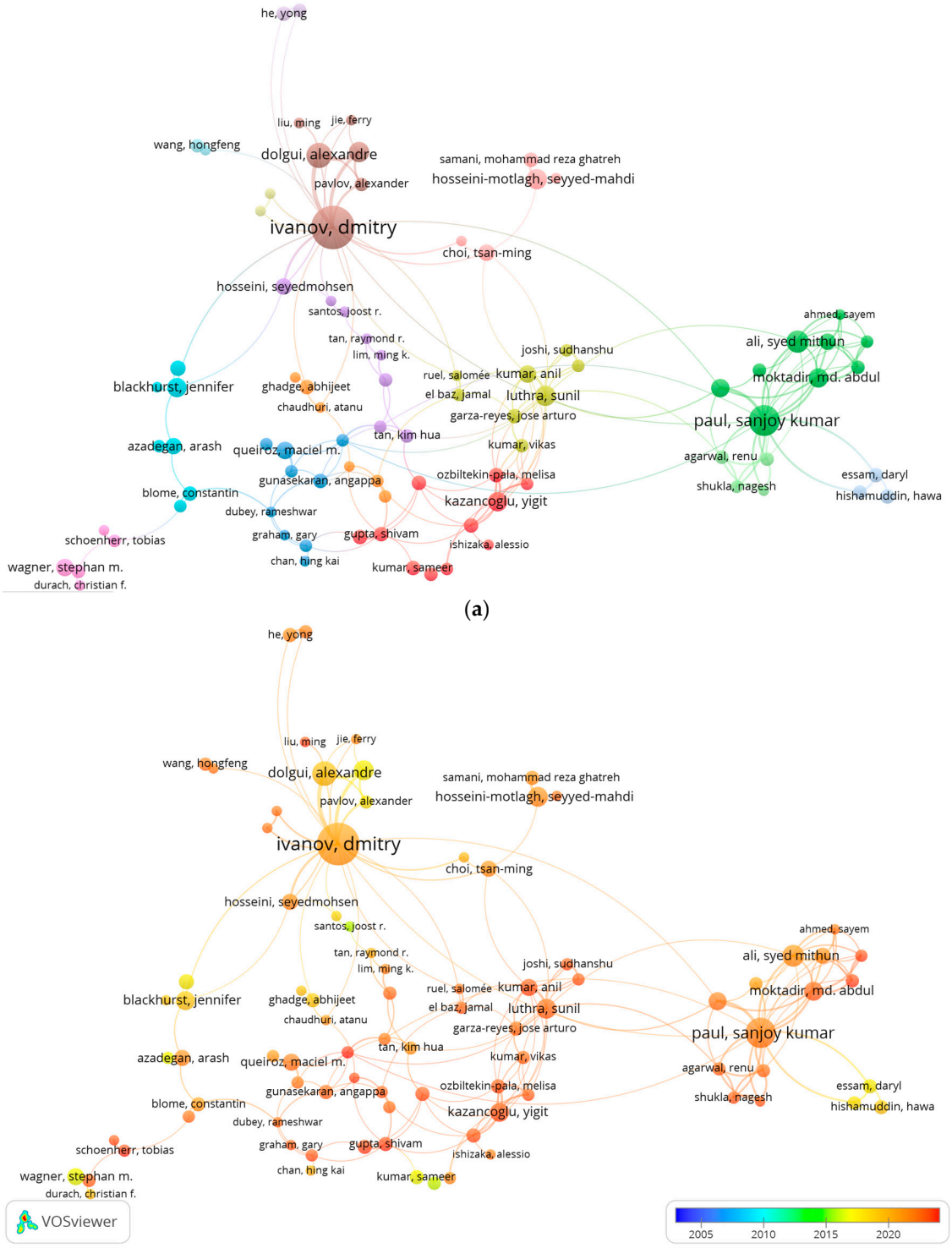


Figure 3. Distribution of papers across periods (limited to journals with a number of papers ≥10).

The papers in the sample were authored by 11,040 single authors, resulting in an aggregated average of 2.60 authors per paper. A deeper analysis of the authors shows that both the average and maximum number of authors per paper have significantly increased in time ($p < 0.001$). The increase in the number of authors per paper could reflect the progressive establishment of collaborations between authors and research groups, which, across the years, is a symptom of the maturity reached in the research field [76]. In line with this consideration, the collaborations among authors were investigated in greater detail, building a co-authorship map with VOSviewer and uploading the data exported

directly from Scopus. By omitting the outlier papers (>25 authors) and setting the minimum number of papers written by the same author at 5, the outcomes in Figure 4 were obtained. Overall, 190 authors (1.72% of the total) turned out to have written at least 5 papers, with 87 of them experiencing research collaborations; 15 clusters of authors were identified. Also, most of the collaborations are quite recent, appearing approximately from 2019 onward, which confirms the previous consideration about the progressive establishment of research collaborations, probably because of the increased maturity of the field.



(**a**)

(**b**)

Figure 4. Co-authorship maps—(**a**) network visualization and (**b**) overlay visualization.

4.2. Keyword Analysis and Trend

As mentioned earlier, a quota of 356 papers in the sample (8.39%) lacked the authors' keywords and was excluded from the keyword analysis; the remaining 3883 papers (91.6% of the sample), after the necessary checks for consistency previously explained, returned a total of 8226 single terms. The distribution of the number of keywords across the papers is shown in Figure 5. As can be seen from this figure, most of the papers include between four and six terms, which is a typical number of keywords in journal papers. Some outlier papers, with a very low or very high number of keywords, were also observed.

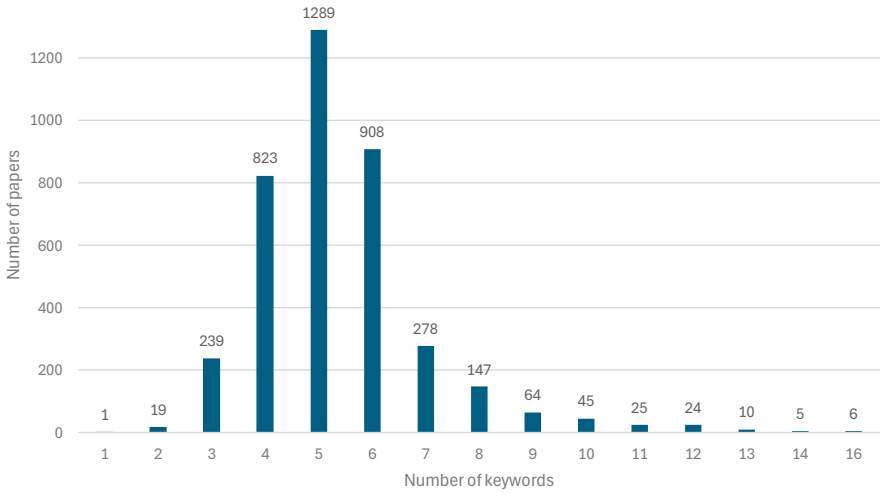


Figure 5. Distribution of the number of keywords across the sample of papers.

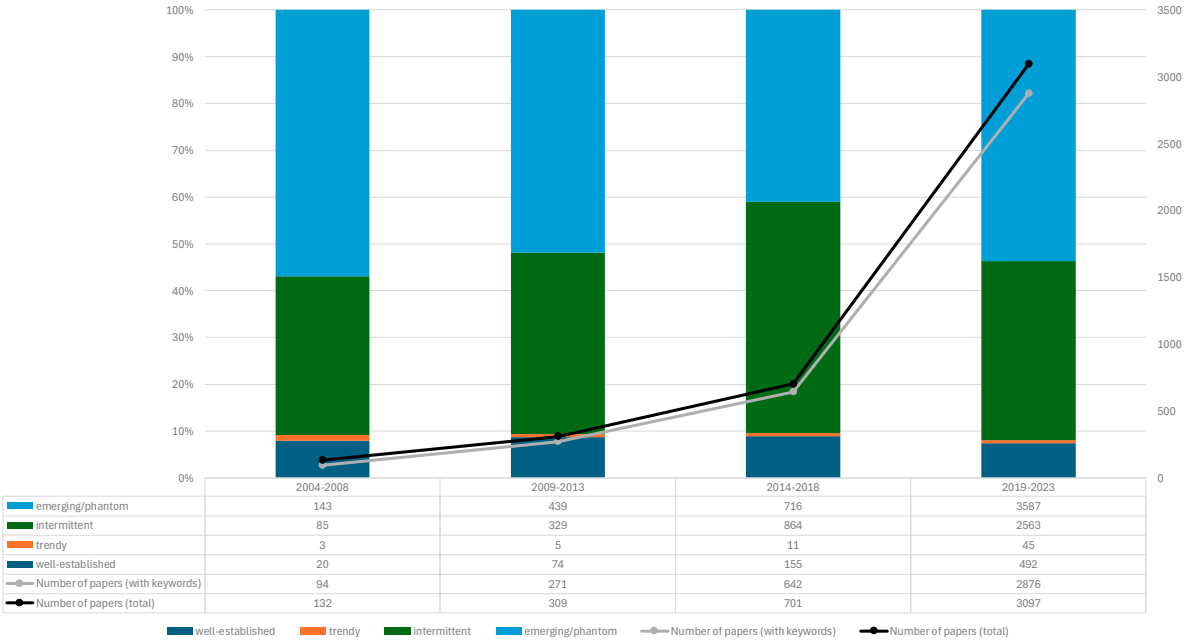
The keywords resulting from the sample of papers were classified into well-established, intermittent, trendy, or emerging/phantom on the basis of their persistency and frequency. The analysis was made for each five-year period, so as to appreciate the changes in time of relevance of the topics treated, thus highlighting increased or declined interest. Because the analysis targets various periods with the same duration, the boundary between high and low persistency of a keyword is simply determined by taking half the timespan (i.e., 2.5 years) for all periods. The borderline between high and low frequency was instead determined for each period of analysis, looking at the keyword distribution and taking the average frequency (rounded to the next integer number) as a boundary. The boundaries in Table 2 were set; and the keywords were consequently mapped into well-established, intermittent, trendy, or emerging/phantom. As can be seen from Table 2, the sum of keywords mapped in the four periods is greater than 8226 (and, specifically, it scores 9531), as it is always possible that some terms appear in more periods (1305 in this case).

Table 2. Number of keywords mapped and frequency boundary for each period of analysis.

	2004–2008	2009–2013	2014–2018	2019–2023
Number of keywords	251	847	1746	6687
Average frequency	1.63	1.68	1.87	2.36
Frequency boundary	2	2	2	3

The share of the different keyword categories across the four periods of analysis is shown in Figure 6. Because the number of papers published varies significantly across the periods (from 94 in 2004–2008 to 2876 in 2019–2023, looking at the papers including keywords), absolute values are not so meaningful, and percentage values were preferred in the representation. In general terms, trendy topics always cover the smallest percentage of keywords, less than 1% on average. The quota of well-established topics is around 8% in all the periods of analysis (from 7.36% to 8.88%), without a significant variation across the different periods. Intermittent topics cover 40% of the contents mapped, on average, with a

peak of ≈50% in the period 2014–2018. Lastly, emerging/phantom topics cover 51% of the themes, on average, with a peak of ≈57% in the period 2004–2008.



	2004-2008	2009-2013	2014-2018	2019-2023
emerging/phantom	143	439	716	3587
intermittent	85	329	864	2563
trendy	3	5	11	45
well-established	20	74	155	492
Number of papers (with keywords)	94	271	642	2876
Number of papers (total)	132	309	701	3097

Figure 6. Distribution of the number of keywords across the sample of papers.

Looking in detail at the various periods of analysis (Table 2 and Figures 6 and 7), the first period returned 251 single keywords, among which 20 well-established topics were found. These topics all describe known themes related to supply chain disruptions; examples of the related terms include supply chain management, risk, risk management, and disruption management. Interestingly, some terms describing methodological tools also fall into this category, e.g., game theory, case study, or optimization. Trendy topics are very limited in number and refer to inventory, supply chain design, and information security; all these terms describe aspects that can be related to supply chain disruptions, but, obviously, are not crucial to that topic. Intermittent topics are significantly more numerous (85 terms), and again, mainly include terms describing collateral or complementary facets of supply chain disruptions. As an example, resilience, risk management, or vulnerability are among those terms. Finally, among the emerging/phantom topics (143 terms), we found keywords describing topics of (still?) limited interest in the area of supply chain disruptions or new topics (for the reference period). Radiofrequency identification (RFID) and life cycle assessment (LCA) are possible examples of the new topics; indeed, the first studies about RFID technology in the supply chain date back to 1995–2005 [77,78], and possibly, similar considerations hold true for LCA studies. Examples of niche topics, instead, include either particular tools (e.g., Markov chains) or the specific supply chain or context investigated (e.g., healthcare).

In the second period of analysis (2009–2013), the total number of keywords was significantly higher (847), primarily because of the increase in time in the number of papers published; 87 keywords (10.27% of the total) were already present in the first period of analysis, while the remaining 760 terms (89.73%) introduce new concepts. Among them, 74 terms were classified as well-established topics, and included known themes in the area of supply chain disruptions; again, supply chain management, risk, and risk management fell in this class. Resilience is also present among the well-known topics, thus showing an increase in the frequency of this term, previously classified as intermittent. The increased interest in this topic is also confirmed by the introduction of new terms (supply chain resilience or reliability) in this period, all falling into the category of well-established topics. Five trendy topics, i.e., heuristic, production, outsourcing, genetic algorithm, and bullwhip

effect, were found in the second period of analysis; four of them introduced new concepts, while the bullwhip effect was already present in the first period, among the emerging topics. Hence, the interest in this theme has increased. As already observed for the first period of analysis, emerging/phantom topics are numerous (439 terms) and describe very specific problems, not always correlated with supply chain disruptions. Examples of these topics include inventory problems (e.g., the newsvendor problem) or decision-making tools (e.g., AHP or QFD). Similar considerations can be made for intermittent topics, which are numerous as well (329 terms) and refer to specific problems or facets of supply chain disruptions (e.g., robustness or vulnerability).

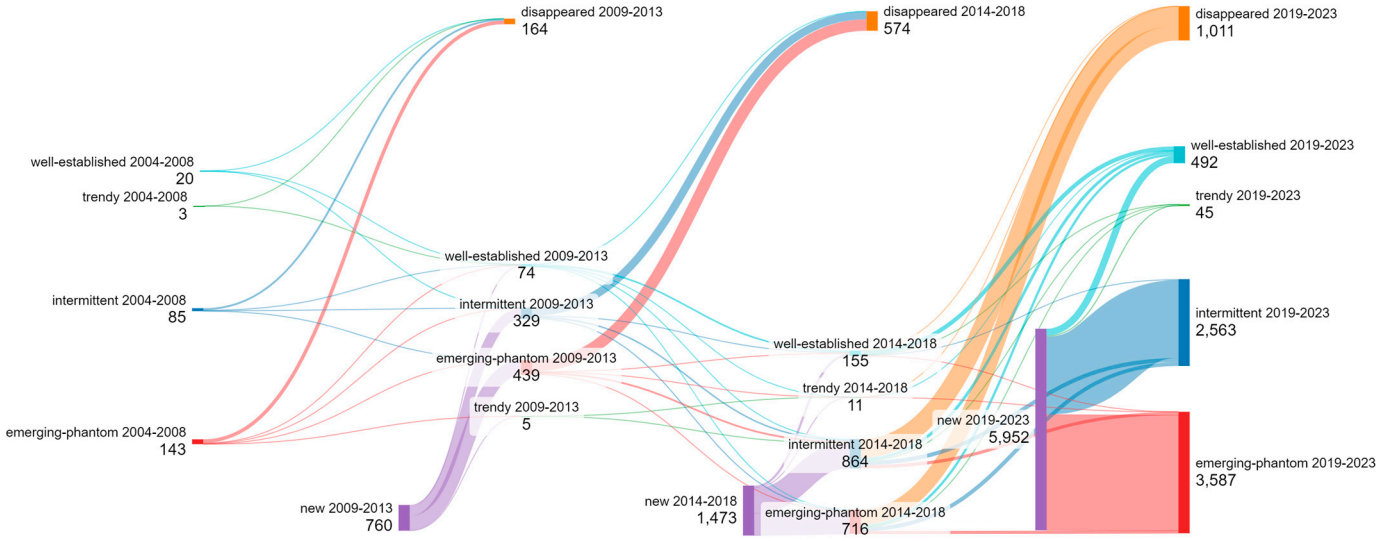


Figure 7. Map of the keyword classes across the various periods.

In the third period of analysis (2014–2018), a significant increase in the number of keywords can be observed again, resulting in 1746 single terms, 170 of which (9.74%) were already present in the previous period. Well-established topics include 155 terms, almost all expressly related to supply chain disruptions (e.g., risk management, resilience, disruption risk, disruption management, risk, demand disruption, uncertainty, robustness, or vulnerability). Some of these terms were observed also in the previous period of analysis, either as intermittent, trendy, or emerging topics; hence, the general consideration is that the attention toward these themes has progressively increased over time. Trendy topics are few in number (11 terms) and describe either very specific facets of supply chain disruptions (e.g., risk matrix or systemic risk) or ancillary topics (e.g., simulation optimization, pricing, network design, or competition). Intermittent topics form the greatest quota of terms (864 single keywords); most of these terms do not expressly refer to supply chain disruptions but rather to more general themes, such as supply chain, the literature review, decision-making tools, or production. Some keywords, instead, focus on complementary aspects of disruption management, such as risk assessment, environmental uncertainty, or agility. Emerging/phantom topics (716 single keywords) all introduce new concepts, not observed in previous periods, and in general, not directly related to supply chain disruptions; again, these terms refer to either methodologies (e.g., structural equation model), technological innovations (e.g., Industry 4.0), or to risk-related topics (e.g., risk indicators, environmental risk, and mitigation).

The last period of analysis (2019–2023) largely overlaps with the pandemic period and partially extends into the post-pandemic era. In that period, 6687 keywords were mapped, with 502 of them (7.51%) already observed in the previous period. Among the well-established topics (492 terms), new themes can be observed, largely related to COVID-19, pandemic disruptions, but also Industry 4.0. Interrelated topics include the food supply chain, which was one of the most debated systems during the COVID-19 pandemic [79],

or the ripple effect, which was also observed during the pandemic period [80]. Digital transformation, IoT, or artificial intelligence are themes that can instead be somehow related to Industry 4.0. Interestingly, these topics were already observed in the previous period, as emerging concepts; their resonance in the literature, therefore, has increased significantly in the pandemic period, showing the role of these technologies in counteracting disruptions. Among the trendy topics (45 terms), the presence of the Russia–Ukraine war, as a new term, has been observed. Industry 5.0 is another new theme classified among the trendy topics. A group of 13 trendy topics was already observed in the previous period, either as intermittent or emerging topics, and therefore, either their frequency or persistency has progressively increased; this is, for instance, the case for resilience- or sourcing-related topics. For one topic only (i.e., quality), which was previously classified as well-established, the importance has decreased, moving from the third to the fourth period of analysis. Most of the keywords mapped in the last period describe either intermittent (2563 terms) or emerging/phantom topics (3587 terms). Numerous intermittent topics (116) originate from as many emerging concepts identified in the previous period of analysis, thus showing an increased interest in these themes; examples include risk modeling, risk identification, and robustness. For other topics (24 terms), previously classified as well-established, a decline in interest was instead observed. For example, less debated themes in the last period are revenue sharing contracts, price competition, multi-agent systems, product recalls, or dynamic programming, which, by the way, appear as secondary topics with respect to the area of supply chain disruptions, and, most importantly, in a historical period where a pandemic emergency was being faced. Emerging/phantom concepts, finally, include 3587 terms, with 172 concepts (≈5%) already observed in the previous period of analysis and the remaining 3415 (≈95%) introducing new themes. As per the remaining periods, most of the new concepts describe very specific topics; some of them are somehow related to supply chain disruptions and COVID-19 in particular (e.g., food loss, food supply chain resilience, operational resilience, financial stability, disturbance), while other have a lower relationship with supply chain disruptions (e.g., data analysis, modeling and simulation, or cybernetics). Three emerging/phantom topics were already observed in the previous period, with a "better" classification (well-established), thus showing a decreased interest toward these themes, which, therefore, are expected to become "phantom" in the next years; they are the analytic network process (ANP), port resilience, and multi-echelon supply chain. Similarly, 95 emerging/phantom topics stem from as many intermittent topics of the previous period; again, they could be expected to disappear in the future. By the way, these terms do not expressively refer to disruptions, and therefore, their usage in this field of research for sure could decline.

In aggregate terms, the occurrence of the keywords across the various periods is shown in Table 3.

Table 3. Number of keywords vs. number of periods.

Number of Periods	Number of Keywords	Percentage
1	7251	88.15%
2	714	8.68%
3	192	2.33%
4	69	0.84%

Out of the total number of keywords (8226), 7251 terms (88.15%) appeared in one period of analysis only, and in 50% of the cases, they appeared as emerging/phantom concepts. Rarely, terms that appeared in one period were immediately classified as well-established, even if some notable exceptions exist and mainly refer to recent and widely debated topics, such as themes related to COVID-19 and Industry 4.0. A set of 714 terms (8.68%) was observed in two (frequently adjacent) periods, which often include the last period of analysis (2019–2023). For 174 of these terms (24.4%), a positive trend was observed, meaning that the topic was previously classified as intermittent or emerging/phantom

and then became a well-established theme, showing increasing relevance to the field. On the contrary, a decline in either their frequency of usage or persistency was observed for 207 terms (28.9%), leading to their final classification as emerging, or, more likely, phantom topics. The number of keywords that appeared in three periods is significantly lower (192 terms, 2.33% of the sample); again, the last period of the analysis is frequently present in these three periods. For most of these terms (103 out of 192, 53.6%), a positive trend was observed, with an initial classification as intermittent or emerging/phantom and final categorization as well-established topics. Because of their progressive importance in the field of supply chain disruptions, at present, these topics can be rightfully considered as known and relevant to this field; they include, among others, supply chain resilience, disruption risk, supplier selection, food security, food supply chain, resilient supply chain, system dynamics, robust optimization, reliability, or supply chain network design. The presence of terms like system dynamics or robust optimization supports the previous consideration that operation research/decision-making tools have started being coupled with supply chain disruption problems. It is also interesting to note the presence of interrelated topics in this set of themes, such as sustainability or climate change, for which, again, a similar consideration about their increasing role in research related to supply chain disruptions was made. The themes for which, instead, a decrease in attention has been observed are less in number (29 out of 192, 15.1%); also, in general, these topics are not strictly related to the supply chain disruption literature, and they could probably disappear in the next years.

A small group of 69 topics (0.84%) were observed in all the periods of analysis, suggesting a noteworthy importance in the selected field of research. From an analysis of the single terms, three groups of keywords can be identified, namely the following:

(a) Keywords semantically related to the area of supply chain disruption (21 terms), namely resilience; supply chain disruption; disruption; risk management; supply chain risk management; supply disruption; supply chain risk; disruption management; uncertainty; risk; robustness; demand disruption; supply risk; disaster; vulnerability; risk assessment; supply chain vulnerabilities; transportation disruption; supply uncertainty; terrorism; supply risk management;

(b) Keywords not semantically related to the topic of supply chain disruption but related to more general themes of supply chain or supply chain management (25 terms). These keywords include supply chain; supply chain management; logistics; closed-loop supply chain; supply chain design; supply chain network; global supply chain; supply chain coordination; inventory management; dual sourcing; information sharing; inventory; coordination; bullwhip effect; purchasing; visibility; business continuity planning; sourcing strategy; security; contingency planning; sourcing; backup supplier; safety stock; supply chain planning; and supply management;

(c) Keywords not related to supply chain disruptions nor necessarily linked to supply chain topics (23 terms), namely the following: simulation; game theory; optimization; stochastic programming; case study; innovation; agility; analytic hierarchy process; flexibility; modeling; revenue sharing contract; agent-based model; empirical research; service level; quantity discount; asymmetric information; coordination mechanism; dynamic programming; radio frequency identification; buyback contract; Petri net; integration; and contract.

The trend of these groups of keywords is depicted in Figure 8, in which the colors reflect the different classes previously listed: violet = class (a); pink = class (b); light blue = class (c). A synthesis of the trend, obtained by directly comparing the first and last positioning of the keywords, is reported in Table 4. From the numerical values in Table 4, it is easy to see that most of the keywords appearing in all periods of analysis came to a final classification of well-established topics, in line with the previous consideration about their relevance to the targeted area of research. This consideration is further corroborated by the trends in Figure 8, from which it can be observed that most of the keywords finally classified as well-established include topics semantically related to supply chain

disruptions (19 out of 47, 40.4%). It is also interesting to note that no topics semantically related to supply chain disruptions came to a final categorization of emerging/phantom and two keywords only were finally classified as intermittent topics. Finally, for one topic only (i.e., security), a shift from well-established to emerging/phantom was observed.

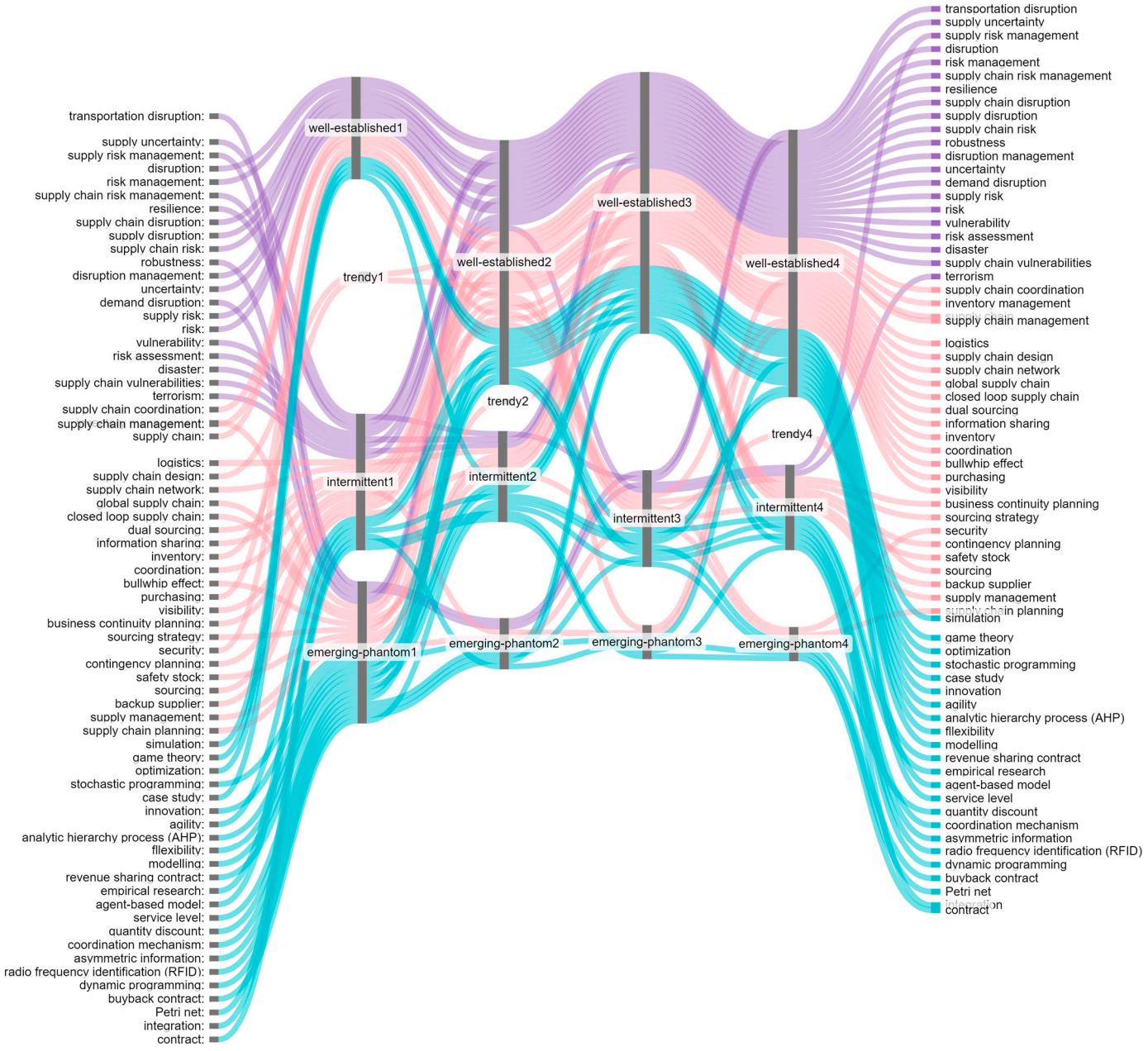
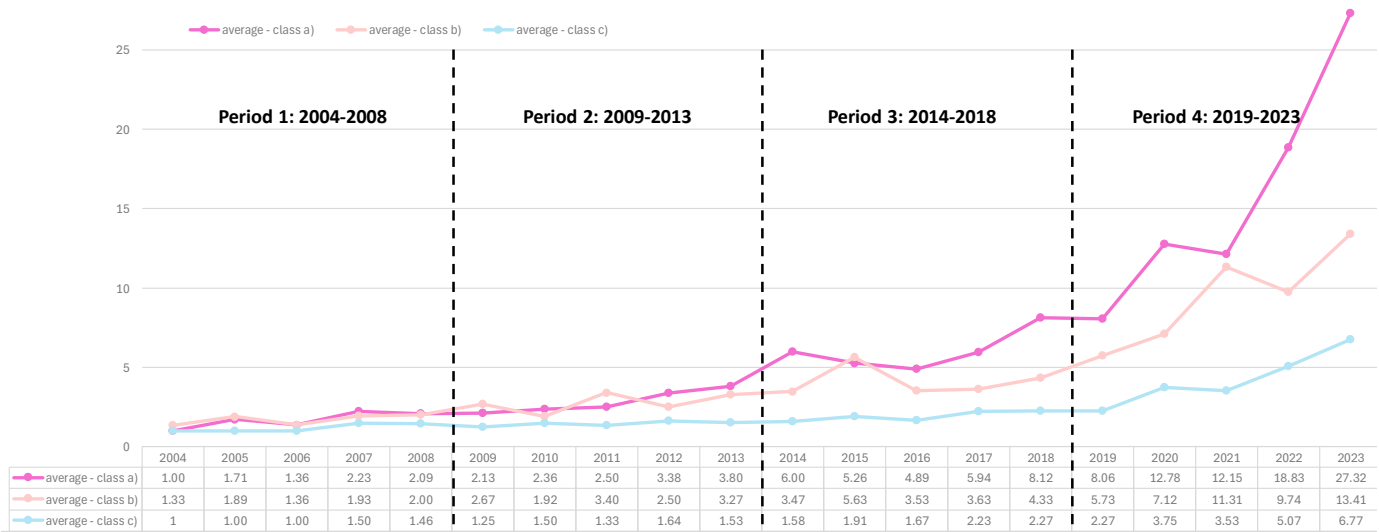


Figure 8. Trend in the keywords observed in all periods of analysis (69 terms).

For the three classes (a, b, and c) of keywords previously described, the trend in time of their average frequency was mapped, with results shown in Figure 9. It is clear from this figure that the keywords belonging to class (a) experienced the greatest increase in time, followed by class (b) and class (c). Also, class (c), including topics not strictly related to supply chain disruptions, appears quite stable over time, with a moderate increase only in the average frequency of the related keywords.

Table 4. Trend in the keywords observed in all periods of analysis (69 terms).

From/to		Final Classification (2019–2023)			
		Emerging/Phantom	**Intermittent**	**Trendy**	**Well-Established**
Initial classification (2004–2008)	**emerging/phantom**	2 (supply chain planning; quantity discount)	10 (supply risk management; buyback contract; supply management; dynamic programming; radio frequency identification; asymmetric information; coordination mechanism; safety stock; sourcing strategy; revenue sharing contract)	0	13 (service level; transportation disruption; bullwhip effect; modelling; flexibility; analytic hierarchy process; inventory management; innovation; demand disruption; global supply chain; robustness; closed loop supply chain; stochastic programming)
	intermittent	2 (contract; Petri net)	6 (integration; terrorism; backup supplier; empirical research; contingency planning; business continuity planning)	1 (sourcing)	15 (supply uncertainty; resilience; agent-based model; visibility; coordination; information sharing; supply chain risk management; dual sourcing; supply chain vulnerabilities; agility; disaster; risk assessment; vulnerability; supply chain network; logistics)
	trendy	0	0	0	2 (inventory; supply chain design)
	well-established	1 (security)	0	0	17 (supply chain; purchasing; supply chain disruption; supply chain management; disruption; risk management; supply chain coordination; supply disruption; supply chain risk; simulation; disruption management; uncertainty; risk; game theory; optimization; case study; supply risk)



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
average - class a)	1.00	1.71	1.36	2.23	2.09	2.13	2.36	2.50	3.38	3.80	6.00	5.26	4.89	5.94	8.12	8.06	12.78	12.15	18.83	27.32
average - class b)	1.33	1.89	1.36	1.93	2.00	2.67	1.92	3.40	2.50	3.27	3.47	5.63	3.53	3.63	4.33	5.73	7.12	11.31	9.74	13.41
average - class c)	1	1.00	1.00	1.50	1.46	1.25	1.50	1.33	1.64	1.53	1.58	1.91	1.67	2.23	2.27	2.27	3.75	3.53	5.07	6.77

Figure 9. Trend in the average frequency of the three classes of keywords observed in all periods of analysis.

Looking at the keywords with frequency ≥ 30, 60 terms were found; interestingly, approximately half of these terms (29 out of 60, 48.3%) express concepts that were not

observed in all the periods of analysis. In general, throughout the development of a discipline, it is to be expected that new/recent terms can be detected when making a keyword analysis, because of the emergence of new concepts when progressively investigating a research field [72]. In this respect, six terms with frequency ≥ 30 were observed in the last period of analysis only, thus confirming their recently emerged importance in the field of supply chain disruptions. These terms are COVID-19, the COVID-19 pandemic, artificial intelligence, machine learning, small and medium enterprises, and circular economy. Similar considerations can be made for the additional six terms that were observed in two periods, including the last period (i.e., pandemic; Industry 4.0; ripple effect; blockchain; systematic literature review; and additive manufacturing); again, the interest toward these topics and their relevance to the area of supply chain disruption have increased in time.

As per the previous group of terms, the keywords with frequency ≥ 30, can be easily classified by topic, and in particular, the following categories were found:

1. Query-related terms: as the query settings expressively included terms such as "supply chain" and "disruption", these terms (and their combination "supply chain disruption") were grouped in a single query-related category;
2. COVID-relates terms: this category includes the terms "COVID-19" and "COVID-19 pandemic";
3. Disruption-related terms: these terms are semantically related to the topic of "disruption", which, however, is not necessarily used as a keyword. Those terms are supply disruption; pandemic; disruption risk; disruption management; uncertainty; ripple effect; demand disruption; and disaster;
4. Risk- or resilience-related terms: this category includes terms that were not used in the query settings but that appear to be related to the more general theme of risk management or resilience, whose relationship with supply chain disruptions is obvious. These terms include (supply chain) resilience, (supply chain) risk management, (supply chain) risk, robustness; resilient supply chain, supply risk, reliability, risk assessment; or vulnerability;
5. Supply chain-related terms: as per the classification made previously, these terms do not strictly refer to disruptions, but to more general problems in the area of supply chain or supply chain management. These terms include supply chain management, supplier selection, logistics, supply chain design, supply chain network, global supply chain, supply chain network design, collaboration, supply chain coordination, or inventory management;
6. Sustainability-related terms: the sustainability perspective includes four terms, namely sustainability, closed-loop supply chain, climate change, and circular economy;
7. Technology-related terms: this category includes terms such as Industry 4.0, artificial intelligence, machine learning, additive manufacturing, or blockchain;
8. Tools and methodologies: this group of terms includes typical engineering tools and techniques, such as simulation, game theory, (robust) optimization, stochastic programming, system dynamics, case study, or multi-criteria decision making;
9. Interrelated topics: terms in this category do not strictly refer to the area of supply chain disruptions, nor the more general area of risk or supply chain management. Rather, they introduce complementary topics, such as food security, food supply chain, small and medium enterprises, innovation, agility, or systematic review.

The trend in the average frequency of the terms belonging to the different categories listed above and its comparison with the terms used in the query (black line) is shown in Figure 10. In general, it is easy to observe that all categories of keywords with a frequency ≥ 30 exhibit a positive trend in their usage over time. COVID-related terms appeared in 2020 only, as was expected, but have nonetheless become by far the most used terms in the last years when investigating supply chain disruptions. This outcome obviously denotes that from 2020 onward, disruption was almost synonymous with COVID-19. Risk/resilience-related topics and disruption-related topics exhibit similar behavior, i.e., a moderate increase in time in the timespan on analysis.

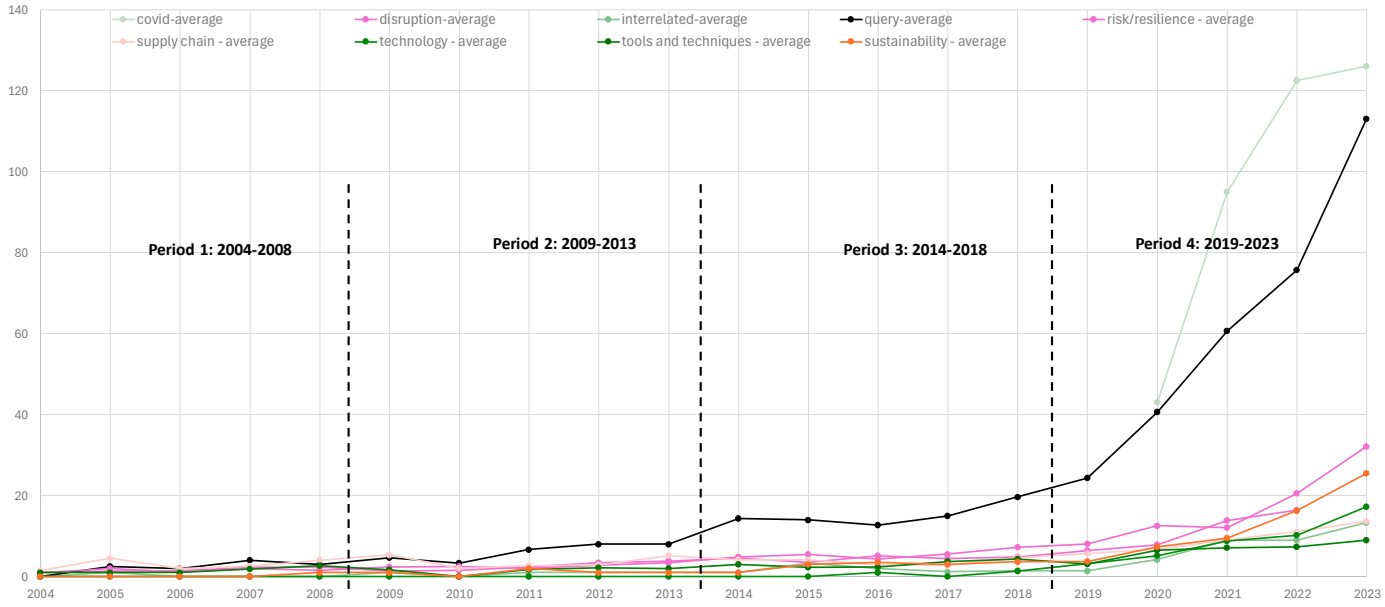


Figure 10. Trend of the average frequency of the classes of keywords with frequency ≥ 30.

The emergence of sustainability-related aspects is an interesting point, as those topics do not appear to be necessarily related to supply chain disruptions. In recent years, indeed, some authors have proposed studies correlating sustainability and disruption management issues; an example is the study by Devi and Srivastava [26], who tried to understand how the pandemic has impacted the dimensions of sustainability. Similar considerations can be made for the technology-related class, which includes various terms, all describing quite recent technologies that can be applied to supply chain management; again, these tools have progressively gained importance in the area of supply chain disruptions. By reviewing the literature on various disruptions associated with the supply chain (such as COVID-19, war, and natural calamities), Raja Santhi and Muthuswamy [81] have demonstrated the important role of Industry 4.0 technologies in enhancing the supply chain's agility, transparency, and resilience. Also, the tools and techniques class has gained progressive importance in the area of supply chain disruptions. The role of artificial intelligence and big data for supply chain risk management has been well debated in [32], while in [33], the importance of simulation as an effective tool for analyzing disruptions in supply chains has been highlighted.

5. Discussion

From the set of analyses shown in the previous section, it emerges that, as might have been expected, in the last five years, COVID-19-related themes played a predominant role in the research works related to supply chain disruptions, since the pandemic represented a major disruption that all supply-chain stakeholders had to deal with. In this context, there was a considerable increase in the use of keywords related to crisis and disaster management, as well as to health-related themes such as drug shortages and vaccine distribution [26,34]. In addition, a rapid rise in the frequency of use of the keyword "e-commerce" was observed, possibly in relation to the lockdown periods worldwide [82,83].

In addition to the COVID-19 outbreak, several other major disruptions have been characterized over the last 20 years. In the last period, a significant number of papers focused on Brexit and the war between Russia and Ukraine. These disruptions resulted, among others, in a strong need to achieve energy security and autonomy. Many papers, therefore, focused on themes such as energy transition, energy security, oil and gas, natural gas, renewables, biofuel, and biomass. These topics are also related to the broader theme of climate change, which emerged in the last period with several well-established keywords, including circular economy, closed-loop supply chain, emissions, life cycle

assessment, environment, and sustainability. Besides the environmental aspect, social sustainability recently became a well-established theme too. One important aspect of sustainability is represented by food waste. In this context, themes related to the agri-food sector saw rapid growth, becoming well-established in the last period of the present analysis (2019–2023). This rise may be also linked to the need for food security in the context of worldwide disruptions, such as, again, pandemic emergencies, international conflicts, or climate change.

The findings above are in line with the results obtained in the recent study by Moosavi et al. [37], focusing on the initial period of the COVID-19 pandemic. In the study, the authors have revealed that resilience and sustainability are primary supply chain topics, and they have found that the major research themes are related to food, healthcare supply chains, and technology-aided tools (e.g., artificial intelligence, the internet of things, and blockchain). Our study confirms these findings but also adds and integrates knowledge thanks to its broader time scope and different approach, highlighting that keywords related to big data, blockchain, digital twin, cybersecurity, automation, IoT, artificial intelligence, digitalization, and 3D printing have become well-established in the last few years, with some of them appearing in the literature after 2019.

Several numerical and digital tools have been leveraged lately to optimize supply chain management, enhance decision making, and improve risk management. Among these, some of the well-established keywords found in the literature of the last period analyzed are simulation optimization, Monte Carlo, agent-based modeling, particle swarm optimization, multi-criteria decision making, and multi-objective analysis and optimization. These tools, together with Industry 4.0 big data and artificial intelligence technologies, can also be exploited to optimize demand forecasting and pricing decision making, reducing uncertainties and maximizing supply chain profits as highlighted in the recent literature. Agrawal et al. [27], for instance, have highlighted game-theoretical modeling as a prevalent method for coordinating channels, with noted gaps in issues like disruption fairness and corporate social responsibility, indicating potential areas for future research. It must be pointed out that at the beginning of the COVID-19 pandemic, these topics represented marginal issues in supply chain studies. Indeed, Svoboda et al. [48], in their study, found that among 306 analyzed articles published before 2020, only 12 studies dealt with themes related to tools and techniques (simulation optimization and evaluation).

Additional crucial aspects that emerged from the analysis are resilience, adaptability, and agility of the supply chain, as well as the importance of the supplier selection process and reliability, the communication and collaboration between actors of the supply chain, and the transparency of information sharing, which results in increased visibility and traceability [29,31,51,53,62]. These topics are strongly related to the diffusion of blockchain technology, as it allows for efficient, reliable, and non-modifiable sharing of information between all shareholders.

6. Conclusions

In the present study, a bibliometric analysis of the literature dealing with supply chain disruptions published in the last 20 years was carried out to highlight the trends and the main topics in the research on this subject.

A total of 4239 papers was included in the analysis, resulting in 8226 keywords being mapped. These numbers immediately highlight the scientific relevance of the subject: while it has been known and discussed for many years, the trends delineated clearly show that the importance of the topic has progressively increased over time due to recent supply chain disruptions and is far from declining. Implicitly, these considerations provide a justification for this study and reaffirm the value of the related outcomes.

As this paper has the form of a literature review, most of the contributions are scientific in nature. In particular, the present review first of all has the merit of being significantly wider compared to the available ones in terms of the timespan covered and of the number of papers analyzed. As a second point, the scientometric perspective taken in this study

allowed for a detailed mapping of the topics covered by research on supply chain disruption and their variation over time, as opposed to previous studies.

Besides the prevalent scientific contribution, some practical considerations can also be derived from the results of this paper. Indeed, the outcomes highlighted several key approaches that allow supply chains to resist and survive disruptions; those approaches could be usefully adopted for facing new and evolving scenarios that could be observed in the future. More specifically, a clear relationship emerged between supply chain resilience and the actors operating at different levels, the transparency and reliability of the shared data, the flexibility, resilience, and agility of the supply chains, and the technological tools used to optimize the supply chain management and enhance the efficiency and reliability of communication and information sharing. From the beginning of the analyzed period, simulation and game theory—digital tools designed to optimize supply chain management—have been well-established themes consistently addressed in the literature. Thanks to the introduction of new tools and the increase in the computational capabilities available, the scope and the depth of the analyses, as well as the complexity of simulated scenarios, considerably broadened over time, becoming closer to reality. In this context, artificial intelligence tools, e.g., machine learning, deep learning, or technologies related to big data, IoT, blockchain, and digital twins, can be leveraged to increase supply chain performance, resilience, and reliability. The increasing importance of sustainability, Industry 5.0, as well as tools and technique-related themes (i.e., simulation, game theory, and optimization) also emerged from the analyses made; again, a relationship with supply chain disruption is evident. Deepening all these possible relationships through focused analyses, either in the form of bibliometric reviews or empirical studies, is a promising future research direction. In addition, the impact of more recent disruptions (e.g., international conflicts), which were not detailed in this paper, could be investigated in future research activities.

Supplementary Materials: Supplementary Material for this paper is available at https://doi.org/10.17632/stbpjgsv5y.1 [66].

Author Contributions: Conceptualization, E.B., N.L., R.M., G.R. and F.S.; methodology, E.B., N.L. and F.S.; validation, E.B., N.L. and F.S.; formal analysis, E.B., N.L. and F.S.; investigation, E.B., N.L. and F.S.; data curation, E.B., N.L. and F.S.; writing—original draft preparation, E.B., N.L. and F.S.; writing—review and editing, E.B., N.L., G.R. and F.S.; visualization, E.B., N.L. and F.S.; supervision, E.B.; project administration, R.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original data presented in the study are openly available in Mendeley, Supplementary Materials.

Conflicts of Interest: The authors declare no conflicts of interest.

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