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Review

Systematic Literature Review on Remanufacturing Trade Based on Bibliometric Analysis

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Abstract: With the extensive development of remanufacturing, remanufacturing trade, as an essential part of it, has also attracted much attention from researchers. Quite a large number of studies related to remanufacturing trade, such as pricing, sales, competition, channel expansion and service strategy, have been published in various journals. This paper aims to focus on the research status on remanufacturing trade through bibliometric analysis that can provide the primary research trends and the future research hotspots by analyzing the progress, parties and themes of the research. In this paper, the review and analysis are conducted on over 121 articles from 2000 until July 2021 with the help of VOS viewer (Leiden University, Leiden, The Netherlands) and Citespace (Drexel University, Philadelphia, PA, USA). The results of the analysis of research progress and research parties suggest that: (a) more and more researchers have started to pay attention to consumers during modeling; (b) sustainable/green aspects are frequently taken into account as a factor, but the sustainable/green standards for remanufacturing trade need to be further developed; (c) studies on remanufacturing trade are more abundant in heavy industry countries. Additionally, the hotspots for future research are identified via the theme analysis, including: (1) with the issuing of various government policies, the impact of these policies on decisions related to remanufacturing trade has been studied gradually and is expected to become a hot topic in the future; (2) a large number of papers conduct research on the basis of the supply chain of remanufactured products; (3) research on the online distribution channel has already been carried out and is constantly deepening; (4) the digital technology is increasingly introduced to remanufacturing trade in recent years.

Keywords: remanufacturing trade; bibliometric analysis; visualization; research hotspots

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1. Introduction

Lund [1], a professor at Boston University, first proposed the definition of remanufacturing, and he believed that remanufacturing is an industrial process in which the old product is restored to a new state. A remanufactured product has the same appearance, quality and performance as the new ones [2].

Remanufacturing currently plays a significant role in solving the problems of environmental pollution and resource shortage, as well as promoting global economic and social development. Remanufacturing, whose basic raw materials are second-hand products or cores collected from consumers or obtained through trade-in or buy-back programs [3], is currently used in several categories of products, focusing on consumer and durable goods, such as aerospace and aeronautical, automobiles, industrial machinery, electronic

equipment, office supplies, photocopiers and refrigerators [4]. It is evidence of remanufacturing effectiveness in solving the problem of waste accumulation by restoring the usability of end-of-life products. Moreover, based on the [5,6], compared with the production of new products, 60% of the energy, 50% of the cost, 70% of the material and 80% of the air pollutant emission are saved. Moreover, the retail price of remanufactured products is only 50–70% of that of new ones [6]. According to the investigation, quite a large number of jobs in the market were created in the United States due to the emergence and development of remanufacturing, with a reported 180,000 full-time employees working as of 2011 [2]. A study by Hollins estimated that approximately 44,300 full-time jobs are supported by remanufacturing activities in the UK [7]. Japan also has a relatively sophisticated remanufacturing industry whose annual production value is about $4.8 billion, with a focus on sectors such as the car industry, ink cartridges, retreading tires and photocopiers [8]. The South Korean government has identified that remanufacturing could promote sustainable growth in "green" industries, create employment and stabilize prices in the country [9].

Realizing the multiple benefits caused by remanufacturing, national governments have taken various measures to encourage the development and growth of the remanufacturing industry. To some extent, various environmental, recycling, climatic and energy-related policies issued by governments have contributed to the result. For instance, the EU's Waste Directive (2000/53/EC) provides guidance for member states to adopt measures for the prevention, regeneration and reprocessing of waste, which has contributed to the development of the remanufacturing industry. Moreover, recycling and reuse policies for various products are issued and implemented in various countries. For instance, End-of-Life Vehicles (ELVs), adopted by the EU's Parliament and Council in 2000, sets up targets for the recovery, disposal and reuse of waste in the environment; Policies and standards guiding the reuse, recycling and recovery of electrical and electronic products are provided by the EU's directive on waste electrical and electronic equipment, known as WEEE [10]; The Waste Management Law introduced by Japan has determined the operation mechanism to promote the recycling of End-of-Life Vehicles and household appliances. Such instructions facilitate the spread of remanufacturing to all kinds of products. To boost the remanufacturing industry, special remanufacturing policies to recommend the use and sale of remanufactured products, named "remanufacturing subsidy policy", have also been issued. The Scottish government plans to provide 70 million GBP to "kick-start Scotland's circular economy" [11], and the South Korean government encourages remanufacturing growth through the Ministry of Trade, Industry and Energy [7]. Further, in Japan, the Law Concerning Recycling of End-of-Life Vehicles sets up supporting funds to subsidize the recycling and processing of used cars [12]. Additionally, advantages, such as tax benefits, are offered in New York and Connecticut when consumers purchase remanufactured goods [9]. Similarly, for the purpose of stimulating consumers to return old products and purchase remanufactured ones, the Chinese government initiated a pilot "trade-in" subsidy program in which consumers can return used products to the merchants and purchase the remanufactured ones at a discounted price, such as automobile parts, engineering machinery and machine tools [13]. A policy implemented by the Chinese government in 2015 regulates that the users using remanufactured vehicle engines and transmissions would receive a 10% subsidy of the replacement price (about 2000 yuan for engine and 1000 yuan for transmissions) [2]. Moreover, the German government introduced measures to encourage consumers to purchase remanufactured products with professional production licenses.

Actually, the key to the successful development of the remanufacturing industry is putting remanufactured products on the market and selling them to consumers to achieve their value in use. However, there are many obstacles when it comes to trading in remanufactured products, such as mutual cannibalization between the new and remanufactured products [1,7], low purchase preference of customers and the reputation loss of manufacturers [1]. Consequently, in order to make full use of the economic, social and environmental

values of remanufacturing, it is incredibly necessary and essential to understanding the status quo, barriers and urgent problems of remanufacturing trade.

Quite a large number of papers related to remanufacturing trade have been published in various journals, such as product pricing, service models, trade-in, carbon trading and subsidy policies. Through literature retrieval, there are six review papers on remanufactured product trading, and the information, including their focus, period, publication time and the number of collected studies is listed in Table 1. Chakraborty et al. [14] conducted a review to provide insight into the latest research trends of pricing for the new and remanufactured products. The factors that affect the marketing of remanufactured products, such as customer willingness, pricing practices and performance evaluation methods, were sorted out by Govindan et al. [15]. Okorie et al. [16] studied the articles on product cannibalization between new and remanufactured products. There are two studies that systematically synthesize and analyze the factors that influence consumers' purchase intention towards remanufactured products, one by Singhal et al. [17] and the other by Ozden et al. [18]. Schallehn et al. [19] studied the articles related to services of used products (second-hand, remanufactured and renting) and pointed out the strategic directions that are helpful for creating customer experience.

Table 1. Researching the status quo of review papers related to remanufacturing trade.

Review Papers	Focus	No. CL	Period	Year
Chakraborty et al. [14]	Pricing related decisions	335	2000–2020	2021
Govindan et al. [15]	Marketing issues	156	1988–2018	2019
Okorie et al. [16]	Product cannibalization	92	2004–2020	2021
Singhal et al. [17]	Purchase intention	21	2011–2018	2019
Ozden et al. [18]	Purchase intention	26	2011–2018	2019
Schallehn et al. [19]	Customer experience of product-service	69	1997–2016	2018

No. CL = Number of Collected Literatures.

Based on the above analysis, it is clear that the existing reviews are focused on specific themes in the remanufacturing trade. Besides, there is no comprehensive analysis of this field that could reveal the progress and trends of research in the past. Moreover, the academic contributions that researchers should pay attention to in the future, such as influential journals, countries and authors in the field, are not presented by these reviews clearly. Furthermore, analysis of keywords according to publication time can identify the evolution trend of research themes and the hotspots of current research. However, most of the current reviews fail to get the emphasis of future research directions because they always make an effort to study a specific theme and neglect the analysis of keywords. Therefore, a comprehensive analysis should be undertaken to reflect the progress and trends of the field, the research parties and the mutual relationship between them, as well as the research content in the field of remanufacturing trade.

The lack of progress and trends of relevant papers in this field may lead to the inability of the existing literature to find the direction of future research. Consequently, to fill the gap, this paper makes an attempt to study the related articles in the field of remanufacturing trade from a macro perspective. Specifically, a comprehensive analysis is introduced to provide help for researchers to realize the detailed information, especially the hotspots of current and emerging topics, to identify the directions of future research in this field. The paper will address the following objectives: (1) Summarize the progress and trends in the field of remanufacturing trade in recent years. (2) Identify the main research parties and their cooperative relationship in the field of remanufacturing trade, such as countries, journals and subjects. (3) Identify the existing and hot themes in the field of remanufacturing trade on the basis of extracting the keywords cited. (4) Provide the potential research directions in the future.

This article's structure is organized as follows. After this introduction, we describe the research methodologies in Section 2. Section 3 provides the results and analysis of the

literature. Based on the analysis of the research, Section 4 discusses the research emphasis and future direction. Finally, the relevant conclusions of this study are summarized.

2. Results Research Methodologies

2.1. Bibliometric Analysis

Pendlebury [20] points out that bibliometric analysis refers to the quantitative method of citation and content analysis for scholarly journals, books and researchers. Integrating mathematics, statistics and documentation, bibliometric analysis uses mathematical and statistical methods to calculate the quantitative relations and laws of various knowledge carriers [21]. There are two different methods to conduct bibliometric analysis. Citation analysis is one of the most important research methods in bibliometric analysis, which describes and analyzes the citation structure and phenomenon of a group of documents by extracting the citation relations between documents [22]. Specifically, the status, progress and trends can be revealed by reviewing a large number of relevant articles with the help of citation analysis. Moreover, citations analysis can also help to describe the relationship and knowledge structure between research parties. Another different method of bibliometric analysis, content analysis, which is on the basis of determining the research unit, can summarize and sort out the content features and rules of the literature and is usually adopted to identify the key features of the literature [22]. In other words, content analysis can help to identify the clusters of keywords and the main parts between them.

As a result, we resorted to adopting this method to analyze the growth of the literature in remanufacturing trade. First, citation analysis was adopted to dig out the progress and popular trends in the field of remanufacturing trade in recent years and explore the main research parties and the relationship between them. Secondly, content analysis was carried out on the basis of extracting the keywords from articles cited to identify the clusters of keywords and the types (aging, hot and emerging) of them.

2.2. Tools

VOS viewer (Leiden University, Leiden, Netherlands) can generate a variety of maps based on bibliometric relationships, such as co-occurrence diagrams of research parties, authors, journals and keywords. It has great advantages in presenting rich and distinct graphics as compared to other visualization software, such as Gephi (Gephi team, Paris, France), which effectively explains and analyzes the results of bibliometrics [23]. However, VOS viewer can only present the clusters of the keywords of the literature and cannot reflect the development and changes of keywords. Citespace (Drexel University, Philadelphia, PA, USA) can generate the timeline map of keywords according to the time they were cited, making the development and changes in research easy to spot. Therefore, a mixed visualization tool involving a combination of VOS viewer and Citespace was used to show the progress and trends of the research in the remanufacturing trade.

Consequently, we first use VOS viewer to conduct the co-occurrence analysis, exploring the relationship between parties that participated in the study, as well as the clusters that were researched by authors in the field of remanufacturing trade. Then, Citespace was introduced to draw a timeline map to make the aging, hotspots and emerging directions of research clearer.

2.3. Sources and Processing

Web of Science has become the primary citation database due to its wide range of academic resources, covering natural sciences, engineering, biomedicine, social sciences, arts and humanities [24]. Secondly, its long timespan and quantity and quality of entries guarantee the reliability of original data in the literature analysis [24]. In this paper, to retrieve and analyze the literature in remanufacturing trade, a thorough database search through the well-known database, WOS, was conducted on 30 July 2021.

The collection of the materials is accomplished through a two-phase process. For the first phase, we limited the document type to "Article" to ensure the reliability and quality

of this research in WOS. Additionally, only the research papers written in English would be considered in our systematic literature review. Further, search terms ("remanufacturing trade", "remanufacturing product purchase" and "remanufacturing product sales") were applied to Titles, Abstracts and Keywords in WOS, respectively. Although no limit was set on the data range, no papers were found from before 2007. Finally, a total of 662 papers were obtained. In the second phase, referring to the study of Alexander et al. [25], we screened the articles based on the two exclusion criteria, namely, semantic relevance and relevance to the research problem [25]. Semantic relevance means that a word may have multiple meanings in different contexts [26]. For example, the term "remanufacturing trade" could capture articles that researched the trading of used products in the remanufacturing environment. However, such articles had to be excluded, as they were not suitable for our research. Firstly, the resulting titles, abstracts and keywords (n = 662) were reviewed to screen each article according to the semantic relevance, and 158 research articles were identified for further selection. Then, to ensure the relevance of an article's topic to the research problem of this paper, the full text of the articles has been reviewed, and a total of 121 articles were left for this research through artificial screening.

3. Results

3.1. Bibliometric Analysis

3.1.1. Progress of Publishing Articles

Figure 1 represents the annual quantitative characteristics of articles published so far. The trend line indicates that the number of references related to remanufacturing trade has increased over time. From Figure 1, we can find that the first study related to remanufacturing trade was published in 2007. Before the year 2015, there were only 13 articles (10.74% of the total articles), which implies that less research has been performed on the remanufacturing trade during the period of 2007–2014. It has been observed that the number of relevant articles has increased from one article in 2007 to a total of 121 articles in mid of 2021. Moreover, the data of 2021 are excluded from the analysis of publishing trends because only articles in the first half of the year were collected. The analysis above indicates that remanufacturing trade represents a new field of study for researchers.

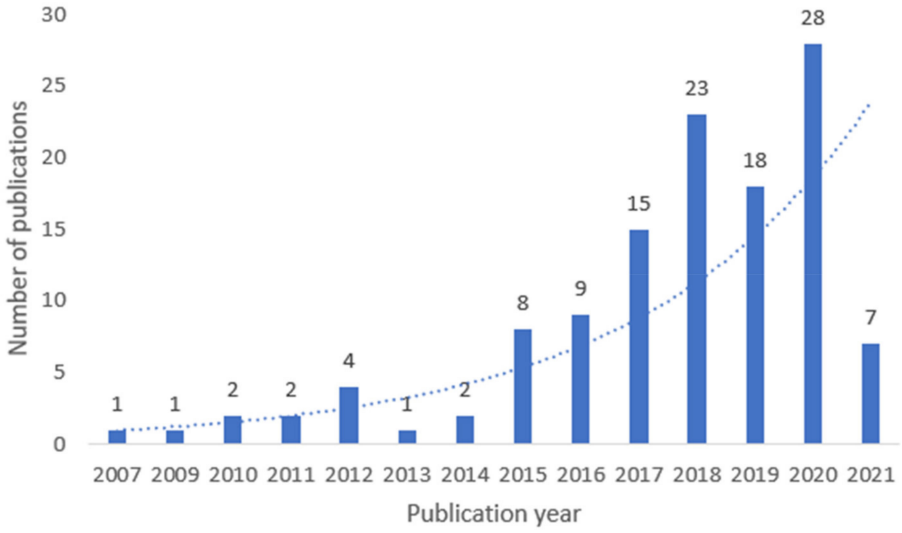

Figure 1. Publishing trends in remanufacturing trades.

3.1.2. Progress of Subject Distribution

Figure 2 shows the 14 subject categories contained in the 121 articles. In terms of the number of papers related to each subject, Engineering is the largest, accounting for 26.88% of the total, followed by Operations Research and Management Science and Environmental Sciences and Ecology (20.79%). Figure 3 represents the changes of subject categories based on the publication year. From Figure 3, it can be observed that the subject categories have

increased significantly from 2 to 14 over the 12 years. It is easy to find that Engineering and Operations Research and Management Science are the only two categories that were continuously studied from 2007 to 2021. According to Figure 3, after 2014, the number of papers of Science and Technology—other Topics, the subject represented by green, had an obvious growth, indicating that the application of technology in the field of remanufacturing trade has attracted attention.

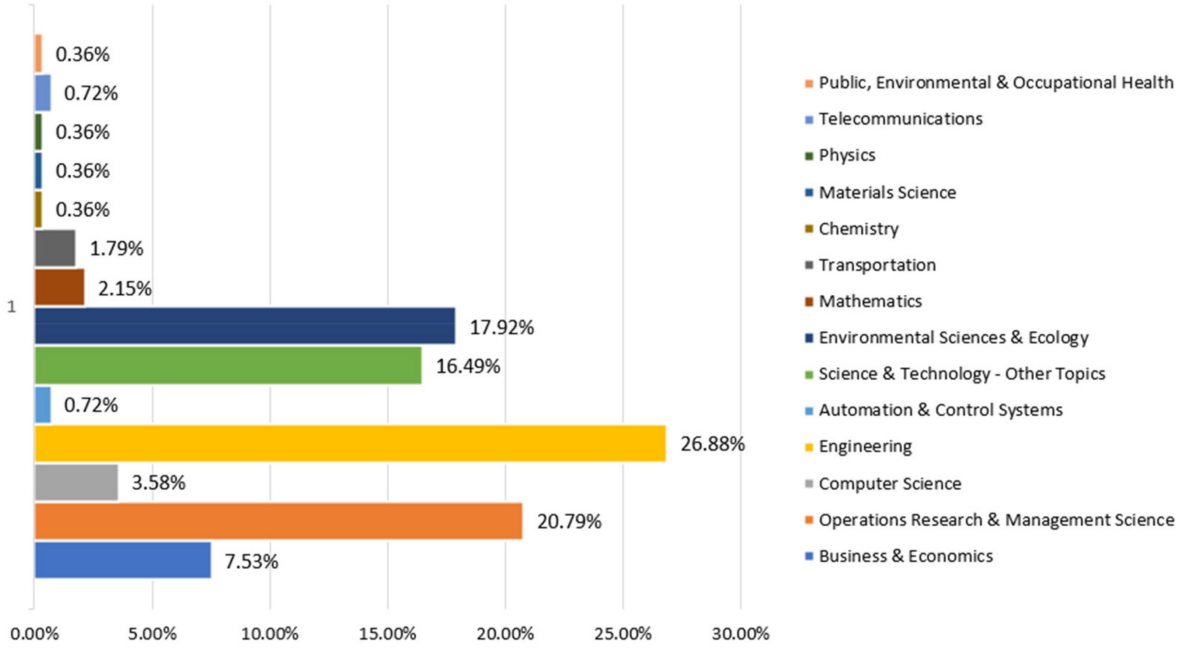

Figure 2. Subject categories.

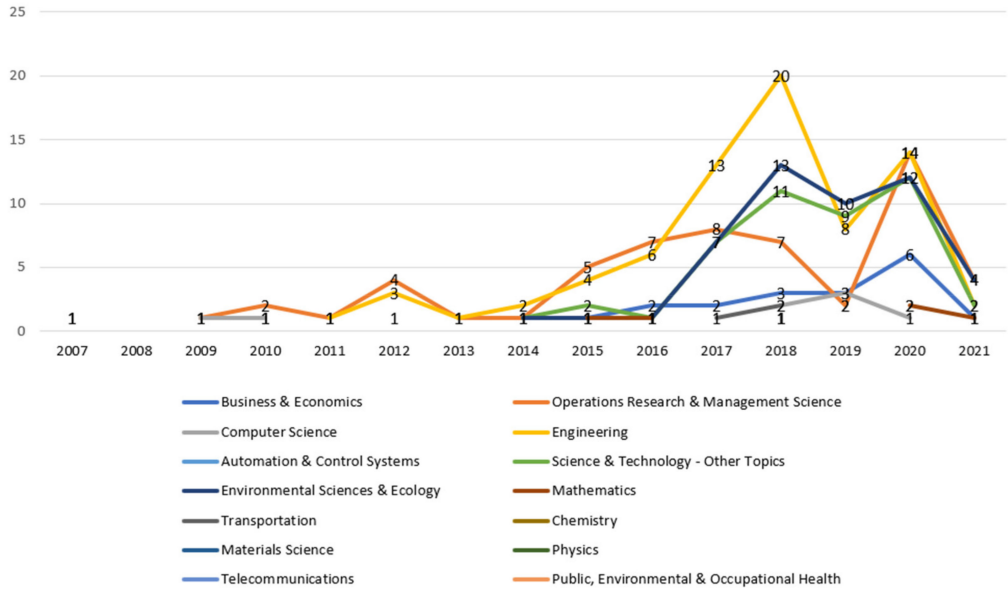

Figure 3. Progress of subject categories.

3.2. Analysis of Research Parities

3.2.1. Analysis of Influential Journals

To quantify the influence of journals related to remanufacturing trade, we refer to the Impact factor (IF) [27] and the H-index [28]. The H-index of the journal means that there are at least h articles among the N articles published by the researcher, and each

article is cited at least h times, while the citation frequency of the other N-h articles is less than or equal to h [28]. It is considered that the H index is positively correlated with journal influence. Based on the H index of remanufacturing trade-related articles published, we extracted the top 10 journals from 32 journals with the number of published articles, which accounted for 73.55% of the total, and ranked them in descending order, as shown in Table 2. From Table 2, the H-indexes of the *Journal of Cleaner Production* and *International journal of Production Economics* are far higher than others; therefore, they are considered as the most influential journals in this field. In terms of *Sustainability*, the low citations and H-index may be due to the fact that the 20 papers it has published were relatively new, but a large number of papers it has published proves that it has great potential. Conversely, the IF of *Resources Conservation and Recycling* and *Transportation Research Part E: Logistics and Transportation Review* is very high, while the H index is very low. This may be due to the low output of their journals.

Table 2. The performance of the 10 most leading journals.

TP	Journal	TC	IF	H-Index
22	*Journal of Cleaner Production*	705	9.297	14
14	*International Journal of Production Economics*	825	7.883	11
20	*Sustainability*	64	3.254	6
8	*International Journal of Production Research*	172	8.56	6
6	*Production and Operations Management*	455	4.962	6
5	*European Journal of Operational Research*	405	5.33	5
5	*Resources Conservation and Recycling*	99	10.203	4
3	*Transportation Research Part E: Logistics and Transportation Review*	93	6.875	3
4	*Journal of the Operational Research Society*	39	2.862	2
2	*International Journal of Systems Science*	55	2.281	2

TP = Total Publications; TC = Total Citations.

The journals listed in Table 2 can be divided into two parts according to their publishing content: one is theoretical research, and the other is technical research. Journals that focus on theoretical research almost prefer articles using empirical research methods, such as *Sustainability*, *Resources Conservation and Recycling* as well as *Transportation Research Part E: Logistics and Transportation Review*. Additionally, the *International Journal of Production Research* focuses on the research and review of technology, and half of its articles related to remanufacturing trade were published in 2020, which may be a result of the increasing demand for technology applications in the field of remanufacturing trade with the development of big data and the Internet in recent years.

3.2.2. Analysis of Influential Countries

Statistically, from 2007 to 2021, a total of 24 countries have published articles related to remanufacturing trade. Table 3 lists the top 10 countries according to their H-index. The two countries that pay the most attention to remanufacturing trade are China and the United States, which align with the sustainable development advocated by China and the status of the United States with the largest scale remanufacturing industry worldwide. Although the H index of China and the United States is similar, the output of the United States is significantly lower, indicating that the quality of articles published by the United States is higher.

Figure 4 visualizes the bibliographic coupling of 24 countries. The nodes represent countries, and their size is related to the number of articles they have published with other countries. The color of each node depends on when the articles were published. Additionally, the lines between nodes indicate that a cooperative relationship exists between them (the thicker the line, the greater the relationship strength). As can be seen from the lines in Figure 4, China and the United States have a strong cooperative relationship, and they are also the top two countries with the largest number of partners, while some countries, such as India, Singapore and Iran, have carried out less cooperation with other

countries. In terms of timing of research, India, The Netherlands and Spain are the first group of countries to conduct research in the domain of remanufacturing trade, which started in 2014, followed by the United States, England, France and Taiwan. However, China has published a large number of articles in a short period of time, probably resulting from the rapidly developing remanufacturing-related policies, which indicates that China attaches great importance to the remanufacturing industry.

Table 3. The top 10 productive countries.

Count	Countries	H-Index
34	USA	22
67	China	20
9	England	7
8	Taiwan	6
5	India	5
4	Netherlands	4
4	Canada	3
4	Japan	3
3	France	3
3	Denmark	3

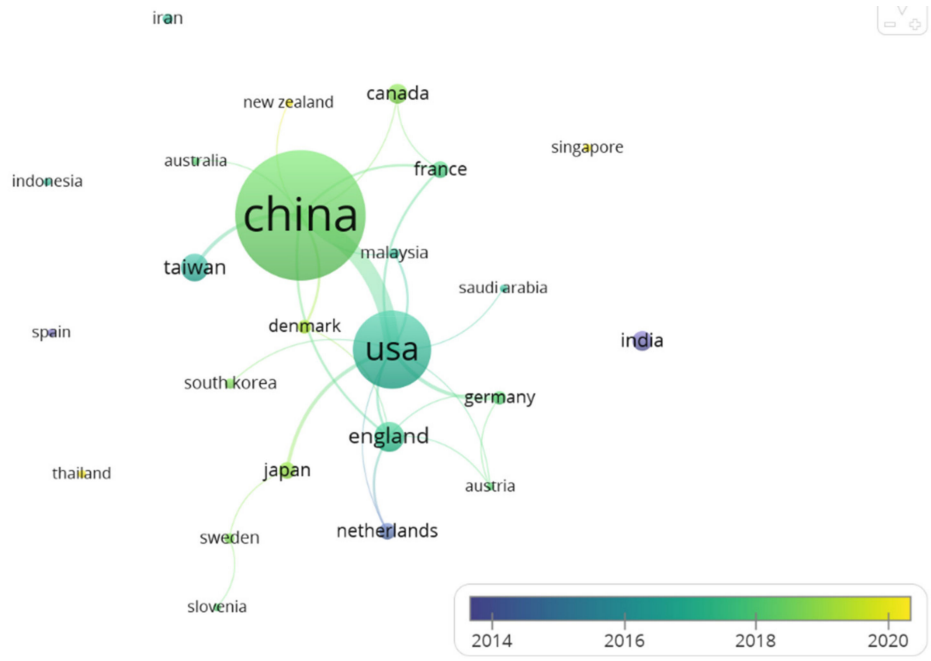

Figure 4. Visual map of the cooperation network of 24 countries.

3.3. Research Themes

3.3.1. Identification of Existing Themes

We identified the existing themes in remanufacturing trade by performing co-occurrence analysis using the VOS viewer software, where each theme is represented by a cluster. To avoid the clustering effect being affected by the nonstandard keywords provided by the authors, before the co-occurrence analysis, we manually carried out word-form reduction and similar word combinations for the original data. Frequent words, such as "remanufacturing", and low-frequency words with a frequency less than five were excluded. Finally, a total of 45 keywords were selected, and the results of the co-occurrence analysis are presented in Figure 5.

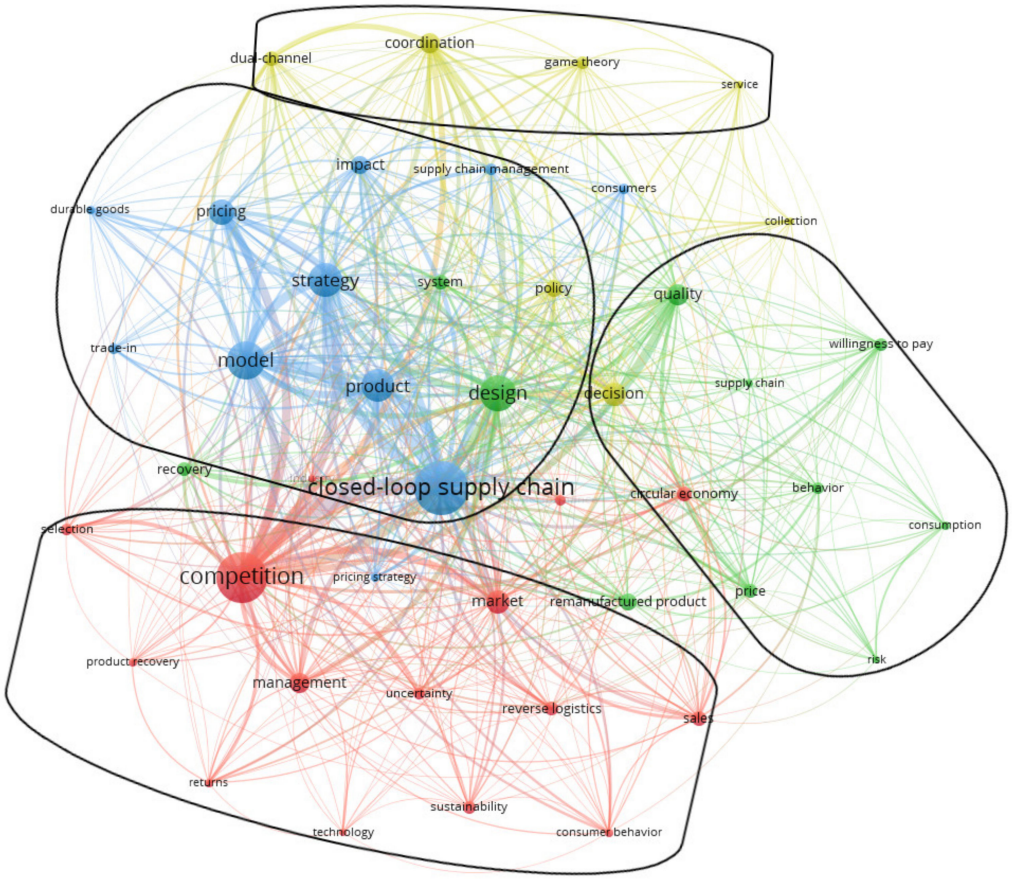

Figure 5. The network visualization map of 45 high-frequency keywords.

In Figure 5, the color and the nodes represent the themes (clusters) and the keywords, respectively. The size of each node indicates the cited times of the keyword it represents (the larger the node, the greater the cited times), and the interlinking lines between these nodes represent the strength and relevance of these keywords (the thicker the lines, the greater the strength and relevance). As Figure 5 demonstrates, we can find four themes: (a) competition (red); (b) pricing (blue); (c) sales and service (yellow); and (d) consumer behavior (green). To gain insight into the current state of research on each theme, we reviewed the entire paper, and the details will be explained in the following.

(a) "Competition" Theme

In the "competition" theme, researchers primarily investigated various existing and potential competition in the remanufacturing trade. Some researchers considered the price competition of products between original equipment manufacturers (OEM), OEM and third-party remanufacturers, as well as two independent remanufacturers. Wang et al. [29] focused on the price competition between new and remanufactured products, where OEM produces new products and the other remanufacturers produce the remanufactured products. Furthermore, Ho et al. [30] developed the study by considering a company that generates both new and remanufactured products, where there is not only internal competition between the new and remanufactured products but also external competition from similar products. Market competition is another critical aspect of remanufacturing trade. Manufacturers need to consider how they can get a competitive advantage over the other manufacturers. Mitra et al. [31] studied the market competition strategy by discussing whether the remanufactures should carry on remanufacturing and selling remanufactured products. Additionally, most studies in market competitive strategies have focused on government policies, such as "trade-in", "government subsidies" and "carbon tax". Feng et al. [32] discussed the competition between two independent remanufacturers

and reported how the competition affects the trade-in strategy. In addition to policies, the customer is also considered. Wang et al. [33] focused on the impact of trade-in policies and customer behavior on the competition strategies of OEMs and third-party remanufacturers. Most papers [29,34,35] discussed the service competition, in which two manufacturers compete with each other in choosing prices and service levels to maximize profits. Additionally, Wu et al. [35] also studied the effect of prices and service competition on supply chain members in terms of decision making and profitability.

(b) "Products Pricing" Theme

In the theme of "products pricing", researchers have focused on the optimal pricing decision and the influence of the factors shown in Table 4 on this decision. Abbey et al. [36] studied the optimal pricing of new and remanufactured products on the basis of the consumer preferences model. Yan et al. [37] formulated a pricing model for recycling and remanufacturing in uncertain conditions to address the optimal pricing. Additionally, pricing decisions are commonly considered in integration with the production decisions, as the pricing strategies in remanufacturing can be influenced by the product design [14]. Zhu et al. [38] developed a model where they can optimize both the optimal pricing and production decisions. Cao et al. [39] considered the production and pricing decisions under remanufacturing subsidy policy and carbon tax policy, respectively, and examined which policy is more beneficial to society. Some researchers have considered multi-factors when studying the optimal pricing for new and remanufactured products so that the results can be more realistic. Miao et al. [13] analyzed the optimal pricing and production decisions of remanufacturing with trade-ins under carbon regulations. Moreover, a mathematical-statistical model was developed by Yazdian et al. [40] to optimize the pricing of returned used products, degree of their remanufacturing, selling price, as well as warranty period. Numerous researchers took the manufacturer's profit maximization as the optimization goal and the methods, such as learning search algorithm [41], nonlinear optimization solver and improved particle swarm optimization algorithm [40], were used to solve the problem. There are also many more researchers [41,42] that employed game theory to obtain optimal pricing strategies. Subsequently, the digital twin was introduced by Tozanli et al. [43] to determine the optimal strategy on discount in 2021, which may be explained by the wide spread and application of digital technology.

Table 4. Factors considered in pricing in remanufacturing trade.

Dimension	Item
Policy	(1) Government subsidies (2) Carbon tax (3) Carbon emission constraints
Consumers-related	(1) Consumers' choice behavior (2) Consumers' environmental awareness (3) Consumers' preference for purchasing channels (4) Consumers' willingness to pay (5) Loss-averse consumers (6) Consumers' acceptance of remanufactured products
Sales channels	(1) Pricing strategy of dual-channel supply chain (2) Pricing strategies for online sales channels (3) The impact of online reviews on pricing strategies
Trade-in program	(1) Trade old for new products (2) Trade old for remanufactured products
Uncertain conditions	(1) Quality of recycled products (2) Quality, quantity and demand of remanufactured products
Service strategies	(1) Warranty decision (2) Money-back Guarantee (3) Free replacement service

(c) "Sales and Service" Theme

In the theme of "sales and service", this kind of literature mainly focused on the strategies of channels, marketing and service. Researchers studied the distribution channels of remanufactured products in terms of the optimal channel strategy, online data, as well as interaction between the channel strategy and other factors (policies, customer preference and internal structure, etc.). Zheng et al. [44] investigated the optimal channel strategy of OEMs and remanufacturers and its influencing factors. Shi et al. [45] explored the interaction between internal structure and distribution channel selection in the remanufacturing environment. Additionally, various studies [39,46] have attempted to study pricing strategies of new and remanufactured products in a dual-channel supply chain. Nguyen et al. [47] developed a data-mining approach to provide a demand model for remanufactured products using the Amazon datasets, and Yan et al. [48] considered the effect of online reviews on optimal pricing of new and remanufactured products. Articles also placed the most emphasis on various policies and marketing measures, such as trade-in programs, government subsidies, advertising and promotion strategies. Some articles paid attention to the effect of these policies and measures on pricing [49–51], products' quality choice [49], emission reduction [51] and other factors. Furthermore, some authors [39] compared and analyzed the most beneficial policies. Others focused on the optimal trade-in, warranty period and other strategies [39,52]. For articles that related to service strategies, the most frequently considered is the warranty strategy, involving the optimal warranty strategy and its interaction with other decisions or factors (e.g., pricing decisions [50], consumer purchase intentions [53], profit for warranty suppliers and supply chain members [54]). Other authors also investigated the Money-back Guarantee [55], extended warranty and free replacement service [56].

(d) "Consumer Behavior" Theme

In terms of consumer behavior, customers' willingness-to-pay for new and remanufactured products were studied by authors [57,58] through a questionnaire-based survey. Some authors [59] focused on the critical factors enhancing purchase intention on remanufactured products. Further, the effect of various factors, such as green manufacturing and warranty service, on the willingness-to-pay for remanufactured products were constantly investigated. Lv et al. [24] explored the effect of similarity between remanufactured and new products on customers' purchase intention for new products. Additionally, the effect of consumers' behavior on remanufactured-related decisions, such as pricing [60], warranty period [53,61] and distribution channel [44], was considered.

3.3.2. Identification of Hotspots

A timeline map is a visual tool that can display the evolution trend of a research subject more intuitively. To explore the trend of research on remanufacturing trade, we visualize the keywords timeline with the help of Citespace, and the map is shown in Figure 6. In the figure, a keyword is represented by a node whose size is positively correlated with the number of times the keyword appeared, and a line is created between two nodes (keywords) when the two keywords are referenced together in an article.

As can be seen from Figure 6, the main feature of nodes distributed before 2013 are that the number is small and the nodes are all large, suggesting that keywords are relatively concentrated and the research hotspots are clear. Conversely, after 2013, the types and the number of nodes (keywords) increased significantly, while their distribution was dispersed, indicating that research directions began to diversify and research hotspots were not intensive. Moreover, it has been observed that some keywords are connected, meaning that they deal with similar themes. Overall, the timeline map showed that the research hotspots of remanufacturing trade research in recent years could be summarized into four aspects: (1) Government policies and recommendations for remanufacturing, such as subsidies, social welfare, carbon tax, trade-in and circular economy. (2) Product supply chain related, such as closed-loop supply chain, supply chain management, competing

supply chain and supply chain management. (3) Online marketing platform involving channel distribution, distribution systems, dual channel, channel selection, as well as online reviews. (4) Methods and techniques of analysis, such as game theory, structural equation modeling and big data.

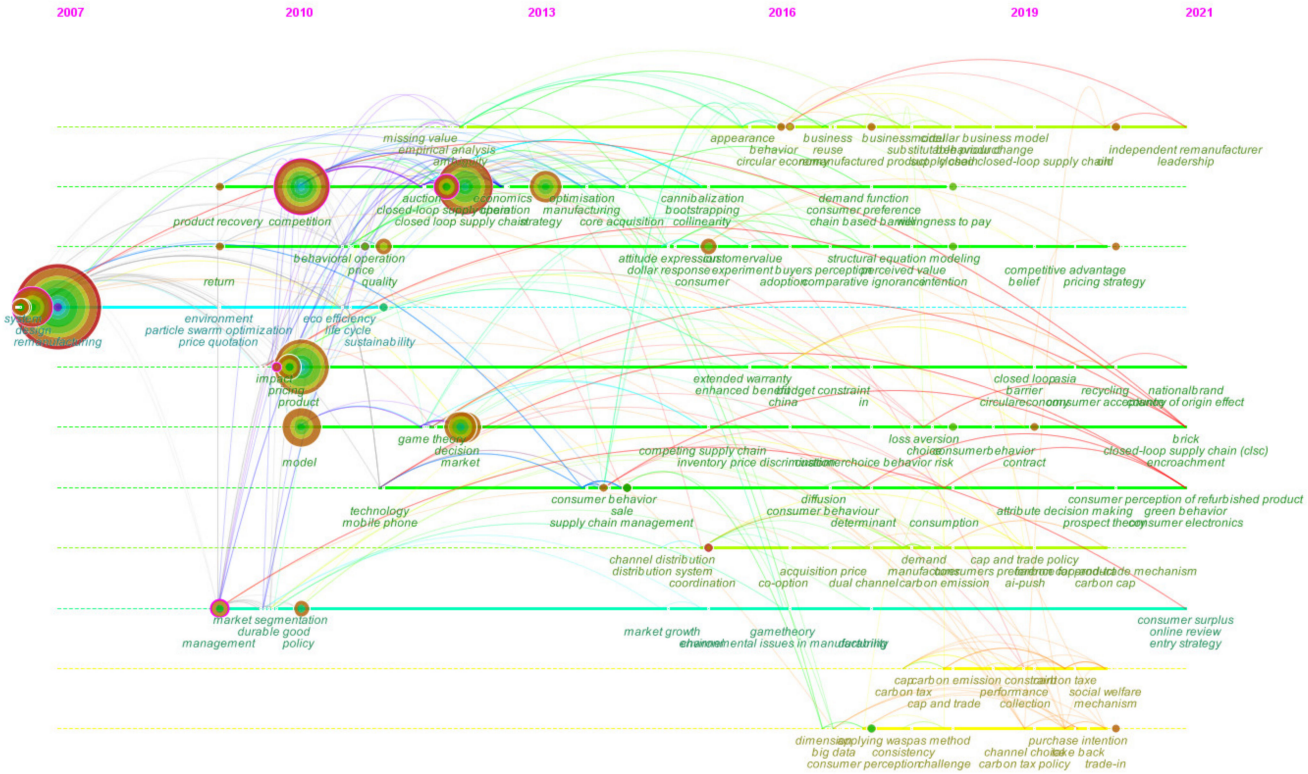

Figure 6. Timeline map of keywords.

4. Discussion

Based on the previous analysis, the special findings are analyzed in-depth to identify research emphasis and trends in the field of remanufacturing trade, helping researchers quickly identify gaps of current research and determining future research directions.

4.1. Main Findings of Growing Trend

As the analysis of research progress and parties, there are several findings that can demonstrate the research trends in the whole remanufacturing trade:

(1) Earlier research articles on remanufacturing trade attached a lot of importance to models related to decision-making. With the recent development of the pull supply chain and increasing important status of customers, the number of articles based on a questionnaire survey dominating force for the investigation of customers' intention is steadily growing. Moreover, the horizons of the research area are expanded by researchers from home to abroad, such as Chinen [62], who studied whether consumers preferred to purchase domestic remanufactured products compared to those made in China. However, the research still focuses on models and numerical analysis rather than surveys dominating in this field. Trade activities characterized by consumer centering are the direction of future development, and research can integrate more concepts, requirements and preferences of consumers into the model.

(2) Most journals focus on the perspective of sustainable development, which conforms to the concepts and essence of the remanufacturing industry. A large number of authors select keywords on the basis of them being sustainable/green, such as "green behavior", "sustainability" and "environmental awareness". However, there are almost no articles that specifically organize and study sustainable/green impacts in

remanufacturing trade, and a complete theory needs to be developed as the core of subsequent research; therefore, this could be filled in the future.

(3) The analysis of countries researching remanufacturing trade demonstrates that the research is popular in countries that have developed heavy industry, such as the United States, Japan, China and Canada. To reduce the waste accumulation and achieve a circular economy, these countries are focusing on developing remanufacturing, and their emphasis on remanufacturing trade shows that remanufacturing trade is an important part of this industry. Such countries that are poor in both studies and cooperation with other countries should further promote the attention to theoretical research. The examples include Germany, which has a well-developed remanufacturing (auto) industry and India, whose environmental problems need to be urgently solved.

4.2. Implications of Future Research Hotspots

The special information we found from the analysis of themes was classified into four categories as follows:

(1) Government policies and recommendations for remanufacturing

Issuing policy related to the remanufacturing industry is a method used by numerous governments to promote the development and growth of remanufacturing. Some studies have investigated the incentive effect of government subsidies on manufacturers and consumers [63,64], and discussed the impact of government subsidies on manufacturers' pricing [61,63,64], social welfare [63], service decisions [61] and channel selection [65]. To a certain extent, this can provide guidance for governments to formulate incentive policies and supply chain members to make decisions. However, not only have subsidies been introduced to encourage remanufacturing, but they are also carbon-related, such as carbon taxes, carbon trading and carbon constraints. Therefore, some researchers have begun to conduct research on the impact of carbon tax [13,39,66,67], carbon constraint [51,68,69] and other related policies on remanufacturing trade. The aggravation of global warming by the carbon emission is forcing countries to convert to green manufacturing and the circular economy to enable resource resilience and environmental protection, which will further promote the attention to regulation and management for remanufacturing globally and publication of more related policies. Consequently, carbon-related policies issued by countries need special attention in the future. However, the conclusions concluded from the model have not been verified by empirical analysis until now, as realistic data of remanufacturing enterprises are difficult to collect [51]. Furthermore, whether the conclusions are universal needs further discussion because most studies proceed based on some assumptions [51]. Therefore, future verification for conclusions that concluded without empirical analysis or considered a certain condition is meaningful. Although such policies deserve deeper and persistent study, too much concentration on certain policies may limit the development of this field; therefore, more types of policies, including import and export policies, industry management policies, as well as the latest remanufacturing related policies, are worth investigating as a theoretical basis for the further research.

(2) Supply chains for remanufactured products

The analysis of the themes above shows that remanufacturing trade is often studied from the perspective of various supply chains, such as two-stage supply chain [68], competitive supply chain [35,70] and dual-channel supply chain [33]. Among them, competition between members in a supply chain or different supply chains are the dominant hotspots, while a small number of authors study the coordination of members in a supply chain. As a matter of fact, there are many entities and decision-makers in the supply chain, and thus, future research could focus more on their cooperation mechanisms, such as revenue distribution and service collaboration. Moreover, the proposition of green manufacturing and a circular economy attracts a growing number of authors, such as Hong [64], to consider products with multi-cycles. In the model of multi-cycle products, the production of remanufactured products is affected by the quality of recycled used products [66]; therefore, it is a

very promising method to model the supply chain of complex remanufacturing trade based on the quality of recycled products. Furthermore, the possibility of trading used products between enterprises could be considered as it could improve the utilization rate of used products. Moreover, remanufacturers and retail sometimes play the role of recycler, which could be considered in a closed-loop supply chain. On the one hand, the most suitable recyclers (OEMs, retailers or third-party recyclers) can be analyzed from the perspective of profits of supply chain members or recycling subsidy policies. On the other hand, the optimal recycling methods (online or offline, direct recycling or trade-in) can be studied based on various factors in the future. The emergence of a large amount of unstructured data caused by personalized consumer demand is forcing supply chain enterprises with a single linear structure to convert to a more elastic and faster dynamic network structure by integrating distribution channels due to the difficulties of meeting market demand. With the strengthening of global relationships and the widespread use of the Internet and mobile phones, a network global supply chain system in the remanufacturing industry is expected to establish.

(3) Online Marketing Platform

Traditionally, products are made by manufacturers and then sold by retailers through their own distribution channels. However, there are many obstacles for retailers to distribute new and remanufactured products at the same time, such as mutual cannibalization between the new and remanufactured products [4,68] and the reputation loss of manufacturers [4]. Therefore, more and more manufacturers are trying to establish an online channel, namely remanufactured products that can be sold online and offline at the same time. Some researchers analyze manufacturers' profits under different channel configurations and then judge optimal sales channel strategies of manufacturers and whether they should open the online channel [44,71]. Moreover, other factors that may affect the strategies of selection for sales channels, such as customers' preference for channels, remanufacturing costs, recyclers of used products [44] and internal structure of the company [45], are also considered. However, due to limitations with regard to the complexity of the remanufacturing trade, the research can be extended by considering factors for real-life, such as how to take into account a manufacturer's channel strategy for two or more product cycles, as well as differences between new and remanufactured products. Currently, activities such as recycling and trading-in used products are carried out offline. With the e-commerce model that has been accepted in today's world, establishing an e-commerce platform for remanufacturing trade specially is expected. The platform will integrate sales, recycling and service, which means that not only the used products would be collected here, but also the remanufactured products would be sold and serviced.

(4) Methods and Techniques of Analysis

Studies always apply the decision method, with Game theory being the most frequently used decision technique, and structural equation modeling is the most common approach used for modeling. Using Game theory, Zhu [53] built an optimal decision model for a closed-loop supply chain, and Cao [71] studied the optimal channel, namely whether enterprises should choose to enter the e-commerce platform. Meanwhile, Pisitsankkhakarn [59] established a partial least squares structural equation model to explore the primary factors that improve consumer demand for remanufactured products. While these methods fit well with the demand, we identify the strategy; the study can be further simplified and promoted by conducting a machine learning algorithm or neural networks. Tozanli [43] used blockchain technology to model product recycling systems to determine product prices, and Yan [48] used data mining to process online reviews generated by electronic sales to predict consumer demand for remanufactured products. Only these two articles took advantage of artificial intelligence, which is a convenient technical science in the digital era with its great ability to identify the potential trends in datasets, as well as improve efficiency in processing data and making decisions. Good technology can make decision-making more convenient and efficient. Digital technology, which is closely related

to the currently important field of big data analysis, is still in its infancy, and very few articles have considered it until now, so researchers can explicitly consider its development and application in their model optimization. In the future, a multi-agent decision-making system of remanufacturing trade characterized by the optimization of the whole process of trade and combined informatics theory and machine learning is to be explored to achieve green, intelligent and efficient trade.

5. Conclusions

We have adopted bibliometric analysis to quantitatively and qualitatively analyze the published research articles in the field of remanufacturing trade. Our study has the following contributions. First, we have presented the growth and progress of published articles in terms of their number and the subject categories they contain. Second, we have examined the list of significant journals, countries, as well as the cooperative relationship between countries. Third, the combination of the co-occurrence and timeline for keywords provides a methodological contribution to identify the existing themes and hotspots of the future. Finally, through detailed content analysis of the literature, we found the research gaps in this field and provided potential directions for further research. It is recommended that researchers and practitioners refer to the hot keywords and research gap provided in this article to investigate methods and themes with good research significance.

Further research may be required for several aspects based on the content of this paper. First, the keywords related to the trade in remanufacturing for biblio-graphic retrieval could be reconsidered or enriched as the keywords we chose for the study may be incomplete. Second, the clusters and timeline of keywords can be interpreted differently as the judgment and analysis are subjective. Third, this paper only focuses on the themes and trends in remanufacturing trade; therefore, in the future, a more detailed classification and summarization, including model methods, purpose, findings and conclusions obtained, can be taken into account. Finally, more comprehensive research in this area can be conducted by expanding the search due to the neglect of other databases except for WOS because of various limitations.

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