



Evolution and Trend Analysis of Research Hotspots in the Field of Pollution-Intensive Industry Transfer –Based on Literature Quantitative Empirical Study of China as World Factory

Langang Feng^{1,2}, Shu Shang², Xin Feng^{3*}, Ying Kong⁴ and Jiahe Bai²

¹Guizhou Key Laboratory of Big Data Statistical Analysis, Guizhou University of Finance and Economics, Guiyang, China, ²School of Big Data Applications and Economics, Guizhou University of Finance and Economics, Guiyang, China, ³School of Economics and Management, Yanshan University, Qinhuangdao, China, ⁴School of Foreign Languages and Culture, Hebei Geo University, Shijiazhuang, China

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*Correspondence:

Xin Feng
149987543@qq.com

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Background: The transfer of pollution-intensive industries in China accounts for an increasing proportion of industrial transfer, and related studies emerge endlessly. Fully exploring its research and development breadth and depth will help clarify the development trend in this field and point out the direction for future research.

Method/Process: From the perspective of bibliometric analysis, with keywords as the core and cluster analysis of research hotspots as the basis, the keywords of pollution-intensive industry transfer in CNKI database are analyzed by CiteSpace software and divided into five categories. Established the text corpus model, and the network analysis transformed into a visual form. Due to the diverse research hotspots in pollution-intensive industry transfer, this article analyzes the evolution of research hotspots in this field to predict its future development trend.

Conclusion/Significance: China, as the world's factory, is affected by relevant policies, and industrial transfers have generally occurred. Industrial transfer, especially the transfer of pollution-intensive industries, has gradually attracted the attention of academic circles and has become a hot topic. When dealing with the transfer of pollution-intensive industries, industrial transfer only transfers pollution across regions. If we want to reduce pollution from the origin, innovation is an essential means. In retrospect, there were rare articles concerning the emerging polluting industries, however, recently since the emerging polluting industries have already constituted as the main source of pollution, more academic attentions are definitely needed. Although the mainstream measurement methods, the related share index method, and the input-output table have their weaknesses, respectively, the deviation share method can overcome the shortcomings of both. Therefore, it can be used as a reference for scholars to measure the transfer of pollution-intensive industries in the future.

Keywords: pollution-intensive industry, industry transfer, bibliometric analysis, environmental pollution, China

INTRODUCTION

The pollution-intensive industries refer to those industries that produce a large number of pollutants indirectly or directly in the process of production. If humans do not treat them, they will be harmful to human, animal, and plant health, affect the quality of the ecological environment, and lead to environmental deterioration (Fang-dao et al., 2013). The pollution-intensive industries usually shift from high-income areas to low-income areas and move from developed areas to underdeveloped regions.

Environmental degradation and environmental quality degradation have become hot topics, and the academic circle is paying more and more attention to environmental issues. Pollutants from pollution intensive industries are the main source of environmental pollution. Zhang et al. (2019) and Wang and Li (2020) proposed that the industrial sector is closely related to the environment, especially the pollution-intensive industries, which are the leading cause of environmental degradation and top priority energy conservation and emission reduction. Keting and Jianjian (2011) proposed that carbon emissions mainly come from industries, and the energy-intensive industries account for about 80% of the total industrial emissions. Tao (2013) and Haixia et al. (2020) believed that although industrial enterprises have gained some economic gains, they have also paid a massive price to damage the environment. Marland and Rotty (1984) studied that carbon dioxide (CO₂) emission generated from urban industrial fossil fuels is gradually recognized as a significant contributor to global climate change. Deng et al. (2012) believed that China is the world's largest energy consumer and dominates global energy consumption, global crude oil imports, global coal consumption, global electricity consumption, and global CO₂ emissions. Arce et al. (2016) studied that China has become the world's largest carbon dioxide emitter. In recent decades, China has become the "world factory" (World Trade Organization, 2019), so most existing research is on how to reduce pollution emissions in China to improve the current climate. Simultaneously, due to the environmental regulations and innovation capabilities in different regions of China, the transfer of pollution-intensive industries¹ has become increasingly common, leading to a broader national ecological pollution problem. Caiyun and Yanqing (2015) exclaimed that the environment in developed countries and regions had been continuously improving. In contrast, the environment in developing countries and underdeveloped areas has deteriorated rapidly due to pollution transfer. Therefore, the study of this article on the transfer of pollution-intensive industries in the world's factories in China has important practical significance.

¹Changes in the geographical spatial distribution of pollution-intensive industries or industrial group, i.e., from one country or region to another.

Due to the authority and subjectivity of China's pollution-intensive industry transfer policy, there is a lot of literature in this field. The previous study mostly adopted the traditional literature review method and only summarized the research contents of the transfer of pollution-intensive industries. For example, Qiwen et al. (2020) systematically summarized the concepts and categories of polluting enterprises/industries, and summarized the transfer characteristics, patterns, and dynamic mechanisms of polluting enterprises/industries. However, as far as we know, few studies have used bibliometrics to conduct literature reviews. Therefore, it is essential to systematically sort out, measure, and analyze the literature on the transfer of pollution-intensive industries. This article uses literature analysis, word frequency statistics, and cluster analysis to study the existing literature on the transfer of pollution-intensive industries with data extracted from CNKI (database of over 2000 Chinese journals) to analyze keyword frequency, hotspot clustering, changes, and trends. Besides, it uses CiteSpace to visualize the filtered data to clarify the evolution and development trend of hot spots in this field and to provide a quantitative basis for policy-making.

DATA ACQUISITION AND RESEARCH METHODS

Data Acquisition

This article takes CNKI database as the literature retrieval system to comprehensively analyze the evolution and trend changes of research hotspots in the field of pollution-intensive industrial transfer. The selected keywords, based on Jiang et al. (2017) are "pollution industry transfer" or "pollution-intensive industry transfer" or "energy industry transfer" or "heavy pollution industry transfer" or "steel industry transfer" or "chemical industry transfer,"² and source category selection "all journals." The time span is set from 1990 to 2020.³ The selected data include the following information: "Title," "Summary," and "Keywords." In order to reflect the typicality and relevance of the selected literature, the repetitive literature is manually removed, finally 593 authoritative and comprehensive academic journal articles are have been finally obtained. Then the papers are downloaded in the text file "txt" format, and the contents of "Title," "Summary," and "Keywords" in these 593 papers are used as data samples for this analysis.

Research Method

Bibliometrics is a kind of measurement method which statistically analyses the research status and research products of a particular

²Pollution industry, energy industry, heavy pollution industry, steel industry, and chemical industry will produce more pollutants in the production process (Jiang Shurui et al., 2017). This article selects the above industries to represent pollution intensive industries.

³1990 was selected as the starting point as the earliest research literature data appeared in that year.

field. Compared with traditional ways of literature review, the use of professional bibliometric methods is characterized by large capacity, long time span, and multi-dimensional analysis and visual presentation. This article uses the bibliometric method to analyze and summarize the research on the transfer of pollution-intensive industries. It primarily uses the literature analysis, the word frequency statistical, and the cluster analysis as follows:

- 1) Literature analysis method refers to a technique that makes quantitative statistics on bibliographies, abstracts, or indexes of a particular research topic and draws statistical results or analytic conclusions. It can help investigators form a general impression of the research objects, help them grasp the historical dynamics of the research objects, and also study the research objects that are impossible to approach, such as those who have already died. This article uses the CNKI database to collect data from the literature on the evolution of characteristics in pollution-intensive industry transfer and count the number of existing research in this field.
- 2) Word frequency statistical method is mainly a statistical analysis of the number of keywords that can reveal the core content of literature in a certain field. It is an important means of text mining and a traditional and representative content analysis method in bibliometrics. The basic principle is to determine the hot spots and their changing trends through the change of word frequency (Heting, 2019). The higher the frequency of keyword occurrence, the higher the attention on this topic. This method can determine hotspots of the research and development status in a specific area. This article analyzes the frequency of keywords on the transfer of pollution-intensive industries in three parts, i.e., title, summary, and keywords, aiming to determine the hot spots and their changing trends in this field.
- 3) Cluster analysis is a statistical method that divides the research objects in a particular field into several groups. The research objects in each group have similar characteristics, and each group is mutually exclusive (Xin et al., 2020). Cluster analysis from the selection of keywords analysis to the generation of clusters is carried out in the form of mathematical statistics, which can reduce human intervention and make the results of co-word clustering objectively and truly reflect the current situation of literature group content (Wenjin et al., 2008). This method can form an intuitive network graph of several research objects in a specific field. This article uses the Log-Likelihood Ratio (LLR) algorithm in Citespace software to cluster the keywords in the three parts of title, abstract, and keywords in the field of pollution-intensive industrial transfer research, and then forms an intuitive keyword clustering view.

Research Tool

This article uses CiteSpace software to analyze, draws a visual map of the research on the transfer of pollution-intensive industries, analyzes the high-frequency keywords and co-occurrence network, and predicts the development trend of the pollution-intensive industry transfer field through keyword

time zone diagram. It is beneficial to understand the area of pollution-intensive industry transfer better by clarifying the internal dynamic mechanism of the study and exploring the subject development of the pollution-intensive industry transfer.

ANALYSIS OF RESEARCH RESULTS

High-Frequency Keywords and Keyword Co-Occurrence Network

In order to grasp the research hotspots in the field of pollution-intensive industry transfer, this article makes a statistical analysis of the keywords in the “title,” “summary,” and “keywords” parts of 593 papers on pollution-intensive industry transfer, and obtains the frequency of keywords and the information of their first occurrence years. The content of this research field is mainly from five categories: basic theory, measure method, influence factors, hot area, and economy and environment. The basic theory mainly discusses the relevant hypothesis and theory in the field of pollution-intensive industry transfer; the measure method shows the relevant methods to measure the transfer of pollution-intensive industries; and the influence factors affecting the transfer of pollution-intensive industries are introduced. For example, environmental regulations with different intensities in various regions will make the transfer of pollution-intensive industries from regions with higher environmental regulations to regions with lower environmental regulations occur. The mechanism of environmental policies such as environmental protection policies and carbon emission regulations is similar to that of environmental regulations. In addition, different levels in regional innovation and foreign direct investment also can lead to pollution-intensive industries transfer; the hot area indicates that Chinese regions which once were key research areas for pollution-intensive industrial have now transferred in the analyzed literature; the economy and environment, economy refers to the economic change caused by the transfer of pollution-intensive industries, or the transfer of pollution-intensive industries caused by different economic factors. Environment refers to the change of environmental situation in the field of pollution-intensive industry transfer and the environmental protection measures taken.

These five categories are discussed from three perspectives: research foundation, research process, and research results; the basic theory and measure method belong to the research basis, the influencing factors belong to the research process, and the hot spots and the economic consequences belong to the study results. These three perspectives cover the vast majority of research contents in the field of pollution-intensive industry transfer. Therefore, in the literature's data set, the literature's keywords are statistically arranged in frequency from more to less. The keywords with higher frequency are divided into five categories according to the research aspects to comprehensively analyze the hot spot evolution and trend of the research in pollution-intensive industry transfer. The reasons and mechanisms of the transfer of pollution-intensive industries are analyzed to explore the high-frequency keywords in this field. This article

TABLE 1 | The ranking of the frequency of keywords in the field of pollution-intensive industry transfer.

Classification	Keyword	Frequency	Year
Basic theory	Environmental Kuznets curve	10	2006
	The hypothesis of pollution haven	10	2006
	Green barrier	4	2002
	Environmental welfare effect	2	2006
	Total	26	—
Measure method	Deviation share analysis	12	2013
	Industrial competitiveness model	1	2017
	Industrial gradient coefficient	1	2012
	Total	14	—
Influence factor	Environmental regulation	65	1995
	Foreign direct investment	35	2006
	Environmental protection policy	8	2004
	International trade	3	2005
	Innovation	2	2007
	International direct investment	2	2005
	Development strategy	2	2009
	Carbon emission regulation	1	2015
	Total	118	—
	Hot area	Central and western region	11
Beijing-Tianjin-Hebei integration		9	2015
Guangdong province		5	2007
One Belt and One Road		3	2016
Yangtze River economic belt		3	2016
Tianjin		2	2013
Beibu Gulf economic zone		2	2008
Total		35	—
Economy and environment	Environmental protection	15	2003
	Economic growth	9	2013
	Industrial structure	8	2001
	International industrial transfer	7	2004
	Economic development	5	2003
	Air pollution	5	2004
	Carbon emission	3	2014
	Gross domestic product	2	2014
	Environmental investment	2	1998
	Ecological environment protection	2	2005
	Carbon transfer	2	2017
	Eco-environmental effect	2	2009
	CO ₂ emission	2	2010
	Globalization	2	2006
	Low carbon economy	2	2015
	Regional economy	2	2015
	Total	70	—

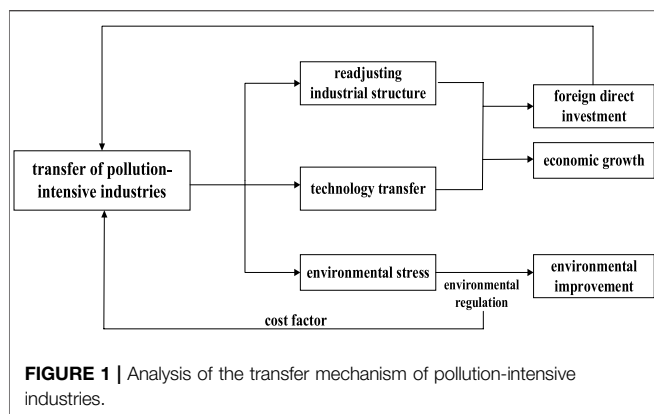
summarizes the occurrence frequency of the top keywords and the information on the first occurrence year (**Table 1**). Among them, the keywords shown in **Table 1** are only some of the top keywords, while the keywords with low occurrence frequency do not show too much.

By dividing the keywords into five categories for research, we can see the high-frequency keywords and their evolution trend in each type of the pollution-intensive industry transfer research field and make a comprehensive analysis of this field. However, it is not easy to thoroughly analyze the five categories' effects in this field and their relationship only through the frequency of keywords and the year of their first appearance. Therefore, this article also adds a mechanism analysis chart to consider

the influencing factors and economic consequences in the transfer of pollution-intensive industries and show the relationship between the two categories and the field.

1) Basic theory

From the research in China, the keyword frequency of the primary theory category is 26 times, including environmental Kuznets curve, the hypothesis of pollution haven, green barrier, and environmental welfare effect. They first appeared between 2002 and 2006. With the deepening of the research, the theoretical basis of the transfer of pollution-intensive industries in China is becoming more affluent. Scholars have also realized that the



research on the transfer of pollution-intensive industries is developing dynamically. It is necessary to add the game analysis between the transferor and the receiver into the research framework of the transfer of pollution-intensive industries.

2) Measure method

The keyword frequency of measure method class is 14 times in total, including deviation share analysis, industrial competitiveness, and industrial gradient coefficient. The industrial gradient coefficient was first introduced into the study of pollution-intensive industry transfer in 2012, and “deviation share analysis” was firstly applied to the transfer measure of pollution-intensive industries in 2013. It was only in 2017 that the industrial competitiveness model was combined with the transfer of pollution-intensive industries.

3) Influence factor

The keyword frequency of influencing factors appeared 118 times in total. The keyword of environmental regulation appeared in 1995 and was the earliest keyword with a frequency of 65 times, indicating that environmental regulation is the most crucial factor affecting the transfer of pollution-intensive industries. Besides the ecological regulations, various policies and measures also impact the transfer of pollution-intensive industries, such as environmental protection policy, development strategy, and carbon emission regulation. Among them, regions with strict environmental regulations have high pollution costs. The pollution-intensive industries shift from areas with increased environmental regulations to low environmental regulations to save costs. International trade also plays a decisive role in influencing the transfer of pollution-intensive industries. Foreign direct investment appeared 35 times in 2006; international trade appeared three times in 2005; and international direct investment appeared two times in 2005. Innovation first appeared in 2007 and appeared twice. Innovation ability is a relatively new influencing factor and the primary means to solve the root causes of global environmental pollution caused by the transfer of pollution-intensive industries. We firmly believe that research on innovation ability is worthy of scholars' attention.

To clarify the relationship between this field and other categories of mechanical principles with influencing factors, **Figure 1** is drawn to analyze the mechanism in this field. From this, we can see that the transfer of pollution-intensive industries leads to industrial restructuring, technology transfer, environmental pressure, and other economic consequences. Industrial restructuring and technology transfer promote foreign direct investment and enable economic growth; because of the high environmental stress, the environmental regulations formulated by the government tend to be stricter, which in turn improves the environment. Besides, stringent environmental regulations raise costs for enterprises, which definitely lead to the relocation of pollution-intensive industries. Therefore, conclusion is drawn that the economic consequences generated by the transfer of pollution-intensive industries further promote the influencing factors, which in turn stimulate the transfer of pollution-intensive industries, forming a mutual promotion mechanism.

4) Hot area

The keyword frequency of hot area was 35 times in total, including central and western regions, Beijing-Tianjin-Hebei integration, Guangdong province, One Belt and One Road Region, and Yangtze River Economic Belt, which firstly appeared in 2007, 2015, 2007, 2016, and 2016, respectively. Overall, research in the central and western regions appeared earlier. But in recent years, as regional development strategy demonstration belts Beijing-Tianjin-Hebei, One Belt and One Road Region, and Yangtze River Economic Belt have gradually attracted academic attentions. The Beijing-Tianjin-Hebei region is called the “Capital Economic Circle” in China. The Yangtze River Economic Belt and One Belt and One Road Region are the primary development strategies of China at present. Simultaneously, Beijing-Tianjin-Hebei, Yangtze River Delta, and other regions are economically developed regions and heavily polluted regions as well, which have already become research hotspots in recent years.

5) Economic consequences

The keyword frequency of economic consequences was 35 times in total, including environmental protection, economic growth, industrial structure, international industrial transfer, economic development, air pollution, and carbon emission, which first appeared in 2003, 2013, 2001, 2004, 2003, 2004, and 2014, respectively. The keywords of economic consequences run through the fundamental research, which is a hot spot in the transfer of pollution-intensive industries and a bridge linking pollution-intensive industries with the influencing factors.

By analyzing high-frequency keywords, we find that, as the world's factory, China is affected by environmental policies and other factors. Industrial transfer generally occurs especially in the transfer of pollution-intensive industries, which has gradually attracted academic attention. While environmental regulation is the most crucial factor affecting the transfer of pollution-intensive industries, innovation ability is a relatively new

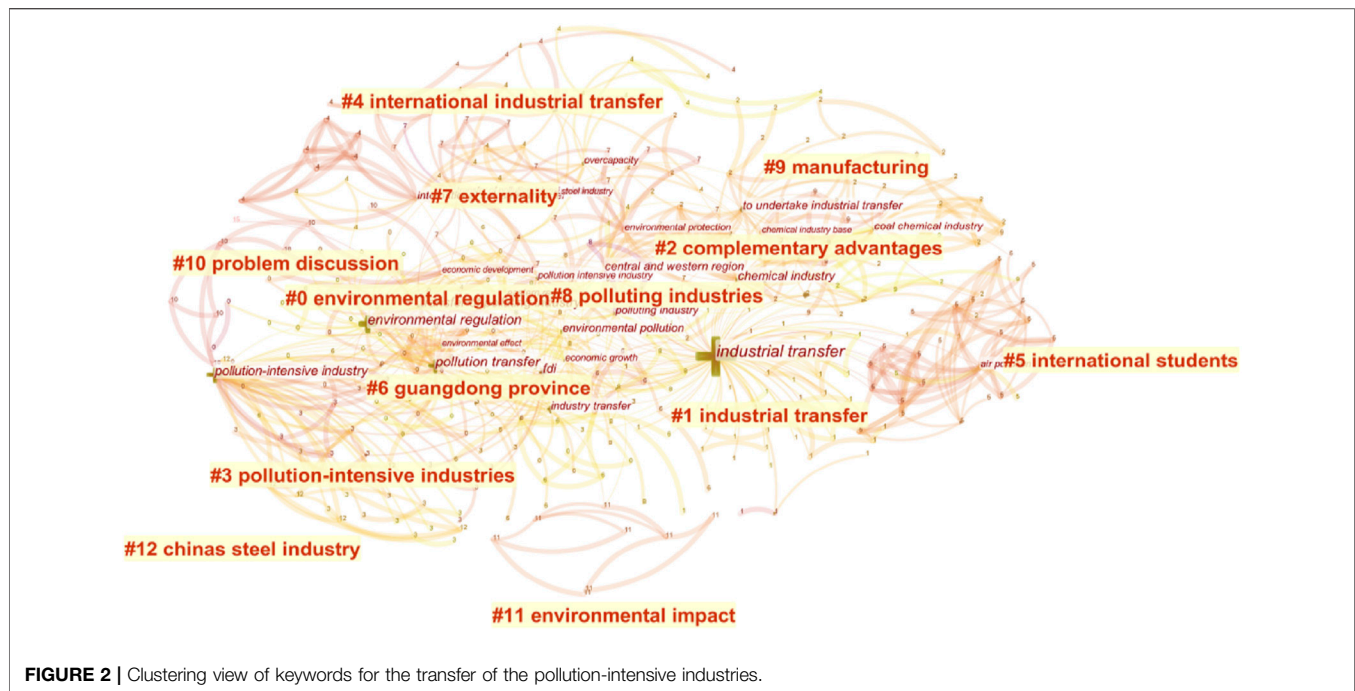


FIGURE 2 | Clustering view of keywords for the transfer of the pollution-intensive industries.

influencing factor. As the theoretical basis for the transfer of pollution-intensive industries in China is becoming more and more abundant, the measurement methods are also changing rapidly. Deviation share analysis was first combined with the transfer of pollution-intensive industries in 2013. It is the most frequently used measurement method so far, and the one we believe has the best research prospect.

Research Hotspot Cluster Analysis

To quickly and accurately sort out the Frontier hotspots in this study field, find out which keywords are vital in the literature network, this study uses the Log-Likelihood Ratio (LLR) algorithm to conduct cluster analysis on the study hotspots through CiteSpace software. Through the cluster view, we can find the Frontier hotspots and keywords in the field of pollution-intensive industry transfer research. This article selects the top 50 keywords from each article for statistical analysis and clustering and obtains a total of 527 keywords⁴ (Figure 2).

Through cluster analysis, the keywords of the research literature in the field of pollution-intensive industry may be grouped into 12 categories, including environmental regulation, industrial transfer, complementary advantages, pollution-intensive industries, international industrial transfer, international students, Guangdong province, externality, polluting industries, manufacturing, problem discussion, and China's steel industry (Figure 2). Cluster analysis can quickly understand the clustering situation of the research field to grasp the hot study topics in this field. Besides, this article further

divides the 12 clusters into five categories according to the above categories for specific analysis: theoretical basis, measurement method, influencing factors, research area, and economic consequences to clarify the research context of the transfer of pollution-intensive industries and capture the Frontier hotspots in this field.

1) Basic theory

The theoretical basis category, pollution haven, environmental Kuznets curve, and green barrier are the fundamental theories in pollution-intensive industry transfer. Scholars such as Chichilnisky (1994), Copeland (1994), Baumol and Oates (1988), Copeland and Taylor (2004), and Dean et al. (2008) theoretically explained the existence of pollution refuges. Qiying and Haitao (2019) based on the two opposing theories of “pollution haven” and “pollution halo,” tested the pollution refuge effect of foreign investment. Hui and Jin-xi (2020) used the environmental Kuznets curve to measure the pollution transfer in Beijing and Hebei Province.

2) Measure method

The measure methods include the deviation share method, the industrial competitiveness model, and the industrial gradient coefficient, which shows that scholars mainly use these models in the pollution-intensive industrial transfer. The industrial competitiveness model and the industrial gradient coefficient belong to the relative share index method. Based on the basic idea of the deviation share method, Ai-hua and Fan (2018) constructed an improved model of regional industrial transfer and pollution transfer and carried out quantitative measurement

⁴The top 50 keywords in each article have the same rate, so the number of keywords obtained is less than the total number of articles.

of restricted industrial transfer and pollution transfer in China. Mei (2006) used the industrial competitiveness coefficient to prove the regional correlation of the effects of carbon emission influencing factors. Through literature review, we found three main categories of measurement methods for the transfer of pollution-intensive industries. In addition to the two mentioned above, many scholars also use input-output tables to measure the transfer of pollution-intensive industries. For example, Hong-guang et al. (2011) established a quantitative method to calculate the regional industrial transfer using the regional input-output model. They also combined the China regional input-output table, and estimated the regional industrial transfer in China from 1997 to 2007.

3) Influence factor

The influencing factors mainly include environmental regulation and foreign direct investment. Besides, innovation capacity also has a specific impact on the transfer of pollution-intensive industries. For example, Bing-tao and Li-ming (2019) studied that with the relative environmental regulation intensity from low to high, the environmental pollution caused by the transfer of highly polluting industries became severe. Bing-tao and Li-ming (2019) studied the relationship between the foreign direct investment of American enterprises and the cost of pollution reduction. They found that industries with high price of emission reduction were more inclined to make foreign investment. The impact of international trade on the transfer of pollution-intensive industries is noticeable. Wang and Huang (2015) explored that in the long run, effectiveness means to solve the problem of environmental pollution mainly depending on technological progress, especially green technology-oriented innovation (Zhiqing et al., 2014).

4) Hot area

The study regions mainly include Guangdong, Western China, Beijing-Tianjin-Hebei, One Belt and One Road Region, and Yangtze River Economic Belt. Among them, the central and western regions are the essential places for industrial transfer, and the eastern areas are the main places for industrial transfer. Longbin (2013) confirmed that the west part is the transfer area of most polluting industries through the statistics of the transfer and outflow of representative products of polluting industries in different regions of China; Qi (2014) found that the east part is the leading area of industrial transfer, while the central and western are the main receiving areas for industrial transfer; Hui and Jinxi (2020) found that along with the regional industrial transfer between Beijing and Hebei province, there is also a noticeable transfer of regional environmental pollution sources in them; Tang et al. (2017) considered that the Beijing-Tianjin-Hebei Integration Strategy was driving industrial transfer from Beijing to Hebei; Chen et al. (2017) by applying LMDI method to the industrial transfer theory, evaluated driving forces of carbon emission changes from manufacturing industries in the Pearl River Delta (PRD) of China; Youjin et al. (2020) considered the technological symbiosis, industrial symbiosis and market symbiosis are critical transmission paths to promote China's

industrial transfer to "One Belt and One Road" countries to achieve mutual benefits; Chen et al. (2019) considered that there is a trend of gradient transfer of "One Belt and One Road" industries, especially polluting industries.

5) Economic consequences

Economic consequences mainly summarize a series of effects of the transfer of pollution-intensive industries, such as complementary, international industrial transfer, problem discussion, environmental pollution, industrial upgrading, economic growth, and industrial structure adjustment. Wen-bin and Fang-yi (2018) believed the pollution-intensive industries were important primary industries, and there were many related industries upstream and downstream which provided essential raw materials and energy for China's economic construction and played a vital role in supporting the development of the national economy. Bo et al. (2020) suggested that manufacturing was directly or indirectly linked to nearly three-quarters of China's energy-related greenhouse gas emissions in 2012. Ke-ting and Jian-jian (2011) studied that pollution-intensive industries consumed a lot of energy and were characterized as high emissions and pollution sources, putting tremendous pressure on ecological and environmental protection and national energy security. Mulatu, (2014) discussed that environmental pollution from the pig industry is an urgent problem to be studied and solved, especially on large-scale pig farms.

Throughout the academic circles, we found that the current research in this field focuses on environmental pollution, environmental protection, economic growth, industrial structure adjustment, and other impacts of the transfer of pollution-intensive industries, while ignoring the research of the transfer location. Thus, the study on the intensive industry transfer field is designed to be conducted from two aspects. The first one is the positive effect of industrial transfer on transfer, including improving industrial status, promoting advanced industrial structure, and improving environmental pollution; the second is the negative effect of industrial transfer on transfer, including reducing the competitiveness and employment of transferred industries.

Keywords Vicissitude and Trend Forecast

The transfer of pollution-intensive industries will not only promote economic development but also bring some environmental problems. This article combines the time zone diagram of research keywords in pollution-intensive industry transfer (Figure 3), in the environmental regulation research field from 1990 to 2020. Among them, the abscissa represents each year, and the ordinate represents keyword clustering.

The time zone diagram of key words in the study of pollution-intensive industry transfer can intuitively show the change process of research direction over time. From the time trend of the time zone diagram, hot keywords appeared less frequently in 1990–1993, and keywords increased significantly since 1994. However, in order to clarify the research stage of the transfer of pollution-intensive industries, it is not enough to rely far on time zone diagrams. Therefore, based on the analysis of the time zone diagram of pollution-intensive industry transfer, combined with

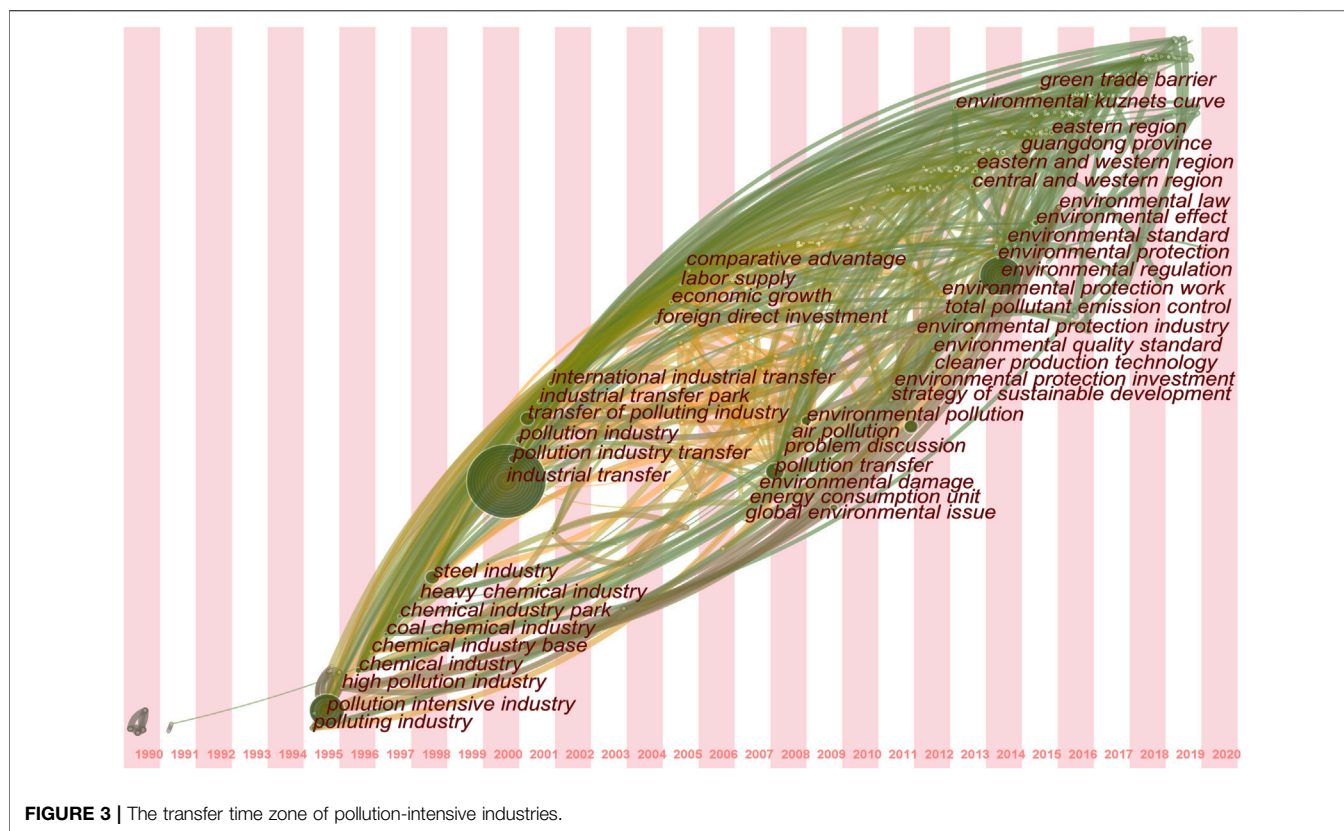


FIGURE 3 | The transfer time zone of pollution-intensive industries.

the specific situation of the fourth and fifth industrial transfer in the world,⁵ this article discusses the hot spots of each research stage in the field of pollution-intensive industry transfer. Also, this research can be roughly divided into two research stages: the embryonic stage from 1990 to 2008 and the development stage from 2009 to 2020.

In the embryonic stage from 1990 to 2008, it was the fourth industrial transfer in the world. The importing country was the developing country, which was the biggest beneficiary. At this stage, the study direction of the transfer of pollution-intensive industries in China focuses on the positive benefits of foreign direct investment, economic benefits of pollution industry development, and other developing industries such as manufacturing. In the development stage of 2009–2020, after the outbreak of the international financial crisis in 2008, the fifth world industrial transfer has been ushered in. At this stage, the research direction of scholars is more focused on environmental regulation, environmental pollution, air pollution, environmental control, environmental standard, central region, etc. Based on the embryonic stage, scholars can objectively study the economic effects of the transfer of pollution-intensive industries from both

positive and negative sides. At the same time, they enrich their theoretical basis through the Environmental Kuznets curve theory and also begin to conduct in-depth study and reflection on the transfer of pollution-intensive industries in different regions. For example, Jianhua et al. (2016) evaluated some basic problems faced by inter-regional transfer of polluting industries in China, including how to fully define polluting industries, what are the advantages of transfer status, and whether there are some rules to control this situation. Bingtao and Liming (2018) calculated the dynamic agglomeration index of high-pollution industries, the agglomeration index of environmental pollution, and the intensity index of relative environmental regulation, and found that the transfer of high-pollution industries mainly brought about the deepening of the agglomeration degree of industrial wastewater pollution and industrial waste gas pollution.

The study on the transfer of pollution-intensive industries in the two different periods has a different focus, mainly due to the other characteristics of the global industrial transfer in these different periods, thus indicating that the transfer of pollution-intensive industries has a vital “timeliness.” In short, the research enthusiasm for fundamental theories and methods in the transfer of pollution-intensive industries has a relatively long duration. In contrast, some special hot spot issues have a relatively short period and are easily affected by the macroeconomic environment at that time. After the 2008 financial crisis, research on whether pollution-intensive industry transfer can solve the financial crisis and improve the economic level has

⁵The time period of the fourth industrial transfer in the world is from the 1980s to the 1990s, and the time of the fifth industrial transfer in the world is after the 2008 financial crisis. The motivation of the world industrial transfer is mainly the change of the world economic situation. Therefore, this article takes these two periods as the basis for dividing the stages of pollution-intensive industrial transfer.

increased rapidly. With the economic recovery, people began to pursue a higher quality of living environment (Hang et al., 2012). So the research on the economic benefits brought by the transfer of pollution-intensive industries has become a hot topic. In the development stage of the transfer of pollution-intensive industries after 2008, the focus of academic research in this field has shifted to the environment (Lihui and Chuanqing, 2021). The government and society have also paid more and more attention to the environmental effect of the transfer of pollution-intensive industries (Zhang et al., 2020), which will force the transfer of pollution-intensive industries to develop toward improving the ecological civilization system, establishing the environmental responsibility of enterprises, and paying attention to the regional differences in the environment, and finally realize the harmonious coexistence of man and nature to jointly build a beautiful world.

CONCLUSION AND OUTLOOK

This article reveals the basic overview of the research field of pollution-intensive industrial transfer in the past 3 decades. Through bibliometric analysis of the literature on pollution-intensive industrial transfer, the following three conclusions are drawn: First, when dealing with pollution-intensive industrial transfer, we found that the transfer of pollution-intensive industries refers to the transfer of pollution-intensive industries across regions, that is, the transfer of pollution-intensive industries from one region to another. This kind of behavior makes the pollutant discharge place of polluting industry change from the place where the polluting industry was transferred from to the current place where the polluting industry is transferred to, which does not reduce the discharge of pollutants from the origin. In order to reduce pollution from the source, corresponding innovations in pollution-intensive industries are the means that must be followed (Wang and Huang, 2015). Secondly, most of the previous articles discussed traditional polluting industries, and the research on traditional polluting industries has been abundant. There are many research countermeasures for the environmental pollution problems caused by traditional polluting industries. However, there are few existing literatures about emerging polluting industries, and there are few solutions for pollution control of emerging polluting industries. The environmental pollution caused by emerging polluting industries, such as pig raising and home appliance industry, has become a major problem, which deserves the attention of scholars. Finally, the mainstream method related to the share index method and the input-output table has certain shortcomings, where the deviation share method can just make up for them both. Among them, the relevant share index method cannot directly show the specific industrial transfer volume; the input-output table is only compiled every 5 years and cannot reflect the latest industrial transfer characteristics. Therefore, the deviation share method is a method that has become popular in recent years. Since this method can overcome the shortcomings mentioned above, it can be used as a reference for future

scholars to further study the transfer of pollution-intensive industries.

At present, the research on the transfer of pollution-intensive industries focuses on traditional polluting industries and the areas where pollution-intensive industries are transferred. However, with the continuous emergence of new environmental factors, those problems are becoming more and more serious. In the future, the research on the transfer of pollution-intensive industries should focus on the followings:

- 1) It is imminent to solve the global pollution caused by the transfer of pollution-intensive industries from the origin.

We found that due to the influence of relevant policies, industrial transfer has occurred generally. With the increase of industrial transfer, industrial transfer, especially the transfer of pollution-intensive industries, has gradually attracted the attention of the academic community becoming a hot topic. The transfer of polluting industries refers to the transfer of polluting industries between regions. This behavior of polluting industries can only change the pollutant discharge places from the place of once out-transfer to the place of in-transfer nowadays. It cannot reduce the environment pollution from the origin. Therefore, in order to reduce the environmental pollution caused by pollution-intensive industries, innovation is the only means that must be followed, i.e., only technological innovation and progress can truly reduce pollution from the very beginning (Peng and Li-wen, 2014). Innovation is not only a key factor affecting the transfer of pollution-intensive industries, but also an important means to solve pollution from the origin, which is worthy of further research by scholars.

- 2) The out-transfer of industries and the whole transfer of emerging polluting industries will attract academic attentions.

Throughout the academic world, most of the current research focuses on the place where pollution-intensive industries are inherited, while ignoring the places where pollution-intensive industries are transferred. Scholars in the future can conduct in-depth research on the changes in the status, industrial structure, environmental conditions, and employment of the outgoing real estate industry from the perspective of industrial transfer. Here, we refer to non-traditional polluting industries as emerging polluting industries, such as the pig industry mentioned by Mulatu (2014). In the past, farmers were both farming and raising pigs. Pigs to fertile fields and planting constructed a beneficial cycles with each other, so the pressure on environmental protection was relatively low. However, with the specialization and expansion of aquaculture, the main bodies of cultivation and cultivation are separated, therefore, causing serious pollution to the environment. Jianjun et al. (2018) pointed out that since the beginning of the 21st century, the regional transfer of the pig industry has become more and more obvious. Through literature review, we found that most of the previous articles focused on the economic consequences of traditional polluting industries and their industrial transfer, while the economic consequences of emerging polluting

industries were rarely involved. With the advancement of technology, the pollution generated by traditional pollution-intensive industries is easier to solve, while the pollution generated by emerging heavy polluting industries has become a major problem, such as water pollution caused by the pig industry (Jianjun et al., 2018) and household appliances secondary pollution caused by improper disposal of waste household appliances (Ai et al., 2012), unfortunately, there are few related studies related to the field. Therefore, the emerging polluting industries and their transfer deserve the attention of scholars.

3) The deviation share method has become an inevitable choice for measuring the transfer of pollution-intensive industries.

In the measurement method, the relevant share index method is a method with high frequency, but it cannot directly show the specific industrial transfer volume. We found that the inter-regional input-output table and the inter-regional input-output model are more popular research methods. Unfortunately, the input-output table is only compiled every 5 years, so it cannot reflect the latest characteristics of industrial transfer. At present, in the quantitative measurement research of industrial transfer, more and more scholars use the deviation share method to study the problem of industrial transfer. In the research of pollution-intensive industrial transfer, this method has become more popular in recent years and can make up for some deficiencies as for the relevant share index method and the investment-output table. Therefore, it can be used as a reference for future scholars to study the transfer of pollution-intensive industries.

In today's vision of a beautiful world, the transfer of pollution-intensive industries has become a hot topic. This article believes that technological innovation for promoting energy-saving and consumption-reducing equipment renewal as well as production process innovation are the fundamental countermeasure to solve the impact of pollution-intensive industries on the environment. It is suggested that all industrial transfers should aim at "building beautiful and ecological world," fully consider the needs of the

ecological well-being of the people, and reduce the impact of industries on the environment from the source. To sum up, we cannot simply pursue the speed of economic development, but fundamentally achieve "good and fast" economic development.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

LF: conceptualization, methodology, writing-original, funding. SS: writing-original, writing-review-editing, data curation. XF: visualization, formal analysis. YK: translate, supervision. JB: supervision.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2022.732734/full#supplementary-material>

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