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Review

Research Themes, Evolution Trends, and Future Challenges in China's Carbon Emission Studies

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Abstract: A profound analysis of China's research achievements in the realm of carbon emissions holds the potential to furnish insightful references for analogous endeavors and inquiries in other nations. Employing the CiteSpace tool, this paper identifies five major focal points in Chinese scholars' research on carbon emissions: carbon emission computation and prediction, influencing factors of carbon emissions, carbon footprint, carbon emission efficiency, and differential analysis of carbon emissions. Subsequently, this article systematically scrutinizes and dissects the outcomes of Chinese scholars' endeavors in the aforementioned five focal points, culminating in recommending China's forthcoming research on carbon emissions. (1) The research findings reveal a diversified evolution in the methods employed for calculating and predicting carbon emissions in China. However, due to the limited exploration of delineating carbon emission boundaries, instances of overlap and deviation in carbon emission quantification have emerged. (2) Factors influencing carbon emissions can be categorized into five major classes: economic, demographic, energy-related, policy-driven, and others. Yet, studies investigating industry-specific influencing factors remain relatively scarce. (3) Overcoming challenges associated with cross-boundary measurements, comprehensive effects, and policy applications is imperative in carbon footprint research. (4) Significantly disparate levels of carbon emission efficiency prevail across distinct regions or industries, with intricacies characterizing the influencing factors and a notable dearth of micro-level investigations. (5) The analysis of carbon emission differentials primarily encompasses regional disparities, industrial differentials, and temporal variations, lacking sustained tracking studies on the nuances of carbon emission disparities.

Keywords: China; carbon emissions; CiteSpace; research themes; challenges

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1. Introduction

Despite a deceleration in the global growth rate of carbon emissions since 2010 and a negative growth observed in global carbon emissions in 2020, the challenges posed by the global carbon emission issue persist. In 2022, global carbon emissions reached a staggering 366 billion tons, presenting a formidable challenge to the global ecological environment [1]. The management and mitigation of carbon emissions constitute a pivotal facet in realizing regional sustainable development, spanning across various dimensions encompassing environmental, economic, and societal realms. Carbon emissions, as a prominent greenhouse gas, directly influence climate dynamics. Excessive carbon emissions contribute to global temperature escalation, rising sea levels, and other environmental predicaments, precipitating irreversible impacts on regional ecosystems and natural resources. Addressing carbon emissions in the developmental context steers enterprises towards adopting more environmentally conscious production methods, augmenting resource efficiency, and thereby fostering regional economic sustainability. Carbon reduction endeavors can ameliorate air quality, mitigate environmental pollution, and elevate the quality of life for residents, bearing paramount significance for the health of regional societies and their residential environments.

As the world's largest carbon emitter and the second-largest economy globally, China's research achievements in carbon emissions wield a catalyzing effect on global carbon reduction [2]. For instance, the Chinese government's initiatives, such as advancing carbon market construction and implementing carbon taxation policies, have proven effective in reducing the nation's carbon emissions. Consequently, a comprehensive analysis of China's research outcomes in the field of carbon emissions holds the potential to furnish valuable insights for analogous endeavors and inquiries in other countries. Furthermore, by comprehensively reviewing carbon emission research in China, this study contributes to a more nuanced understanding of the current state of research in the field. It provides a profound academic background and identifies potential avenues for future research, offering valuable insights for academic scholars. Additionally, such insights can serve as a scientific basis for decision making by the Chinese government, fostering sustainable economic development, enhancing environmental quality, and propelling the nation towards a low-carbon, green future.

The primary objective of this paper is to conduct an in-depth analysis of the developmental trajectory of carbon emission research in China. It systematically reviews pertinent themes, reveals their evolutionary trends, and explores potential challenges that may be encountered in the future. This paper employs the CiteSpace tool to conduct a quantitative and keyword analysis of research publications by Chinese scholars in the Web of Science database. This analysis aims to discern the evolving trends and research themes of Chinese scholars in the realm of carbon emissions. Subsequently, the paper systematically reviews and appraises the outcomes of Chinese scholars' research on carbon emissions from five perspectives: carbon emission calculations and predictions, influencing factors of carbon emission (CE), carbon footprint, carbon emission efficiency (CEE), and differential analysis of CE. In conclusion, the paper provides recommendations for the next phase of CE research by Chinese scholars.

2. Research Design

2.1. Method Statement

Bibliometrics is a method of assessing the impact and contribution of research through a quantitative analysis of the scientific literature. There are numerous software tools available for conducting bibliometric analyses. Common bibliometric software tools include Bibexcel 1.0, Ucinet 6.8, and Citespace 6.2. Among them, Bibexcel is suitable for providing assistance as a visualization tool. Ucinet serves as a social network analysis tool, particularly adept at analyzing large datasets. Citespace, on the other hand, is a more comprehensive bibliometric software tool specialized for literature analysis [3]. In this paper, we utilize Citespace to analyze the research outcomes of Chinese scholars in the field of carbon emissions, encompassing analyses of research themes, evolutionary trends, and future challenges.

CiteSpace constructs a network graph of literature citations, utilizing algorithms to identify clusters and key nodes within the citation network. It incorporates temporal information for spatiotemporal analysis, aiding researchers in exploring academic literature and revealing evolutionary patterns and crucial insights within a discipline. Furthermore, compared to other bibliometric tools, CiteSpace boasts several advantages. As open-source software, CiteSpace benefits from widespread engagement and application within the research community. Its robust visualization capabilities generate citation networks, cluster maps, spatiotemporal evolution graphs, and other visual representations, offering an intuitive portrayal of literature relationships and disciplinary development trends. Moreover, it supports large-scale data analysis, making it suitable for handling extensive literature databases and providing users with comprehensive and in-depth bibliometric insights. Ultimately, CiteSpace stands as a potent open-source bibliometric tool with multifaceted functionalities. It facilitates the construction of visual citation networks through citation network analysis, allowing users to gain profound insights into citation chains and academic exchanges. With support for spatiotemporal analysis, CiteSpace enables users to observe the evolutionary processes of the literature over time, uncovering trends, key nodes, and research hotspots within a discipline. Additionally, CiteSpace provides clustering and keyword co-occurrence analysis, aiding users in identifying research hotspots and subfields within a discipline.

2.2. Data Statement

Web of Science (WOS) is a crucial platform for accessing academic information. In this study, we utilized the Social Sciences Citation Index (SSCI) within the WOS database, focusing on the theme "CE*". We narrowed the search down to the document type "Article" and selected the country category as "PEOPLES R CHINA". The retrieval spanned from 2003 to 2023, resulting in a total of 12,721 relevant papers. Subsequently, per CiteSpace tool requirements, we exported the retrieved paper data and employed the COOC tool to clean the exported data, specifically emphasizing merging and deleting synonyms within keywords. Finally, leveraging the specialized literature analysis tool CiteSpace, we analyzed the obtained literature, unveiling the research themes and evolutionary trends in the field of carbon emissions among Chinese scholars over the past two decades [4].

3. Review of Research Achievements in Carbon Emission in China

3.1. Analysis of Publication Volume, Journal Level, and Keyword Analysis

3.1.1. Analysis of Publication Volume

Carbon emissions represent a current focal point in academic research, with a sustained upward trajectory evident in the number of relevant papers authored by Chinese scholars, as illustrated in Figures 1 and 2. Examining the distribution of paper quantities over the past two decades, the research journey of carbon emissions in China can be delineated into four distinct phases.

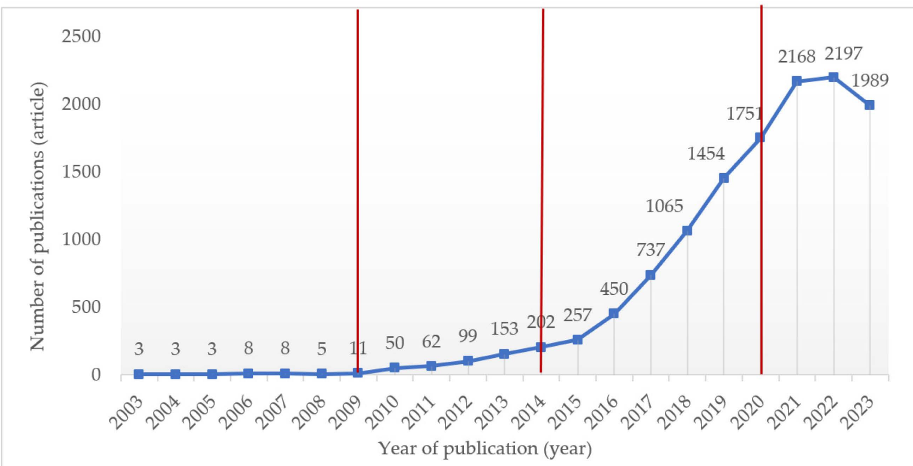

Figure 1. Number of CE research papers published by Chinese scholars in international journals from 1 January 2003 to 31 December 2023.

Phase One (2003–2009) marked the initial stage of research and policy formulation. The number of published papers increased from 3 to 11. During this phase, there were relatively few research outcomes on carbon emissions in China, reflecting a lower level of government attention to the issue, and CE control policies had yet to be implemented. Phase Two (2010–2014) witnessed incremental growth and policy deepening. The number of published papers increased from 50 to 202. CE research in China gradually increased, accompanied by the progressive implementation of government policies addressing carbon emissions. Initiatives such as evaluating carbon emissions per unit of GDP, advancing low-carbon cities, and piloting carbon markets were introduced during this period. Phase

Three (2015–2019) was characterized by rapid growth and global attention. The number of published papers increased from 257 to 1751. The Chinese government committed to achieving a carbon peak by 2030, prompting Chinese scholars to actively explore carbon reduction strategies, leading to a sharp increase in research outcomes. Phase Four (2020–2023) represents continuous growth and a pursuit of carbon neutrality. The number of published papers has remained stable at around 2000. With the Chinese government setting the goal of carbon neutrality by 2060, research outcomes by Chinese scholars in the field of carbon emissions continue to escalate.

In summary, CE research in China has made significant strides over the past two decades. China has emerged as a key participant in the global field of CE research, providing crucial support in addressing climate change challenges.

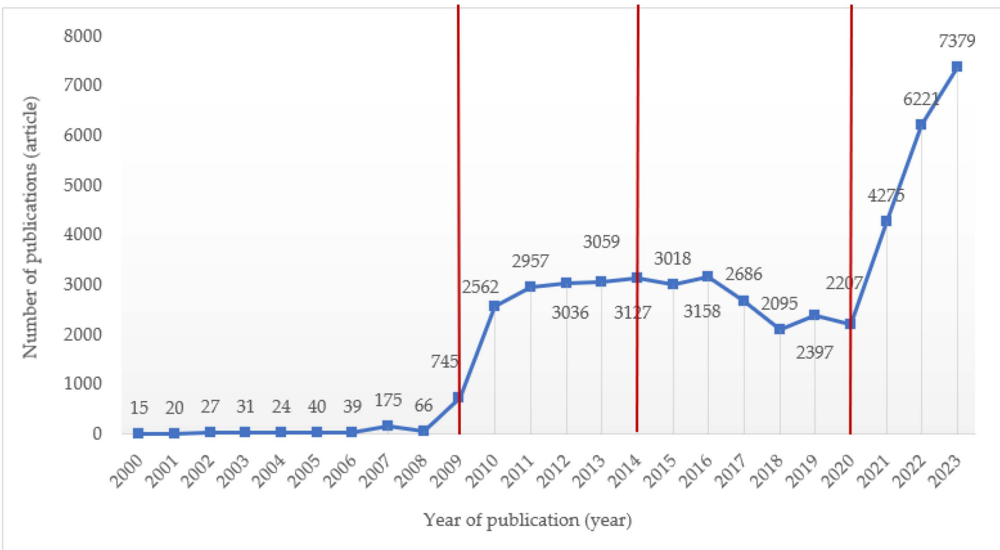

Figure 2. Number of CE research papers published by Chinese scholars in Chinese journals from 1 January 2000 to 31 December 2023.

3.1.2. Analysis of Journal Level

Utilizing the Journal Citation Reports (JCR) tool, we analyzed the impact factors of papers authored by Chinese scholars on carbon emissions. JCR employs statistical computations based on citation data among journals, categorizing them into different quartiles (Q1, Q2, Q3, Q4) according to their citation performance. A higher impact factor indicates increased citation rates for the articles within, signifying the influence of the research outcomes reported, and also underscores the elevated scholarly standing of the respective journal.

Among the 12,721 carbon emission-related papers published by Chinese scholars, contributions to Q1, Q2, Q3, and Q4 journals amounted to 4501, 2936, 4555, and 729, respectively. Notably, articles featured in Q1 journals constitute 35% of the total sample. The top-ranking Q1 journals include the *Journal of Cleaner Production, Applied Energy, and Energy*, highlighting the substantial quality and impact of Chinese scholars' research achievements in the field of carbon emissions. This underscores their significant contributions to advancing the domain of carbon emissions.

3.1.3. Analysis of Keywords

Keywords serve as the essence of a paper, encapsulating its core perspectives and providing a high-level summary. Leveraging the CiteSpace tool, this paper utilizes the generated keyword co-occurrence network (illustrated in Figure 3) and keyword timeline graph (illustrated in Figure 4) to systematically delineate the research themes and evolutionary trends in China's CE studies over the past two decades.

The keyword co-occurrence network comprises 674 nodes interconnected by 2424 links. Noteworthy keywords such as "carbon emissions", "carbon peaking", "energy consumption", "intensity", and "dynamics" are associated with research on CE computation and prediction. Keywords including "economic growth", "impact", "policy", "urbanization", "international trade", "decomposition analysis", foreign direct investment", "innovation", "driving forces", and "industrial structure" are linked to studies on the influencing factors of carbon emissions. Keywords like "carbon footprint" and "supply chain" are intertwined with research on carbon footprints. Meanwhile, keywords such as "efficiency", "energy efficiency", and "environmental efficiency " are tied to studies on CEE. Lastly, keywords including "China", "industry", "regional differences", "sector", "country", and "city" are associated with research on the differential analysis of carbon emissions.

In summary, through a keyword analysis of the research outcomes by Chinese scholars on carbon emissions, this paper categorizes the research themes into the following five points: CE computation and prediction, influencing factors of carbon emissions, carbon footprint, CEE, and differential analysis of carbon emissions.

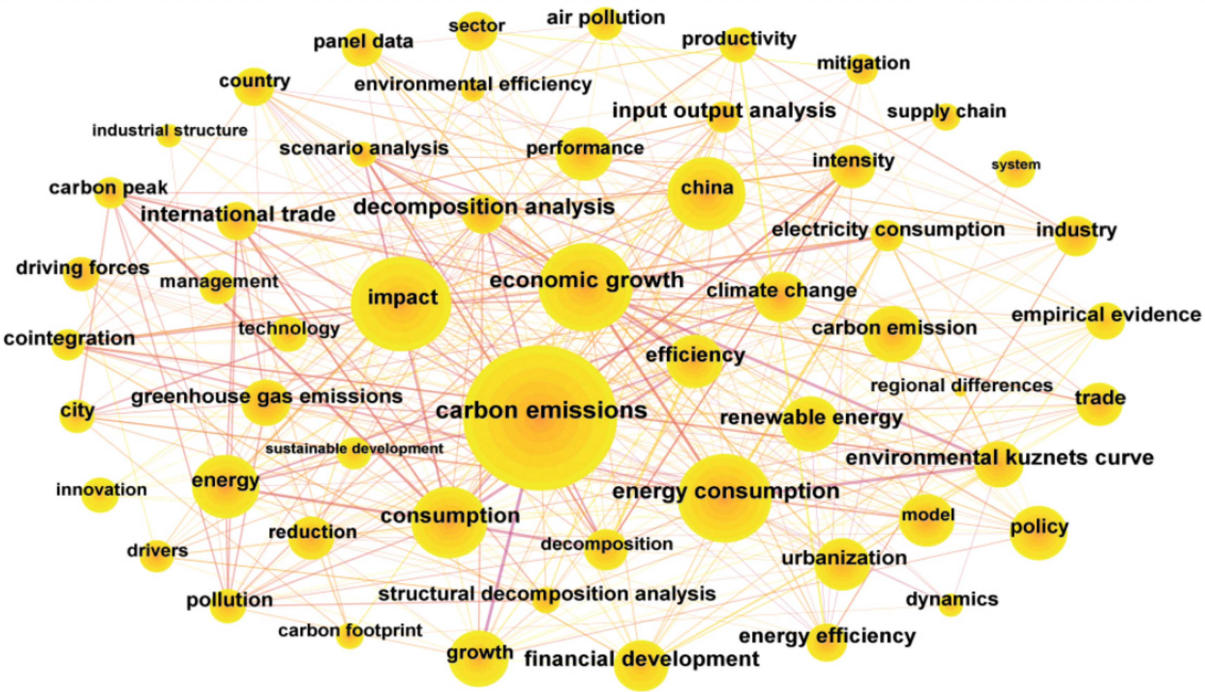

Figure 3. The keyword co-occurrence network of China's carbon emission research papers.

As depicted in the keyword timeline graph, research on carbon emissions in China commenced with the calculation of carbon emissions, and the study of factors influencing carbon emissions has been a continuous thread throughout. In the interim, topics such as carbon footprint, CEE, CE prediction, and differential analysis gradually evolved into focal research points.

Firstly, from 2003 to 2007, Chinese scholars conducted a significant amount of CE estimation research to comprehend the current state of carbon emissions. Key terms included "carbon emissions", "energy consumption", "intensity", and others. Secondly, in pursuit of establishing carbon reduction pathways, Chinese scholars persisted in researching the factors influencing carbon emissions. This evolved from early research (2006–2010) focused on economic growth, decomposition analysis, international trade, and impact to mid-term studies (2011–2016) addressing technology, driving forces, management, carbon tax, financial development, environmental regulation, and innovation, and later studies (2017–present) exploring trade openness, renewable energy consumption, technological progress, globalization, green innovation, green finance, green credit, the digital economy, and others. Research on CE forecasting commenced in 2007 but has not received attention until recently. Following the Chinese government's commitment in 2016 to achieve carbon peaking by 2030, Chinese scholars have conducted a considerable amount of empirical research on CE forecasting. Relevant keywords include "carbon peak", "dynamics", and others. Since 2005, CEE has gradually become a focus of Chinese scholars, with keywords such as "energy efficiency", "efficiency", "data envelopment analysis", "environmental efficiency", and others. Additionally, from 2013 onward, carbon footprint research has gradually attracted the attention of Chinese scholars, with keywords like "carbon footprint" and "supply chain", among others. However, in recent years, research on carbon footprints has gradually decreased. Finally, after 2009, to understand regional and industry-specific CE characteristics, Chinese scholars have gradually turned their attention to CE differential analysis. Relevant keywords include "industry", "city", "panel data", "sector", "regional differences", and others.

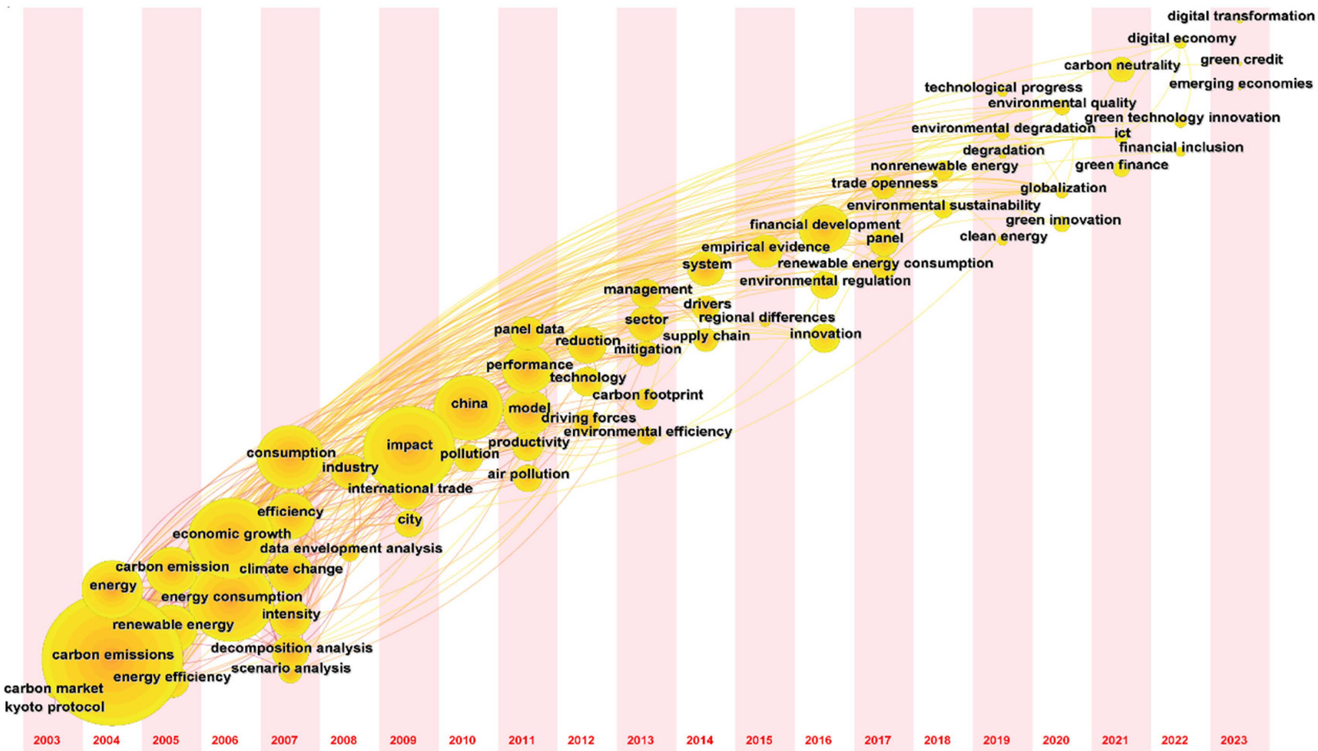

Figure 4. The keyword timeline graph of China's carbon emission research papers.

3.2. Review of Research Results on Carbon Emission Calculations and Predictions

3.2.1. Review of Research Results on Carbon Emission Calculations

Chinese scholars have extensively calculated carbon emissions for different regions and industries. Notably, scholars such as Xu [5], Shao [6], Han [7], Wang [8], Fan [9], and others have individually computed carbon emissions for entities like China, Beijing, industrial sectors, agriculture, and the transportation industry. Research indicates that Chinese scholars employ various methods for calculating carbon emissions, including the energy consumption method [10], life cycle assessments (LCAs) [11], and the input–output method [12]. A comparative evaluation of the results obtained from these methods is presented in Table 1.

Over the past few decades, Chinese scholars have made significant strides in CE computation, yet they are still confronted with several challenges. Firstly, Chinese scholars often adopt a single method for calculating carbon emissions, with limited comparative studies across different methodologies. Secondly, the determination of CE sources within industries is not comprehensive. Existing research tends to focus on certain pre-production and production stages, overlooking calculations for post-production activities such as transportation, storage, and processing. Lastly, the absence of systematic research on regional and industry-specific CE boundaries leads to overlaps and deviations in the computation of carbon emissions.

Table 1. Comparative analysis of CE calculation methods.

Method	Advantages	Disadvantages
Energy consumption method [10]	The method of energy consumption allows for a flexible selection of suitable indicators based on specific circumstances.	If there is bias in the data source, this approach may result in significant errors in the final calculation of carbon emissions.
Life cycle assessment [11]	The life cycle method allows for a detailed analysis of each stage in the production process when calculating carbon emissions, avoiding omissions. It is an objective and quantifiable metric that mitigates subjective biases.	In sectors with numerous production stages, this method suffers from drawbacks such as high computational workload and a propensity for omissions.
Input–output method [12]	The input–output method enables the estimation of implicit carbon emissions and provides a convenient way to calculate the carbon emissions of multiple industries.	This method is characterized by a relatively weak level of precision in its calculations.

3.2.2. Review of Research Results on Carbon Emission Prediction

Chinese scholars have extensively researched CE prediction using various forecasting models tailored to different research objectives. The research outcomes can be broadly categorized into two main types. First, efforts have been directed toward refining CE prediction models to enhance the precision of forecasts. Second, studies have focused on predicting carbon emissions for specific regions or industries, aiming to discern trends in the development of carbon emissions and subsequently formulate strategies for carbon reduction.

In the domain of model improvement, Fang et al. proposed an improved particle swarm optimization (PSO) algorithm-based Gaussian process regression method. This approach effectively optimizes the hyperparameters of the covariance function in Gaussian process regression [13]. Ma et al. introduced a mixed CE prediction model based on multi-factor identification, specifically utilizing a firefly algorithm-optimized multivariate gray model [14]. For the application of CE prediction, Sun et al. employed the IPAT model to design 48 scenarios for forecasting China's carbon emissions. Based on the forecast results, they formulated developmental paths that could lead to carbon peaking by 2030 [15]. Li et al. predicted CE trends in the Chinese construction industry, revealing that the industry is projected to reach its carbon peak in 2045 [16]. Additionally, Cheng [17], Ma [18], Su [19], and others conducted CE prediction studies for Jiangsu Province, the Chinese tourism industry, and the manufacturing sector, respectively.

In summary, Chinese scholars have explored various methods for CE prediction. However, the theoretical foundations and supporting assumptions of different modeling approaches differ, leading to divergent prediction results. Furthermore, the focus of Chinese scholars on CE prediction research has primarily been at the macro-level, encompassing national, provincial, and industrial scales, with relatively fewer studies conducted at the micro-level, such as in the case of parks and individual enterprises.

3.3. Review of Research Results on Factors Influencing Carbon Emission

3.3.1. Review of Research Methods for Influencing Factors

A thorough analysis of the influencing factors of carbon emissions contributes to a more comprehensive understanding of the mechanisms behind CE growth or reduction. This understanding is crucial for the formulation of precise carbon reduction measures. Chinese scholars have employed various models for the analysis of factors influencing carbon emissions, including factor decomposition [20], the STIRPAT model [21], the environmental Kuznets curve [22], correlation coefficient analysis [23], regression analysis [24], causal analysis [25], and Computable General Equilibrium (CGE) models [26]. An evaluation of each method is summarized in Table 2.

Table 2. Evaluation of research methods for influencing factors of carbon emissions.

Method/Model	Model Evaluation
Factor decomposition method [20]	Factor decomposition methods are widely employed in research on the influencing factors of carbon emissions, with the Kaya Identity and the Logarithmic Mean Divisia Index (LMDI) models being extensively used.
STIRPAT model [21]	The STIRPAT model, an optimization of the IPAT model, is effective for analyzing the influencing factors of carbon emissions under different scenarios.
Kuznets curve [22]	The environmental Kuznets curve (EKC) model is commonly used to study the relationship between carbon emissions and economic growth.
Correlation coefficient analysis method [23]	Correlation coefficient analysis allows for a qualitative and quantitative analysis of the correlation between any influencing factor and carbon emissions, though it can only analyze the relationship between one factor and carbon emissions at a time.
Regression analysis method [24]	Regression analysis can establish regression models between carbon emissions and multiple factors, enabling a qualitative and quantitative analysis. However, severe multicollinearity issues often exist among the factors, and methods to eliminate multicollinearity are challenging to implement effectively.
Causal analysis method [25]	Granger causality testing is a common method for causal analysis, providing qualitative insights into the causal relationships between indicators. However, it lacks the capability for quantitative analysis.
Computable General Equilibrium model [26]	Computable General Equilibrium models are primarily used to analyze the impact of environmental taxes, such as carbon taxes and energy taxes, on carbon emissions.

3.3.2. Review of Influencing Factors

Chinese scholars have conducted numerous empirical studies from multiple perspectives on the influencing factors of carbon emissions. This paper categorizes the influencing factors proposed by Chinese scholars into five major classes: economy, population, energy, policy, and others. The specific influencing factors are outlined in Table 3.

Table 3. Classification of CE-influencing factors.

Category	Influencing Factors
Economy	Economic growth, industrial structure, foreign direct investment, international trade, insurance, green finance, industrial clustering, digital economy
Population	Population structure, population growth, population aging, population mobility, standard of living, education level, fertility rate, consumption level
Energy	Energy structure, energy efficiency, energy investment, energy supply chain, household energy consumption, energy prices
Policy	Carbon tax, carbon emission trading, Paris Agreement, GDP assessment, resource tax, clean energy support policies, environmental regulations
Others	Technological level, level of urbanization, climate conditions, public transportation, employment rate, level of road infrastructure, crime rate

In economic studies, Chinese scholars have delved extensively into the theoretical underpinnings and empirical analyses concerning the intricate relationship between the economy and carbon emissions. Notable contributions include Zhang's exploration of economic growth [27], Zhou's investigation into industrial structure [28], Raihan's scrutiny of foreign direct investment (FDI) [29], Wang's examination of international trade [30], Jiang's insights into the insurance sector [31], Liu's focus on industrial agglomeration [32], and Ma's exploration of the digital economy [33], spanning across various economic domains. The research outcomes underscore the dependence of numerous economic activities on fossil fuels and other high-carbon energy sources, leading to an escalation in carbon emissions. However, carbon emissions reciprocally impact economic development, as excessive emissions can induce climate change and environmental issues, adversely affecting the economy. Divergent impacts on carbon emissions emanate from different economic perspectives, potentially fostering an escalation or reduction in carbon emissions. The detailed findings are elucidated in Table 4.

Table 4. The primary conclusions of CE studies' influencing factors from an economic perspective.

Influencing Factors	Primary Conclusions
Economic growth	The impact of economic growth on carbon emissions is intricate, manifesting regional, sectoral, and developmental characteristics. Developed regions typically achieve low-carbon economic growth, while emerging economies often experience increased carbon emissions alongside growth. Carbon-intensive industries, such as energy and heavy manufacturing, tend to see emissions rise in tandem with GDP growth, whereas the service sector and innovative domains usually contribute to emission reduction. Countries in the early stages of development exhibit high emissions, which gradually decline as they mature, eventually achieving emission reduction. Consequently, formulating emission reduction policies that consider these diversities becomes paramount.
Industrial structure	The structural adjustment towards low-carbon industries and the service sector facilitates carbon emission reduction.
Foreign direct investment	The impact of foreign direct investment (FDI) on carbon emissions is intricate. On the one hand, it can introduce advanced production technologies and management practices, enhancing carbon efficiency to reduce emissions. On the other hand, it might increase product manufacturing, leading to increased resource extraction and energy consumption, thereby elevating carbon emissions. This influence is contingent upon the nature and sector of FDI while also influenced by regional policies, industry characteristics, and production resources.
Trade openness	The impact of trade openness on regional carbon emissions is diverse. In China, trade openness leads to an increase in the production and export of high-carbon-emission goods, thereby amplifying carbon emissions through a transmission effect. However, diversified trade can reduce economic dependence on specific markets, lower risks, and drive industrial upgrading and technological progress, reducing carbon emissions. This underscores that the impact of trade openness on carbon emissions is influenced by multiple factors, such as the type of trade, international markets, and economic structure, triggering varied effects on carbon emissions.
Insurance	The insurance industry provides financial support for carbon reduction projects, reduces investment risks for businesses, and encourages the adoption of carbon reduction measures and the development of clean technologies. Simultaneously, it plays a crucial role in addressing losses caused by climate change and providing compensation and recovery support to affected businesses, thereby helping alleviate the adverse impacts of climate-related risks on enterprises.
Industrial agglomeration	Industrial agglomeration leads to the concentrated use of energy and production materials, thereby increasing carbon emissions. However, industrial agglomeration can reduce transportation carbon emissions by minimizing the transportation of products during production. Additionally, industrial agglomeration can promote technological innovation and the adoption of clean technologies, contributing to a reduction in carbon emissions. There is an inverted "U"-shaped relationship between industrial agglomeration and carbon emissions, with technological innovation playing a crucial role in determining the turning point.
Digital economy	Digital technologies, such as remote work and e-commerce, reduce commuting and retail energy consumption while enhancing energy management and monitoring capabilities. This contributes to a reduction in carbon emissions.

Secondly, Chinese scholars have extensively explored the impact of the population on carbon emissions from various perspectives. This includes Guo's research on population structure [34], Chen's work on population growth [35], Wang's investigation into population aging [36], Wu's analysis of population mobility [37], and Zhang's examination of residents' living standards [38]. The research findings indicate that population is a key factor influencing carbon emissions. On the one hand, it directly affects consumption-related carbon emissions through population structure effects. On the other hand, it indirectly influences production-related carbon emissions through its effects on the economy and energy. Different population perspectives have significant variations in their impact on carbon emissions. Population aging, education level, and income level exhibit negative effects on carbon emissions, while population growth has a positive effect. Population mobility has a dual impact. The specific impact conclusions are outlined in Table 5.

Table 5. The primary conclusions of the study on CE-influencing factors from a population perspective.

Influencing Factors	Primary Conclusions
Population structure	Age, gender, education, and income, among other demographic factors, all impact carbon emissions. The influence of age and gender structures on carbon emissions is primarily due to variations in energy use and consumption among different age groups and genders. Young people play a significant role in carbon emissions, especially in terms of mobility and consumption. Additionally, education level and income play crucial roles, with higher education levels and incomes typically associated with lower carbon emission levels.
Population growth	Population growth typically accompanies an increased demand for products and energy consumption. Moreover, a high population density tends to raise demand for transportation and housing, leading to higher carbon emissions.
Population aging	Population aging tends to decrease carbon emissions. As the population ages, the labor market shrinks, leading to reduced production activities and lower energy consumption, resulting in a decrease in carbon emissions. Elderly populations typically have reduced travel and consumption demands, further contributing to a decline in carbon emissions. Lastly, while population aging may increase the demand for medical services, the impact of the healthcare industry on carbon emissions is relatively small.
Population mobility	Population mobility has a dual impact on carbon emissions. On the one hand, it contributes to reducing carbon emissions as population mobility leads to regional population aging and improvements in knowledge structure. On the other hand, population mobility also triggers regional urbanization and household downsizing, thereby promoting an increase in carbon emissions. The CE impact of population mobility depends on various factors, including the direction of mobility, regional characteristics, and policy measures.
Living standard	Affluent households engage in more consumption and energy usage, resulting in higher carbon emissions associated with a high standard of living. On the flip side, a high standard of living also fosters the adoption of smart home technologies and clean energy, reducing carbon emissions through technological innovation and enhanced resource efficiency.

An in-depth exploration of the impact of energy on carbon emissions has been undertaken by Chinese scholars, including Jiang [39], Zhang [40], Ma [41], Huang [42], and Su [43], among others, from various perspectives such as energy structure, energy efficiency, energy investment, energy supply chain, and household energy consumption. The research outcomes indicate that energy consumption is a direct source of carbon emissions. However, different energy sources and technologies exhibit varying levels of carbon emissions. Therefore, factors related to energy, such as energy structure and energy efficiency, have a significant influence on carbon emissions, as depicted in the detailed impact conclusions in Table 6.

Table 6. The primary conclusions of the study on CE-influencing factors from an energy perspective.

Influencing Factors	Primary Conclusions
energy structure	The research underscores that adjusting the energy structure is an effective approach to reducing carbon emissions, but its effectiveness is subject to the comprehensive impact of various factors. Increasing the proportion of fossil fuels in the energy structure will escalate carbon emissions, while elevating the share of clean energy will reduce carbon emissions.
energy efficiency	Enhancing energy efficiency can significantly reduce carbon emissions, allowing the same amount of energy to be utilized for more production or services. An improvement in energy efficiency has a particularly pronounced impact on carbon emissions in industries, transportation, and construction, fostering a decline in emissions from these sectors.
energy investment	Energy investments can stimulate advancements in energy production technologies, fostering a decline in carbon emissions. Furthermore, such investments can promote the adoption and utilization of clean energy, thereby reducing carbon emissions.

Table 6. *Cont.*

Influencing Factors	Primary Conclusions
energy supply chain	Carbon emissions are significantly influenced by various aspects of the energy supply chain, encompassing production, transportation, and distribution. An efficient supply chain has the potential to diminish energy consumption, reducing carbon emissions through measures such as minimizing transmission losses and transportation energy consumption. Additionally, renewable energy supply chains tend to exhibit lower carbon emissions due to their reduced energy loss, whereas conventional energy supply chains often involve energy waste and high carbon emissions.
household energy consumption	As the fundamental unit of human society, households have surpassed industrial energy demands, becoming a primary force in societal carbon emissions. The impact of energy consumption on carbon emissions varies among households. Single-person households generally exhibit lower emissions, while multi-member households and family-owned enterprises may have higher emissions. Carbon emissions from high-income and elderly households differ due to their resources and lifestyles. Furthermore, the relationship between household energy consumption and regional carbon emissions follows a reversed "U"-shaped curve.

Researchers such as Ding [44], Zhang [45], Chen [46], Yang [47], Hu [48], and others have extensively analyzed the impact of government policies on carbon emissions, focusing on perspectives such as carbon tax, CE trading, the Paris Agreement, GDP assessment, and resource tax. The research outcomes indicate that the government can influence carbon reduction through incentive measures and economic tools. However, the implementation of development and reform policies by the government may lead to an increase in carbon emissions. The detailed impact conclusions are outlined in Table 7.

Table 7. The primary conclusions of the study on CE-influencing factors from a policy perspective.

Influencing Factors	Primary Conclusions
Carbon tax	The carbon tax policy is a crucial pathway for reducing carbon emissions. This policy reduces carbon emissions by promoting clean energy use, incentivizing energy-saving practices for businesses, and fostering the development of environmental industries and clean technologies. Additionally, the carbon tax policy provides financial support to the government for projects related to carbon reduction and climate improvement.
CE trading policies	The impact of CE trading policies varies across different regions, industries, and enterprises. This type of policy has significantly reduced carbon emissions in the eastern part of China, but its effectiveness in the central and western regions remains unclear. CE trading policies have a notable effect on carbon emissions in the secondary industry, while their impact on the service industry is relatively minor. Furthermore, high-emission enterprises demonstrate a significant reduction in emissions under this policy, whereas moderately polluting enterprises show a smaller impact.
Paris Agreement	The Paris Agreement has facilitated a reduction in China's carbon emissions. The international commitments outlined in the agreement have motivated the Chinese government to adopt more proactive carbon reduction policies. These policies include strengthening the construction of carbon markets, improving energy efficiency, and promoting clean energy to achieve a carbon emission peak and strive for carbon neutrality earlier. Additionally, the Paris Agreement encourages international cooperation, fostering technology transfer and the research and application of clean technologies, further contributing to reducing carbon emissions.
GDP assessment policy	The GDP assessment policy exacerbates the growth of carbon emissions. Local governments, driven by the pursuit of higher GDP growth, may prioritize the development of energy-intensive and high-carbon-emission industries, neglecting the importance of carbon reduction. Additionally, by relying solely on GDP as a benchmark, governments may lack the motivation or interest to implement environmental measures or invest in the research and development of green technologies.
Resource tax	The resource tax policy can effectively promote a reduction in carbon emissions. Taxing resources with high carbon emissions encourages businesses to decrease their use of these resources, thereby cutting down on carbon emissions. Furthermore, the impact of the resource tax policy on carbon emissions varies across different industries and regions. For highly carbon-intensive industries, the resource tax may significantly reduce their carbon emissions. In industries or regions with lower carbon emissions, the impact of the resource tax may be comparatively minor.

The fifth aspect delves into the profound exploration by Chinese scholars of additional factors influencing carbon emissions. These encompass Li's examination of the technological level [49], Xu's scrutiny of urbanization [50], Shao's analysis of employment rates [51], and Li's assessment of public transportation levels [52]. The research findings show that technological proficiency, urbanization, employment rates, and public transportation levels all have a dual impact on carbon emissions, manifesting different emission effects under the influence of regional circumstances. The specific research conclusions are detailed in Table 8.

Table 8. The primary conclusions of the study on CE-influencing factors from other perspectives.

Influencing Factors	Primary Conclusions
Technological level	The technological level exerts a dual impact on carbon emissions. The adoption and advancement of advanced clean technologies, as well as the promotion of enhanced energy efficiency, can effectively reduce carbon emissions. However, the widespread utilization and development of modern technologies may lead to increased carbon-intensive production and consumption, as observed in electronic devices and electric vehicles, thereby contributing to higher carbon emissions.
Urbanization	The relationship between urbanization and carbon emissions depends on the developmental stage of a country or region and its urban planning strategies. In regions with lower levels of development, urbanization may predominantly lead to an increase in carbon emissions. Conversely, in developed countries or areas implementing sustainable urban planning, urbanization is typically associated with a decrease in carbon emissions.
Employment rates	The relationship between employment rates and carbon emissions varies depending on the region and industry. In different countries or regions, the connection between employment rates and carbon emissions may differ due to policy variations, industrial structures, and energy sources. In high-income countries, a high employment rate is often associated with lower carbon emissions because these countries are more inclined to adopt clean technologies and sustainable production methods.
Public transportation level	An efficient public transportation network can encourage citizens to reduce their use of private cars, thereby reducing carbon emissions from transportation. However, the CE impact of public transportation is influenced by the region and the size of the city, with varying contributions to carbon emissions in different regions and cities.

Chinese scholars have made significant contributions to the field of CE factors. They have employed diverse analytical methods, expanded their research from single countries or regions to multi-regional comparative development, and continually enriched the factors under investigation. However, there are still several limitations. Firstly, the examined factors mainly include macro factors such as the economy, population, energy, and policies, with less consideration for micro factors like lifestyle and transportation and their impact on carbon emissions. Secondly, the focus has been primarily on national, provincial, and municipal levels, with relatively fewer studies at the micro-level, such as industrial parks, enterprises, or households. Additionally, in the study of CE factors in specific industries, it is essential to consider industry-specific factors that may influence carbon emissions in that sector. For example, in the transportation industry, factors like road congestion could be crucial. Lastly, many existing findings are based on computational models that analyze the impact of individual factors on carbon emissions, lacking an analysis of the combined effects of several factors.

3.4. Review of Research Results on Carbon Footprints

3.4.1. Review of Research Results on the Definition of Carbon Footprint

The concept of a carbon footprint originated from the ecological footprint proposed by Wack in 1996 [53]. Although Chinese scholars have conducted numerous studies on the definition of the carbon footprint, a consensus has not yet been reached, and there are three mainstream viewpoints. First, some scholars consider the carbon footprint to be the carbon emissions generated from burning fossil fuels during human activities [54]. Second, others define the carbon footprint as the CO_2 and other greenhouse gas emissions, measuring the total emissions throughout the entire lifecycle, including raw material acquisition and the production, distribution, use, and recycling of a product [55]. Third, some scholars emphasize that the key to the concept of a carbon footprint lies in measuring direct and indirect CO_2 conversions as a standard to quantify the impact of human activities on climate change [56]. In summary, there is controversy among Chinese scholars regarding the definition of the carbon footprint, especially concerning the measurement of greenhouse gas types and carbon boundaries.

3.4.2. Review of Research Results on Carbon Footprint Calculation

Chinese scholars primarily research carbon footprint calculation methods based on the principles of life cycle assessment. The research results can be categorized into two main types: process analysis and input–output analysis. On the one hand, scholars such as Wang [57], Qi [58], and Li [59] utilized a process analysis to calculate the carbon footprint of corn production, steel enterprises, and textiles, respectively. On the other hand, researchers like Zhen [60], Liang [61], and Fan [62] applied an input–output analysis to calculate the carbon footprint of the Yellow River basin, provinces, and industries in China.

Among the existing carbon footprint analysis methods, the process analysis method provides a relatively accurate research scale but struggles to avoid truncation errors arising from delineating system boundaries. Consequently, it faces difficulties in studying entities at the micro- and macro-levels. On the contrary, the input–output method relies on data primarily derived from average CE data, and its inseparable system boundaries prevent it from effectively describing carbon footprints at various stages. As a result, it cannot facilitate efficient micro-level research.

3.4.3. Review of Research Results on Carbon Footprint Applications

The characteristics of a carbon footprint vary across different study subjects. Chinese scholars have conducted numerous empirical studies on carbon footprints, examining products, individuals, households, businesses, projects, and services.

In product-focused carbon footprint research, the findings reveal significant disparities in carbon emissions among different products. These variations are primarily influenced by production, transportation, usage, and disposal processes. Some Chinese researchers have noted that food and beverages often exhibit high carbon footprints, whereas vegetables and plant-based food items tend to have lower carbon footprints [63]. Furthermore, the manufacturing and utilization of electronic products contribute substantially to carbon emissions, underscoring the importance of encouraging sustainable production and recycling practices [64]. Lastly, reducing carbon footprints is notably facilitated by adopting renewable energy sources, high-efficiency insulation materials in construction, and the widespread use of electric vehicles [65].

In individual-focused carbon footprint research, the findings indicate that personal choices regarding transportation, food consumption, energy usage, and shopping behaviors have a significant impact on carbon footprints. Chinese scholars have observed that utilizing public transportation, reducing meat consumption, adopting energy-saving measures, and purchasing sustainable products can effectively lower an individual's carbon footprint [66,67]. Additionally, some studies have also shown that factors such as educational level [68], socio-economic status [69], and geographic location [70] play a role in influencing an individual's carbon footprint.

Thirdly, research focusing on households as the subject of carbon footprints reveals that a household's carbon footprint is significantly influenced by factors such as household size, living area, transportation mode, heating and cooling methods, food purchases, and the source of electricity [71]. Some studies further indicate that strategies to reduce households' carbon footprints include improvements in energy efficiency, the adoption of renewable energy sources, waste reduction, sustainable improvements in food purchasing choices, and the adoption of sustainable transportation methods [72].

Fourthly, research focusing on enterprises as the subject of carbon footprints reveals that the carbon emissions of a business depend on factors such as its industry, production processes, supply chain, and energy usage. Some Chinese scholars have found that businesses can reduce their carbon footprint by improving energy efficiency, adopting clean energy sources, reducing logistics-related carbon emissions, and implementing carbon reduction measures [73]. Additionally, some studies suggest that social responsibility and principles of sustainable operation play a crucial role in business decisions related to emission reduction [74].

Fifthly, research focusing on specific projects as the subject of carbon footprints demonstrates that using green building materials, energy efficiency improvements, and the utilization of renewable energy can significantly reduce the carbon emissions of construction projects [75]. Some Chinese scholars have also discovered that using renewable energy, improving transportation efficiency, and enhancing transport management can reduce the carbon footprint of transportation projects [76]. Moreover, the carbon footprint of manufacturing projects is significantly influenced by production processes, energy usage, and the choice of raw materials [77].

Sixthly, research focusing on services as the subject of carbon footprints indicates that significant reductions in carbon footprints can be achieved in catering services by selecting local ingredients, reducing food waste, improving supply chain management, and enhancing food storage efficiency [78]. Hotels and tourism services can reduce their carbon footprint through energy efficiency improvements and measures to decrease the use of disposable items. Additionally, tourists opting for sustainable travel methods and low-carbon activities contribute to CE reduction [79]. The carbon footprint of healthcare services is associated with energy usage, waste management, and the selection of medical equipment [80]. The carbon footprint of retail and e-commerce services is linked to supply chain management, packaging choices, and decisions related to logistics and warehousing [81].

In summary, Chinese scholars have conducted extensive theoretical research and empirical analyses in the field of carbon footprints. However, challenges such as cross-boundary calculations, comprehensive effects, and policy applications need to be overcome. Firstly, with the development of globalization, the boundaries of carbon footprints have become blurred due to multinational companies and international supply chains, making the calculation and management of cross-boundary carbon footprints more complex. Secondly, existing carbon footprint studies often focus on the impact of individual factors, lacking a comprehensive analysis of the combined effects of multiple factors. Finally, although there are many studies on how to reduce carbon footprints, applying these studies to policies and practices still poses challenges.

3.5. Review of Research Results on Carbon Emission Efficiency

3.5.1. Review of Research Results on the Definition of Carbon Emission Efficiency

Chinese scholars have yet to reach a consensus on the definition of CEE, which is divided into narrow CEE and broad CEE. Narrow CEE primarily refers to CEE within the traditional single-factor framework, expressed as the ratio of total carbon emissions to a single factor [82]. Examples include carbon emissions per unit of GDP, carbon emissions per unit of energy consumption, and per capita carbon emissions per unit of GDP. Broad CEE refers to CEE within the overall factor framework, calculated based on the input–output indicator system [83]. Existing research results indicate that narrow CEE is often too direct and one-sided. For instance, defining CEE as carbon emissions per unit of GDP tends to favor developed countries. Therefore, broad CEE is increasingly gaining recognition among scholars.

3.5.2. Review of Research Results on Carbon Emission Efficiency Calculation

Chinese scholars have conducted extensive empirical research on broad CEE at regional and industrial levels using methods such as Data Envelopment Analysis (DEA) [84], CE weighting [85], and the Malmquist Carbon Efficiency Index [86]. The research scope includes countries [87], urban clusters [88], cities [89], industries [90], manufacturing [91], aviation [92], and more. The calculation method for narrow CEE is the use of the carbon production efficiency index, with countries being the primary research focus [93].

Different methods are suitable for different research objectives. DEA and CE weighting are applicable for assessing relative efficiency, aiding in identifying inefficient units and industries. However, DEA can only provide a relative efficiency assessment and cannot measure the absolute efficiency of units. The Malmquist Carbon Efficiency Index can evaluate the evolution of CEE. The carbon production efficiency index provides a unit carbon emission measure suitable for tracking absolute efficiency at the unit level. In practical applications, researchers and policymakers need to consider the strengths and weaknesses of different methods and choose the one that aligns with their research goals and data availability.

3.5.3. Review of Research Results on Carbon Emission Efficiency Applications

Different regions or industries exhibit significant differences in CEE levels, and Chinese scholars have delved into the factors influencing CEE. Firstly, in research on factors affecting regional CEE, Zhan et al. found that developed regions generally exhibit higher efficiency [94]. Zhou et al. discovered that industrial structure is also a crucial factor, with regions having a higher proportion of clean industries typically achieving more effective emission reduction [95]. Dong et al. found that energy structure and technological level play a critical role, as the use of clean energy and efficient technologies can enhance regional CEE [96]. Li et al. observed that higher levels of urbanization are typically associated with higher CEE [97]. Liu et al. found that the support of local policies and regulations also has a significant impact on regional CEE [98].

Secondly, in research on factors influencing industry CEE, Dan et al. found that asset structure and asset utilization efficiency play a crucial role across different industries, influencing production and investment decisions [99]. Li et al. identified transportation as another influencing factor with significant impacts on production and CEE across different industries, each affected differently [100]. Finally, Du [101], Yi [102], Li [103], and others discovered that spatial agglomeration, management level, and energy structure, respectively, have important effects on the CEE of the construction industry, logistics industry, and manufacturing industry.

Finally, Chinese scholars have further investigated the changing patterns of CEE from a spatiotemporal evolution perspective. Research findings from Ding [104], Chen [105], and others all indicate significant variations in CEE across different regions, industries, and time periods. Gao et al. found that the CEE of industries has gradually improved over time, attributed to technological progress and policy interventions [106]. Zhong et al. observed significant differences in the trends of CEE changes across different regions, influenced by regional characteristics, resource supply, and policy support [107].

In conclusion, Chinese scholars have made significant progress in the field of CEE, yet they still face several challenges. There is a relatively limited amount of research at the micro-level, and expanding studies to the micro-level could provide more detailed and specific insights. Additionally, improvements in CEE may have positive spatial spillover effects on neighboring regions. Further research is needed to understand the impacts of these spatial spillover effects. Finally, studies on CEE need to consider the complexity of time and space, as there are substantial differences across regions and periods. This complexity emphasizes the need for greater attention to the breadth and depth of research on CEE.

3.6. Review of Research Results on Carbon Emission Differences Analysis

3.6.1. Review of Research Results on Carbon Emission Difference Analysis Methods

Chinese scholars employ two primary methods for the analysis of CE differentials: the comparative analysis method and the coefficient of variation analysis method. The comparative analysis method involves scrutinizing disparities in carbon emission levels among distinct regions, industries, products, or periods [108]. The coefficient of variation analysis method utilizes statistical indicators such as the Gini coefficient [109], Theil index [110], spatial difference method [111], etc., to quantify and compare CE disparities across diverse entities. Comparative analysis stands out as an intuitive and versatile approach, swiftly revealing CE differences among research subjects but lacking in-depth interpretation. Conversely, the coefficient of variation analysis offers a more refined measurement sensitive to data variability. Hence, a comparative analysis proves suitable for preliminary screening, facilitating an understanding of differences. On the other hand, a coefficient of variation analysis is better suited for quantitatively measuring the degree of differences. However, caution is warranted concerning its sensitivity to outliers and uneven data distributions.

3.6.2. Review of Research Results on Carbon Emission Difference Analysis Applications

Based on the research dimensions, Chinese scholars' research on CE disparities can be categorized into regional, industrial, and temporal.

Firstly, studies reveal significant variations in carbon emission levels among different types of regions. Some research suggests that resource-rich regions typically exhibit higher carbon emissions, while innovative and financial regions tend to have relatively lower carbon emissions [112]. Moreover, the impact of the same influencing factors on carbon emissions varies across different regions. For instance, Chinese scholars such as Niu [113], Zhou [114], and Zhang [115] separately investigated the influence of economic levels, population, and industrial structure on carbon emissions in different regions.

Secondly, research indicates significant disparities in CE levels among different industries. Carbon-intensive industries such as heavy industry, energy, and transportation typically exhibit high carbon emissions, while service industries like information technology, finance, and healthcare tend to emit fewer carbon emissions [116]. The influencing factors on carbon emissions vary across different industries. Carbon-intensive industries are significantly influenced by factors such as industrial structure, energy consumption intensity, and technological levels [117]. Service industries are more prone to reducing carbon emissions through digitization and efficient energy use [118]. Some studies also address the carbon reduction potential in different industries, highlighting the ongoing challenges in industrial carbon reduction [119] and noting potential increases in carbon emissions in the tourism industry due to increased tourist flows [120].

Lastly, research indicates significant disparities in CE levels across different periods. Early developmental stages are typically associated with high carbon emissions, while carbon emissions tend to decrease in later stages of societal development. This suggests a non-linear relationship, resembling an inverted U-shape, between development stages and CE levels [121]. The influencing factors for carbon emissions also vary across different time periods. In the early stages, energy-intensive industries and infrastructure development have a substantial impact on carbon emissions. In the middle stages, technological innovation and industrial upgrades come into play, increasing the potential for emission reduction. In the later stages, government policies and energy transitions play a crucial role in controlling carbon emissions [122]. Some studies emphasize the critical role of policies and governance. In the early developmental stages, government policies may lean towards economic growth, but in the middle and later stages, they tend to focus more on emission reduction measures. Adjustments and policy initiatives are instrumental in shaping the trends of carbon emissions across different time periods [123].

In conclusion, Chinese scholars have conducted extensive theoretical research and empirical analyses on the issue of CE differentials. However, they still face several challenges. Firstly, the existing research lacks a comprehensive tracking study of CE differentials, with an insufficient comparison of disparities and trends in carbon emissions across different regions and industries. Secondly, Chinese scholars' analysis of regional CE differentials is primarily focused on the meso-scale, including provincial and city levels, with relatively fewer studies on differentials at the national level.

4. Conclusions and Prospects

4.1. Conclusions

This article provides a summary of the research themes and evolving trends in the field of carbon emissions studied by Chinese scholars. The research on carbon emissions by Chinese scholars has evolved through five major themes, starting with the calculation of carbon emissions, and research on the influencing factors of carbon emissions runs through the entire process. CEE, carbon footprints, CE prediction, and differential analysis have gradually become research topics. By reviewing the relevant literature on each CE theme, this article compiles the research achievements and shortcomings of Chinese scholars in the field of carbon emissions. Based on the challenges faced by Chinese scholars in each theme of carbon emission research, this article puts forth the following six recommendations.

In the calculation of carbon emissions, Chinese scholars should conduct more comparative studies to evaluate different methods for CE calculations. This aims to determine the most accurate and applicable methods, thus establishing more scientifically grounded standards for CE calculations. Additionally, research efforts should expand the scope of calculations, particularly focusing on post-production processes such as transportation, storage, and processing. This expansion ensures comprehensive and accurate calculations. Finally, it is recommended that clear boundaries for regional and industrial carbon emissions be established to avoid double counting and overlap. Achieving this requires interdisciplinary research and collaboration with governmental agencies.

Regarding CE predictions, Chinese scholars should tailor their choice of predictive models to the characteristics of their study objects and continuously optimize them to ensure the reliability of their prediction results. Furthermore, there is a need to enhance research at the micro-level, including CE analysis at the level of industrial parks and individual enterprises. This approach allows for a more detailed understanding of emission sources and mitigation opportunities, providing finer guidance. Lastly, attention should be given to the sustainability of supporting assumptions and the reliability of data, ensuring the scientific validity and verifiability of models and methods.

In the realm of CE-influencing factors, Chinese scholars need to pay more attention to micro-level factors such as lifestyle and the number of motor vehicles. This approach allows for a deeper understanding of the micro-mechanisms behind carbon emissions. Secondly, there is a necessity to broaden the research scope, with a specific focus on micro-level entities such as industrial parks, enterprises, and households. This expansion would facilitate a comprehensive understanding of the contributions of different levels to carbon emissions. Furthermore, in studying industry-specific CE factors, it is crucial to consider the unique factors associated with specific industries. Lastly, research efforts could explore the combined effects of multiple factors rather than relying solely on single-factor analysis.

In the context of carbon footprint research, Chinese scholars should emphasize the exploration of methods for calculating and managing cross-boundary carbon footprints. This approach contributes to a better understanding and reduction in carbon footprints within global supply chains. Secondly, there is a need for more comprehensive effects studies to understand the combined impact of multiple factors on carbon footprints. Finally, future research should highlight policy applications, establishing a bridge that connects scientific research with policy formulation and implementation.

In the realm of CEE, Chinese scholars should enhance their focus on the micro-level, including entities such as enterprises, industrial parks, and households. Additionally, researchers should delve deeper into exploring the positive spatial spillover effects that improvements in CEE might have on neighboring regions. This would provide more comprehensive support for transnational and international carbon reduction policies. Lastly, it is essential to emphasize both the breadth and depth of CEE research to gain a more comprehensive and accurate understanding of the evolution of CEE.

Regarding CE differential analysis, Chinese scholars should pay attention to the dynamic spatial and temporal changes in CE differentials in the future. Tracking trends in carbon emissions for different regions or industries is crucial. Secondly, there should be a focus on inter-country CE differential analysis, revealing the differences in carbon emissions among different countries and the impact of the international CE division of labor and trade. Lastly, interpreting CE differentials often involves multiple fields, and interdisciplinary research collaboration is encouraged to gain a more comprehensive understanding of these differences.

4.2. Limitations and Future Research Direction

This article exclusively summarizes research themes and evolutionary trends within the domain of carbon emission research as pursued by Chinese scholars. However, it lacks an analysis of carbon emission research themes and trends on a global scale, particularly in developed countries such as the United States, the United Kingdom, Japan, and others. Furthermore, a comparative analysis of the research outcomes in China is notably absent. In the subsequent phase, our team intends to broaden the perspective to encompass the United States and the entire world, meticulously organizing research achievements and trends in carbon emissions. This comparative analysis will serve as a valuable reference for shaping future research directions for carbon emissions in China.

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