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RESEARCH PROGRESS AND PROSPECTS ON CARBON FOOTPRINT

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Transition to sustainable development assumes the necessity to decrease the carbon footprint. The environmental information needed to determine the carbon footprint is insufficient. There are various methods for carbon footprint accounting. Currently, the results of carbon footprint assessments at different scales are mostly based on the analysis of static data, which cannot reflect the future development trend of carbon emissions. This paper focuses on studying the calculation model of carbon footprint to enable the estimation and measurement of environmental pollution costs, including the assessment of the role of factors such as economy, population, technology and policy.

Keywords: carbon footprint; low-carbon economy; environmental cost measurement; carbon footprint model.

ПРОГРЕСС И ПЕРСПЕКТИВЫ ИССЛЕДОВАНИЯ УГЛЕРОДНОГО СЛЕДА

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Переход к устойчивому развитию предполагает необходимость уменьшения углеродного следа. Необходимая для этого информация на современном этапе недостаточна. В литературе рассматриваются различные методы для учета углеродного следа. Большинство оценок углеродного следа на различных уровнях основываются на статистических данных, которые на до конца учитывают будущие тенденции эмиссии углерода. Данная статья сосредоточена на изучении модели оценки углеродного следа для измерения затрат, связанных с загрязнением, включая учет таких факторов, как экономика, население, технологии и политика.

Ключевые слова: углеродный след; низкоуглеродная экономика; измерение экологических издержек; модель углеродного следа.

Introduction

Low-carbon development is widely recognized as an effective model for addressing global warming, energy crises, and environmental protection. As a result, many countries around the world are focusing on taking effective measures to reduce greenhouse gas emissions. The literature on the use of carbon footprint to study carbon emission reduction is relatively extensive, with most studies focusing on changes in the value of carbon footprint and the factors that cause such changes. However, few studies have provided comprehensive reviews of the decomposition model of factors affecting carbon footprint from basic to extended applications. To address this research gap, this paper sorts through classic and recent literature related to carbon footprint, summarizes the research progress, identifies the main influencing factors and the decomposition model of these factors, and proposes future research prospects as well as problems that need to be addressed. The research on carbon footprint accounting and its influencing factors not only expands the research field of carbon footprint but also contributes to regional environmental protection and low-carbon development. Additionally, it has significant academic value for building a theoretical system for carbon footprint. This paper primarily focuses on studying the calculation model of carbon footprint to enable the estimation and measurement of environmental pollution costs, which can establish an effective link between ecological economy and environmental accounting.

A study on the influencing factors of carbon footprint

Economic growth has driven the development of countries, but it has also led to environmental pollution issues, and the conflict between economic growth and the carrying capacity of resources and the environment has become increasingly apparent. The relationship between economic growth and carbon emissions has been examined, and it has been concluded that there is no Environmental Kuznets Curve (EKC) relationship between per capita GDP and CO2 emissions [1]. The factors that influence carbon emission reduction can be further subdivided into population factors, mainly including population size, population structure, and household consumption. Satterthwaite's research [2] shows that population urbanization has a significant impact on carbon emissions, and controlling population growth alone cannot achieve the goal of reducing carbon emissions. Demographic factors are also important factors that affect carbon emissions. In addition to the total population, demographic factors also include population structure, such as the level of urbanization, age composition, and family size. The level of technology can reflect a country or region's resource utilization efficiency, balance between economic development and environmental protection, and is a key driving force for changes in carbon footprint. Moreover, the influencing factors of carbon emission reduction also involve carbon emission reduction policies, which include carbon trading policies and carbon tax policies. Research has shown that government environmental governance policies, such as taxes and forestry investment, can effectively reduce carbon emissions, but the collection of resource taxes has not played an effective restraint role.

A study on the decomposition model of the influencing factors of carbon footprint

To identify the key influencing factors of carbon footprint, a decomposition model is necessary. Decomposition models of the factors affecting carbon footprint can be classified into three categories based on their time frame and related content, as described below.

Kaya Model and IPAT Model

The fundamental models for decomposing the factors affecting carbon footprint include the Kaya model and the IPAT model. The Kaya model, proposed by Kaya at the IPCC seminar in 1989, is formulated as shown in Equation (1):

$$ECO2 = ECO2 / E \times E / GDP \times GDP / P \times P. \quad (1)$$

In Equation (1), *ECO2* represents the total CO2 emissions over a certain period, E represents energy consumption, GDP represents gross domestic product, and P represents the total population during the same period. The IPAT model, proposed by Ehrlich et al. in 1971, is formulated as shown in Equation (2):

$$I = P \times A \times T. \quad (2)$$

The formula (2) represents the IPAT model, where I is the environmental pressure, P is the population, A is the level of economic development, and T is the level of technology.

The Kaya model presents a simple mathematical expression and multiplier decomposition to represent the primary factors that influence carbon emissions, such as economy, policy, and population. The level of economic development and the economies of scale of the population are four macro-factors that impact carbon emissions [3]. However, its decomposition format is sometimes too arbitrary, leading to severe collinearity among the decomposition factors. Additionally, the economic meaning and relevance of the decomposition cannot be guaranteed. On the other hand, the IPAT model is based on population, consumption, and environmental impact [4]. Chen et al. (2013) [5] applied the IPAT model to analyze the factors that affect carbon emission reduction under four carbon dioxide emission scenarios. However, the IPAT model can only reflect proportional changes on both sides of the equation. It employs a constant elastic coefficient that is highly restrictive and cannot be used to analyze specific factors that influence the carbon footprint.

STIRPAT Model

The extended model for decomposing the influencing factors of carbon footprint is mainly the STIRPAT model. To overcome the limitations of the IPAT model, Dietz et al. (1994) [6] proposed a stochastic environmental impact assessment model, i. e. the STIRPAT model, which is a random regression model of the impact of population, economic, and technological changes on the environment. The specific formula for the STIRPAT model is shown in formula (3).

$$I = aPb\ Ac\ Td\ e. \quad (3)$$

In formula (3), *I*, *P*, *A*, and *T* represent environmental pressure, population size, affluence, and technology level, respectively. «*a*» is the model coefficient, «*b*», «*c*» and «*d*» are the indices of each influencing factor, and «*e*» represents model error. The model not only estimates each coefficient as a parameter but also allows for appropriate decomposition of each factor.

Conclusion

The research scope of carbon footprint covers micro, meso, and macro levels, and involves various fields and industries. However, the environmental information provided by carbon footprint is insufficient, and its relevance in formulating climate policies is relatively weak, with a limited research perspective. There are various methods for carbon footprint accounting. Currently, the results of carbon footprint assessments at different scales are mostly based on the analysis of current static data, which cannot reflect the future development trend of carbon emissions, and the obtained results have obvious transient characteristics. The factors affecting carbon footprint are diverse and can be roughly divided into factors such as economy, population, technology, and policy. Due to the large differences in the influencing factors of carbon emissions in various regions, there is relatively little research on the differences in the influencing factors of carbon footprint in special regions. In addition, there are many studies on the direct impact of each influencing factor on a specific area, but less research on related impacts such as spatial correlation. Furthermore, further research is needed to confirm and quantify the environmental pollution cost through the accounting of carbon emissions.

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