The comprehensive impact and mechanism of carbon finance on carbon emission: Evidence from 30 countries and regions

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Abstract

This study presents new evidence of the comprehensive impact of carbon finance on carbon emission by conducting panel data models, including fixed and random effects, to analyze the impact.

Based on Chinese carbon finance data from 2001 to 2020, the empirical results show the following: (1) Carbon finance positively impacts significantly reducing carbon emissions. (2) The impact of carbon finance on carbon emissions is related to regional differences. (3) The impact of carbon finance on carbon emissions differs based on population size thresholds. (4) The impact of carbon finance on carbon emissions differs based on population size thresholds. By considering these practical implications, policymakers, businesses, and stakeholders can better navigate the complexities of carbon finance and develop strategies that contribute significantly to global efforts to mitigate climate change.

Introduction

Climate change has emerged as one of our most significant global challenges, driven primarily by the continuous increase in carbon emissions. Burning fossil fuels and other human activities have led to a substantial rise in greenhouse gas concentrations in the atmosphere, resulting in adverse effects such as rising temperatures, extreme weather events, and ecosystem disruptions. According to the Global Carbon Project, global carbon dioxide (CO2) emissions reached a record high of 37.1 billion metric tons in 2019 (Global Carbon Project, 2020). This alarming trend necessitates urgent actions to mitigate carbon emissions and transition towards a low-carbon future.

How does carbon finance impact carbon emissions? In light of the pressing need for effective solutions to combat climate change, this research aims to investigate the role of carbon finance in influencing carbon emissions. Understanding how carbon finance can effectively contribute to reducing carbon emissions is crucial for informing policy decisions and developing sustainable strategies.

To ensure clarity and consistency throughout this study, defining key terms related to carbon finance is important. Carbon finance refers to financial mechanisms and instruments that aim to internalize the cost of carbon emissions into economic decision-making processes and incentivize emission reductions (UNEP, 2008). It encompasses financial tools and mechanisms enabling the trading, pricing, and investment in projects to reduce greenhouse gas emissions (CDM, 2008). It includes carbon markets, cap-and-trade systems, and financing mechanisms for renewable energy projects (UNEP, 2006).

A comprehensive review of existing literature provides valuable insights into previous research on the impact of carbon finance on the reduction efforts of carbon emissions. Table 1 summarizes key studies that have explored this relationship:

Table 1 Key studies of the relationship between carbon finance and carbon emission

Study	Findings
Smith et al., 2018	Carbon pricing mechanisms can effectively reduce emissions
Zhang and Li, 2019	Carbon finance promotes renewable energy investments
Johnson and Brown, 2020	Financial incentives influence corporate emission reductions
Wang et al., 2021	Carbon trading contributes to global emission reductions

These studies highlight the positive influence of carbon finance on reducing carbon emissions. The positive influence could be divided into two fields: carbon emissions trading and carbon credit.

Carbon emissions trading refers to buying and selling carbon credits in the market. Under this system, companies can sell their carbon credits to other companies that have exceeded their own emissions targets. In this way, companies can offset their carbon emissions by purchasing credits from other companies that have

reduced or avoided emissions. This system provides an economic incentive for companies to reduce their carbon emissions and invest in clean energy and other emission-reduction technologies.

On the other hand, carbon credit is a type of tradeable certificate representing proof that one company has offset its carbon emissions. These credits can be bought and sold in the market and can also be used to meet other companies' emissions reduction obligations. In this way, carbon credit provides a way to transfer the credits of one company to another, allowing companies to reach their emissions reduction goals more efficiently.

However, there is a need for further research to understand the specific mechanisms through which carbon finance impacts emission reduction efforts and to address existing gaps in knowledge.

Despite the existing body of literature on carbon finance and its impact on carbon emissions, certain gaps remain. Previous studies have primarily focused on the effectiveness of specific carbon finance mechanisms or their impact at a macro level. However, there is a lack of comprehensive analysis that examines the nuanced effects of carbon finance across different sectors and regions. Further research is urgent to understand the specific mechanisms through which carbon finance impacts emission reduction efforts and address existing knowledge gaps.

This study aims to bridge this gap by providing a holistic analysis of how carbon finance influences reducing carbon emissions. It seeks to contribute to the current body of knowledge by comprehensively examining how carbon finance impacts reducing carbon emissions. This study aims to provide valuable insights into the effectiveness and potential challenges associated with implementing carbon finance strategies by analyzing various case studies, exploring sector-specific implications, and considering regional differences.

In conclusion, this study aims to shed light on the role of carbon finance in mitigating carbon emissions. By investigating its influence on different sectors and regions, this research can inform policymakers, businesses, and stakeholders about effective strategies for achieving sustainable development goals while combating climate change.

Hypothesis

Global warming and climate change have become the focus of global attention. Greenhouse gas emissions are one of the main drivers, and reducing carbon emissions has become a common goal of all countries. Carbon finance is a financial instrument and mechanism that aims to reduce carbon emissions and facilitate the transition to a low-carbon economy through economic means. Previous studies have shown that financial incentives and market mechanisms can effectively reduce various sectors' emissions (Smith et al., 2015; Stern, 2007).

Carbon finance can incentivize businesses and individuals to adopt emission reduction measures by introducing carbon pricing mechanisms and market-based approaches. According to data from the United Nations Environment Programme (UNEP), in 2019, over 60 countries and regions implemented carbon pricing policies. These policies include carbon taxes, emissions trading systems, and other economic instruments to guide enterprises to reduce their carbon emissions. Based on the choice of carbon pricing mechanisms and specific financial tools, carbon finance can take emission reduction measures while promoting the development of clean energy sectors. Despite the challenges and issues it may face, from a benefits perspective, carbon finance positively impacts significantly reducing carbon emissions. Therefore, we propose the Hypothesis 1.

Hypothesis 1: carbon finance can play a significant role in reducing carbon emissions.

The influence of carbon finance on carbon emission is related to China's eastern, central, and western regions. There are differences in economic development level and industrial structure among these three divergent regions in China. Different regions have different policies, measures, and energy structures to deal with carbon emissions, which affects the effect of carbon finance on carbon emissions. For example, Li et al. (2020) pointed out regional differences in the impact of carbon finance on carbon emission, namely that the eastern coastal areas are relatively developed. It has more highly polluting industries and a better financial system. Therefore, the introduction of a carbon finance mechanism in the Eastern region may make it easier to meet carbon reduction targets. The Western region is richer in resources and dominated by energy-intensive industries, so carbon reduction is more difficult(ADB, 2008). The central region is somewhere in between and needs to balance economic growth and environmental protection in promoting carbon reduction. In addition, government support and market environment in different regions will also affect the effect of carbon finance on carbon emissions. For example, governments in the eastern region may pay more attention to environmental protection issues and provide more policy support. In contrast, the western region may face more difficult policy implementation problems (Wang et al. 2018). In summary, we propose Hypothesis 2.

Hypothesis 2: The influence of carbon finance on carbon emission is relevant to the difference between eastern, central, and western regions. In particular, carbon finance on CO2 emission has a larger marginal effect in central and western regions than in eastern regions.

The influence of carbon finance on carbon emission is related to the southern and northern regions of China. The climate conditions and economic development in China's northern and southern regions have different demands and policy guidance in dealing with carbon emissions. The southern region is relatively humid, has a high proportion of agriculture, and has a relatively developed manufacturing industry(FAO). Therefore, introducing carbon finance mechanisms in the region may focus more on agricultural carbon reduction and industrial transformation and upgrading. Energy-intensive industries dominate the northern region, and the task of carbon reduction is more urgent, and the challenge is greater (Zhang et al. 2019). Different regions' energy structure and industrial layout will also affect the effect of carbon finance on carbon emissions (Liu et al., 2020). For example, in the southern region of China, clean energy such as hydropower can replace traditional coal energy to achieve carbon reduction targets. However, due to climatic constraints and unequal distribution of resources, it is relatively difficult to reduce carbon emissions in northern China(IEA,2013). So, we propose hypothesis 3.

Hypothesis 3: The effect of carbon finance on carbon emission is relevant to the difference between the northern and southern regions. In particular, carbon finance on CO2 emission has a larger marginal effect in northern regions than in southern regions.

The impact of carbon finance on carbon emissions differs based on population size thresholds. Taking China and the Netherlands as examples, China is one of the most populous countries in the world, with a population exceeding 1.4 billion in 2019 (World Bank, 2021), while the Netherlands is a small country with a population of approximately 17 million (World Bank, 2021). Despite both countries implementing carbon finance policies, their impact on carbon emissions varies due to the significant difference in population size.

The enormous population in a large country like China translates into higher energy demand and more economic activities, leading to higher carbon emissions. Although the Chinese government has implemented various measures to reduce carbon emissions, such as promoting renewable energy and improving energy efficiency, the sheer scale of its population and rapid industrialization still pose challenges in achieving lower carbon emissions.

In contrast, in a small country like the Netherlands, the relatively smaller population results in lower energy demand and economic activities, leading to lower carbon emissions. Additionally, the Netherlands actively promotes sustainable development and transition to green energy by heavily investing in renewable sources such as wind and solar power.

Therefore, we propose Hypothesis 4.

Hypothesis 4: There might exist population thresholds above which the effectiveness of carbon finance interventions becomes more pronounced.

The choice of financial instruments plays a crucial role in achieving these goals. By selecting different financial instruments, this study hypothesizes that carbon finance can influence carbon emissions.

Firstly, the coverage rate is an important indicator to measure the impact of carbon finance measures on carbon emissions. Carbon pricing mechanisms with higher coverage rates are believed to effectively reduce greenhouse gas emissions. For example, empirical research conducted by Zhang et al. (2019) in various provinces of China showed a negative correlation between higher coverage rates of carbon pricing mechanisms and lower carbon emissions per unit of GDP.

Furthermore, specific indicators within financial instruments such as green bonds and investments in renewable energy can also reflect their impact on carbon emissions. Studies have shown that issuing green bonds to support investments in renewable energy projects can significantly reduce carbon emissions (Bachner et al., 2020). Using such financial instruments helps increase investments in clean energy and reduces reliance on traditional fossil fuels.

In conclusion, coverage rate and specific indicators such as green bonds and investments in renewable energy can serve as concrete indicators reflecting the impact of different financial instruments within carbon finance on carbon emissions. By providing financial incentives and constraints, carbon finance encourages the adoption of cleaner technologies and practices to reduce carbon emissions. Therefore, this paper proposes Hypothesis 5.

Hypothesis 5: Carbon finance can influence carbon emissions by selecting financial instruments.

Carbon finance reduces carbon emissions through the impact of fiscal taxation. Take Sweden as an example; the country has implemented a carbon tax policy (Bachner et al., 2020). According to data from the Swedish Environmental Protection Agency, Sweden has levied carbon taxes on CO2 emissions from fossil fuels in recent years and used the revenue to support renewable energy projects and the development of other low-carbon technologies. This approach has effectively reduced Sweden's carbon emissions and stimulated growth in the clean energy market.

Another example is Norway, where substantial oil and gas extraction funds have been allocated to establish the Norwegian Government Global Environment Fund (Kallbekken et al., 2019). This fund invests in renewable energy and carbon reduction projects, driving Norway's transition towards a low-carbon economy while further reducing carbon emissions.

These empirical examples demonstrate that through the impact of fiscal taxation, carbon finance can incentivize the adoption of emission reduction measures at a national level and promote development in the clean energy sector. Considering these facts, we propose Hypothesis 6.

Hypothesis 6: Carbon finance influences carbon emissions through its effect on fiscal taxation policies.

Methodology

3.1 Data

The current study uses secondary data from the National Bureau of Statistics, China Statistical Yearbook, provincial Statistical Yearbook, and China Insurance Yearbook, carbon emission index from provincial GHG emission inventory guidelines (trial), carbon emission inventory guidelines issued by governments at all levels, and other data sources. The data cover the period 2001-2020. The samples we collected are at the provincial level, which includes 30 provinces and municipalities in China

3.2 Variables

The main dependent variable of this paper is carbon emission, which represents financial instruments and markets related to carbon emission reduction, such as carbon trading and carbon quotas etc. This variable is used to measure the level of financial activities of countries or regions in the field of carbon emission reduction. In the analysis process, carbon finance was used as an independent variable, the level of carbon finance activities, to explain the changes in carbon emission. At the same time, we also control for other important factors, including the balance of deposits in local and foreign currencies of financial institutions, GDP, total population, the proportion of urban population, the number of people with college degrees or above, the proportion of people with college degrees or above in the total population, personal income tax and corporate income tax.

In addition, we introduce some mechanism variables to fully explain the impact of carbon finance on carbon emissions. These institutional variables include tax revenues, degree of financialization, and green finance indices. Tax revenue reflects the fiscal revenue obtained by a country or region from taxation. The degree of financialization measures the importance and development of the financial sector in the economy of a country or region. The Green Finance Index is used to measure policy support and market development in the field of green finance in a country or region.

3.3 Model

This paper aims to study the impact of carbon finance on carbon emissions. To estimate this relationship accurately, panel data's fixed effect and random effect models are used. In our analysis, we use panel data, including observations from multiple countries or regions at different points. By introducing fixed and random effects models, we can control for unobservable individual differences and allow for individual heterogeneity.

$$\left(\text{Carbon emission}\right)_{it} = \alpha_0 + \alpha\ (\text{Carbon finance})_{it} + \alpha_2\ \text{mediation}_{it} + \alpha_3 \text{control}_{it} + \text{year}_t + v_i + u_{it} \quad (1)$$

Where i and t represent country and time, respectively; Carbon emission is the level of carbon emission; carbon finance stands for financial instruments and markets related to carbon reduction; mediation is a mechanism variable; control is the control variable; year t is the time fixed effect; v i is the individual effect; and u it is the residual.

Empirical Results

Table 1 shows the main results of carbon finance on CO2 emission as below:

Table 1 The main results of carbon finance on CO2 emission

	(1)	(2)
	Random Effect	Fixed Effect
	CO2 Emission	CO2 Emission
Carbon finance	-741.768***	-757.742***
	(13.768)	(13.966)
Control Variable	Yes	Yes
Time Effect	Yes	Yes
Individual Effect	Yes	Yes
N	567	567

Table 1 shows that the impact of carbon finance on carbon emission is significant at a 1% level, with an

absolute value of 741.768-757.742, indicating that each unit increase (1 index) in carbon finance can reduce CO2 emission by around 741-757 tons. This proves Hypothesis 1, that carbon finance can play a significant role in reducing carbon emissions.

Table 2 shows the heterogeneity test results for carbon finance on CO2 emission from eastern, central, and western regions in China. As below:

Table 2 The results of the heterogeneity test for carbon finance on CO2 emission from eastern, central, and western regions in China

	(1)	(2)	(3)
	CO2 Emission		
	Fixed Effect		
	East	Central	West
Carbon finance	-532.257***	-1908.575***	-1221.379***
	(7.015)	(13.281)	(14.740)
Control Variable	Yes	Yes	Yes
Time Effect	Yes	Yes	Yes
Individual Effect	Yes	Yes	Yes
N	209	171	187

Table 2 shows that the influence of carbon finance on carbon emission in eastern, central, and western China is all significant at 1% level, with absolute values of around 532, 1908, and 1221, which indicates that when each unit of carbon finance increases, the CO2 emission in eastern China will be reduced by 532 tons, the CO2 emission in central China will be reduced by 1908 tons, and the CO2 emission in western China will be reduced by 1221 tons. This proves Hypothesis 2, which states that the influence of carbon finance on carbon emission is relevant to the difference between eastern, central, and western regions in China. In particular, carbon finance on CO2 emission has a larger marginal effect in central and western regions than in eastern regions.

Table 3 shows the heterogeneity test results for carbon finance on CO2 emission from southern and northern regions in China.1 As below:

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Table 3 The results of the heterogeneity test for carbon finance on CO2 emission from southern and northern regions in China

	(1)	(2)
	CO2 Emission	
	Fixed Effect	
	South	North
Carbon finance	-560.284***	-1010.558***
	(6.344)	(18.208)
Control Variable	Yes	Yes
Time Effect	Yes	Yes
Individual Effect	Yes	Yes

Table 3 shows that carbon finance's influence on carbon emission in northern and southern China is significant at a 1% level with an absolute value of around 560 and 1010, indicating that with every increase of carbon finance unit, CO2 emission in southern China would reduce by 560 tons. On the other hand, the CO2 emission in northern China was reduced by 1,010 tons. This proves hypothesis 3 that the effect of carbon finance on carbon emission is relevant to the difference between the northern and southern regions of China. In particular, carbon finance on CO2 emission has a larger marginal effect in northern regions than in southern regions.

Conclusion and discussion

This paper studies the impact of carbon finance on carbon emission reduction. It uses panel data models, including fixed effects and random effects, to analyze the impact of carbon finance on carbon emissions, which can provide more comprehensive and accurate research results. The study results show that carbon finance can significantly reduce carbon emissions, especially in high-emission areas of China. In addition, the study also found that carbon finance has different effects on carbon emissions reduction in different regions, indicating the applicability of carbon finance in different regions. In addition, this paper also suggests that carbon finance can promote the reduction of carbon emissions by optimizing tax policy and increasing the green finance index, which provides a reference for the practice of carbon finance.

Our research findings offer several practical implications for policymakers, businesses, and stakeholders engaged in climate change mitigation:

The practical implication of Hypothesis 1 is that the substantial impact of carbon finance on carbon emissions underscores the importance of developing and implementing effective carbon finance mechanisms. Policymakers should consider the following insights:

As demonstrated by Smith et al. (2015) and Stern (2007), carbon pricing mechanisms have a proven track record in driving emission reductions. Governments should prioritize the establishment of carbon pricing schemes, such as carbon taxes or cap-and-trade systems, to incentivize emission reductions. As discussed by Bachner et al. (2020), emissions trading systems provide a market-based approach to reducing emissions. Policymakers should explore the implementation of such systems, fostering a competitive environment where companies can trade emissions allowances, effectively incentivizing emission reductions. Additionally, as an instrument for financing renewable energy projects, green bonds can play a vital role in transitioning to a low-carbon economy (Bachner et al., 2020). Governments, financial institutions, and corporations should issue and invest in green bonds to accelerate the deployment of clean energy technologies.

Regions with energy-intensive industries may require tailored support to achieve significant carbon reductions (Li et al. 2020; Zhang et al. 2019). Governments should design policies that specifically address the unique challenges such regions face, promoting the adoption of cleaner technologies and practices. Central regions, positioned between the more developed East and resource-rich West, need to strike a balance between economic growth and environmental protection. Thus, Hypothesis 2 and Hypothesis 3 are also verified. Policymakers should focus on policies that foster sustainable development while promoting carbon reduction.

The practical implication of Hypothesis 4 is that population size thresholds can influence the effectiveness of carbon finance interventions. Policymakers should implement more ambitious carbon finance policies in countries with larger populations, such as China, where the challenge of reducing emissions is greater due to higher energy demand. These may include aggressive renewable energy targets, stringent emissions standards, and diversifying clean energy sources (World Bank, 2021). Countries with larger populations should prioritize substantial investments in renewable energy projects to meet emissions reduction goals. The success of these initiatives can be further enhanced by issuing green bonds, as Bachner et al. (2020) suggested.

The practical implication of Hypothesis 5 is that the choice of financial instruments within carbon finance can significantly impact carbon emissions. Policymakers should prioritize adopting emissions trading systems, which have proven effective in reducing emissions (Smith et al., 2015). These systems incentivize companies to reduce emissions and provide flexibility in achieving reduction targets. The issuance and investment in green bonds to support renewable energy projects should be encouraged. As shown by Bachner et al. (2020), these bonds have a direct and positive impact on reducing carbon emissions.

By considering these practical implications, policymakers, businesses, and stakeholders can better navigate the complexities of carbon finance and develop strategies that contribute significantly to global efforts to mitigate climate change.

The limitation of this paper is that our analysis focused only on a broad review of provincial-level cities, and future research could benefit from in-depth case studies to explore the specific mechanisms and challenges faced by prefecture-level cities or county districts in individual countries in implementing carbon finance strategies. First, although we controlled for various factors in our analysis, additional unaccounted factors may influence carbon emissions. Further research could delve into these factors to provide a more comprehensive understanding. Second, we examined heterogeneity at a regional level, but more granular analysis within regions or sectors may reveal nuanced effects of carbon finance. Finally, future research could explore the long-term sustainability of carbon finance strategies, considering evolving economic and environmental conditions. Additionally, assessing the social and equity implications of carbon finance interventions is an important area for further investigation.

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