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Can Green Finance Effectively Promote the Carbon Emission Reduction in "Local-Neighborhood" Areas?—Empirical Evidence from China

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Abstract: Carbon emission reduction is a systematic project requiring support from policy, capital, and technology in its promotion, which represents a greater need for green finance. Frontier research focuses on the impact of green finance on local CO_2 emissions, but generally ignores its ripple impacts on carbon emission reduction in adjacent areas. Combining panel data from 30 Chinese provincial-level cities from 2004 to 2019, this study employs a spatial panel Durbin model to empirically test the ripple effect of green finance on carbon emission reduction in adjacent areas and further investigate the formation mechanism of the ripple effect. The results are as follows: (1) Green financial development has a significant inhibitory effect on local and neighboring CO_2 emissions, which affirms the existence of the ripple effect of green finance. (2) Through formation mechanism analysis, it is found that the upgrading of an industrial structure has played a transmission role in the ripple effect of green finance. Finally, based on the empirical results, some suggestions are put forward from the perspectives of innovating green financial services and promoting the effective alignment of green financial development with carbon emission reduction targets and the deep integration of green finance and regional green industry development, so as to better develop the potential of green finance in the realization of the carbon reduction goals.

Keywords: green finance; carbon emission reduction; ripple effect; industrial structure upgrading

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1. Introduction

The acceleration of industrialization and urbanization in China has intensified the exploitation and use of fossil energy in recent years [1], resulting in excessive emissions from carbon dioxide (CO_2) and other by-products of fossil energy consumption [2] and catastrophic consequences for the ecological environment [3]. In 2020, global primary energy consumption and carbon emissions declined by 4.5% and 6.3%, respectively, while China maintained increases of 2.1% and 0.6% (referring to the "BP Statistical Review of World Energy 2021"). According to statistics, China consumed about 4.97 billion tons of standard coal in 2020, generating around 10 billion tons of carbon emissions, which accounted for 30.7% of the world's total CO_2 emissions. The Chinese government has acknowledged the importance of reducing CO_2 emissions for sustainable development and has prioritized climate governance and emission reduction [4]. At the 2015 Paris Climate Conference and the general debate of the 75th United Nations General Assembly, China proposed the ambitious goals of having peaked carbon emissions by 2030 (referring to the "Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions") and achieving carbon neutrality by 2060. Concurrently, to achieve the expected emission reduction target, the concept of "green development" was introduced in the "13th Five-Year Plan" outline, requiring enterprises to actively transform and upgrade toward the green direction.

However, carbon mitigation is a systematic project and the low-carbon transformation of enterprises has often faced various problems in practice, such as insufficient power for transformation, financing constraints [5], and weak technical capabilities [6]. Environmental pollution has significant negative economic externalities [7]. Driven by the goal of maximizing economic interests and profit, enterprises themselves often lack the motivation to actively carry out environmental protection activities [8]. Meanwhile, in the free-market economic environment, the production and technology research and development of traditional nonclean technology fields have profit advantages, compared with the obvious disadvantages of green production [9]. It is difficult to achieve technological progress towards a green and low-carbon direction by relying on the market itself. In fact, low-carbon transformation and green technology research and development of enterprises require substantial capital investment [10]. However, a traditional profit-oriented financial business often neglects to consider resources and environmental issues in the process of capital allocation and tends to direct more funds to projects with high returns and short return cycles [11]. For instance, industries such as steel and petrochemicals have significant advantages in obtaining bank credit [10], while some low-carbon and green industries generally lack sufficient financial support due to long investment cycles and high innovation risks [12]. The misallocation of financial resources in the context of polluting and green industries places considerable strain on the financing needs and industrial development of the latter [13].

Green finance is a new financial model, which addresses the problem of incongruity between economic growth and environmental protection by taking into account the functions of resource allocation and environmental governance [14]. The contradiction between the nonequilibrium flow of financial resources and environmental goals is essentially the contradiction between resource allocation and externalities, and green financial policies can effectively internalize environmental externalities [15]. By giving priority to green industries and low-carbon technological innovation projects in the allocation of social resources, green financial policies can guide the more favorable development of the economic and social environment [16]. By the end of 2020, China's green financing amounted to USD 1.93 trillion, of which the green credit balance was the largest with a total of USD 1.78 trillion, accounting for more than 90%, and the financing scale of green bonds and green equity also reached USD 0.15 trillion. As a new trend in China's future financial development, green finance is currently in a period of rapid growth in terms of both rate and increment, which has far-reaching significance for the achievement of carbon emission reduction goals [17]. Previous studies have undertaken in-depth analysis of the impact of green financial policies on corporate investment and financing [18], green technology innovation [19], and carbon emissions [20], but there has been no agreement on research findings regarding the financial development's impact on reducing CO_2 emissions. Clarification of the nexus between green finance and carbon emissions is necessary, given the recent rapid expansion of green finance and the urgency of reducing CO_2 emissions in China. Furthermore, the acceleration of China's industrial regionalization layout has promoted the formation of cross-regional industrial chain division networks and innovation networks [21], which has deepened the industrial linkages among regions and also affected the regional emissions to a certain extent. In fact, the existence of inter-regional industrial associations and imitation behaviors may result in the carbon emission reduction patterns and low-carbon technology application in the region, triggering a strong demonstration effect in the surrounding regions through technology spillover and knowledge dissemination [22]. Concurrently, environmental pollutants, such as carbon dioxide, are easily diffused, and differences in local environmental policies and the lack of coordinated emission reduction policies among regions may induce the near transfer of pollution [23], which means that carbon emission reduction goes beyond the local environmental governance issues in specific regions. Existing research, however, has focused on how green finance policies affect local CO_2 emissions and has largely ignored their ripple effect in neighboring regions.

Combining the above analysis, this paper proposes the following questions: (1) Can green finance development promote the coordinated emission reduction of carbon dioxide among regions (that is, whether there exists a ripple effect of green financing on neighboring carbon dioxide emissions)? (2) What is the formation mechanism of the ripple effect of green finance on CO_2 emissions in neighboring regions? Accordingly, the answers to the above questions will help to better understand the nexus between green financing and CO_2 emissions and are of value in promoting coordinated emission reductions among regions and the realization of the carbon reduction goals.

2. Literature Review

The nexus between financial development and environmental pollution has been widely studied in recent years [24], but consensus has not been reached regarding the research conclusions on the impact of the former on CO_2 emissions. Some scholars have confirmed the role of financial development in reducing CO_2 emissions from the perspective of industrial structural optimization [25] and improving technological efficiency [26]. However, conflicting conclusions have been drawn in empirical studies in some regions. Charfeddine and Khediri [27] and Acheampong [28] used data from the United Arab Emirates and 46 sub-Saharan African countries to analyze the impact of financial development on carbon emissions. They proved that financial development can not only promote economic growth, but also drive fossil energy consumption, which further increases regional CO_2 emissions. In addition, some studies suggest that differences in financial development measurement dimensions and regional heterogeneity may also lead to differences in results [1]. For instance, Yao and Zhang [29] categorized the influences of financial development on carbon emissions into substitution and income effects, and pointed out that there were significant differences in the above effects. Xiong et al. [30] proposed that financial development reduces carbon emissions in developed regions but increases CO_2 emissions in underdeveloped regions. Market forces and institutional constraints are important factors that hinder financial development and improving the environment in underdeveloped regions.

The improvement and advancement of green finance policies have propelled academic research on green finance. Salazar [31] first proposed the concept and emphasized that financial innovation must comprehensively consider environmental protection issues so that a dynamic balance between environmental governance and economic development can be achieved. Green finance is the product of the integration of the green economy and financial instruments [32]. First, assuming that energy consumption intensity and pollutant emissions remain unchanged, green finance will prioritize investment in green fields with low energy consumption intensity and low pollutant emissions [33]. Second, enterprises or projects that actively carry out green technology innovation will receive more favorable credit funds and wider funding sources [34]. Numerous studies have shown that green finance can reduce CO_2 emissions and promote the sustainable development of the green economy [14]. Regarding the impact of green finance on the microenterprise level, scholars largely agree that green finance can effectively restrain credit financing and excessive investment in polluting enterprises by forming financing constraints [6], and improve the financing convenience and credit support of green enterprises [35], which are critical to the realization of carbon mitigation [36]. For example, Su and Lian [37] pointed out that the green credit policy has a punitive and investment inhibiting effect on heavily polluting enterprises, and has a stronger punitive effect on state-owned enterprises, large enterprises, and those in high-emission areas. Likewise, some studies have found that green finance policies exert negative pressure on the pollution emission behavior of enterprises [38], which can improve environmental quality by reducing their energy consumption and transforming the mode of production, particularly in terms of exploring new, greener production methods and promoting technological progress toward a cleaner direction [39]. With regard to macroscopic research, the important role of green finance development in energy structure adjustment [40], industrial structure upgrading [41], and ecological performance improvement [42] has also been confirmed. The above research bears out that green finance is effective in influencing the investment and innovation behavior of enterprises, enhancing the company's sense of environmental responsibility, which has positive significance for controlling environmental pollution.

The green finance-related issues have attracted much attention in recent years, and the examination of their relationship with carbon emissions has been approached in a number of ways. Some researchers, such as Wang et al. [20], believed that green finance has negative effects on CO_2 emissions. Wang et al. [43] used the dynamic panel data model to analyze and found that green finance can coordinate with environmental regulations and help effectively curb CO_2 emissions. Meo and Karim [44] reached the same conclusion in an empirical study in the top 10 economies and indicated that a green financing scheme is the best financial innovation to minimize CO_2 emissions. Besides, empirical evidence also supports the essential role of green financial development in reducing fossil energy consumption, as well as in improving energy efficiency [45] and clean energy utilization [46], which are both conducive to curbing pollutant emissions.

The above review of literature in the field establishes that existing studies have combined a variety of methods to analyze the impact of green finance policies on local CO_2 emissions, but have largely ignored whether these effects have spatial spillover characteristics, that is, whether they have a ripple effect on emission reduction in neighboring regions. The geographic spillover effects of local policy development and execution have gradually emerged as a result of the lack of coordinated emission reduction plans throughout regions and the unhindered dispersion of environmental contaminants [17], and green finance policies are no exception. Besides, many scholars have confirmed that the provision of varied financial supply policies by green finance has exerted a positive effect on the modernization of the industrial structure. However, few studies have examined the role of industrial structure upgrading in promoting green finance to achieve carbon emission reduction. Therefore, the current study aims to empirically test the ripple effect of green finance on "local-neighborhood" CO_2 emission mitigation through the spatial panel Durbin model (SDM) and explore the role of industrial structure upgrading in the formation mechanism of the ripple effect by combining the characteristic facts of China's regional industrial integration development.

3. Empirical Model and Data Sources

3.1. Empirical Model

Spatial factors often have spillover effects, and carbon emissions are no exception. As a result of ignoring the indirect effects brought by spatial effects, the traditional regression analysis can only capture the direct impacts of the determinants, which may cause the final conclusions to be incongruous with the real scenario [47]. Therefore, a spatial econometric model that takes into account spatial correlation is used in the empirical test to better reveal the influence of green finance on "local-neighborhood" CO_2 emissions. Spatial econometric models may be divided into three categories, with the spatial Durbin model (SDM) being the most versatile because it can be transformed into a SAR or SEM model. As a result, the specific SDM was built to investigate the ripple effect of green finance on emission reduction:

$$CE_{it} = \delta_0 + \beta_1 GF_{it} + \beta_2 Controlx_{it} + \rho_0 \sum_{j=1}^{n} W_{ij} * CE_{it} + \alpha_1 \sum_{j=1}^{n} W_{ij} * GF_{it} + \alpha_2 \sum_{j=1}^{n} W_{ij} * Controlx_{it} + \mu_i + v_t + \varepsilon_{it} \quad (1)$$

where CE_{it} and GF_{it}, respectively, represent the carbon emissions per capita and green finance development levels, and $Controlx_{it}$ indicates the control variables. ρ_0 represents the spatial spillover effect of carbon emissions, β_i indicates the linear coefficients, and α_i indicates the spatial spillover coefficients. μ_i, v_t, and ε_{it}, respectively, indicate the fixed effects and the error term. W_{ij} indicates the spatial weight matrix.

Lesage and Pace [48] proposed that the principle of spatial weight construction is to set a simple spatial weight matrix as much as possible, and a sparse adjacency matrix (most elements in the matrix are 0) is the most effective. Accordingly, we chose the general spatial weight matrix, 0–1 matrix.

Industrial structure upgrading (ISU) was selected to further explore the formation mechanism of the ripple effect, that is, whether green finance influences the carbon emissions in neighboring regions by affecting industrial structure upgrading. Referring to Dong et al. [9], this research introduces the interaction term $(GF \times ISU)$ to perform the mechanism analysis. The specific formulas of the model are constructed as follows:

$$ISU_{it} = \delta_0 + \beta_1 GF_{it} + \beta_2 Controlx_{it} + \rho_0 \sum_{j=1}^{n} W_{ij} * ISU_{it} + \alpha_1 \sum_{j=1}^{n} W_{ij} * GF_{it} + \alpha_2 \sum_{j=1}^{n} W_{ij} * Controlx_{it} + \mu_i + v_t + \varepsilon_{it} \quad (2)$$

$$CE_{it} = \delta_1 + \beta_3 (GF \times ISU)_{it} + \beta_4 Controlx_{it} + \rho_1 \sum_{j=1}^{n} W_{ij} * CE_{it} + \alpha_3 \sum_{j=1}^{n} W_{ij} * (GF \times ISU)_{it} + \alpha_4 \sum_{j=1}^{n} W_{ij} * Controlx_{it} + \mu_i + v_t + \varepsilon_{it} \quad (3)$$

where ISU represents industrial structure upgrading. $GF \times ISU$ is the interaction item of the independent variable GF and the mechanism variable ISU.

3.2. The Variables' Setting and Data Source

3.2.1. Data Source

This study uses panel data covering 30 Chinese province cities from 2004 to 2019 based on the availability and reliability of original data. All data were taken from the *China Statistical Yearbook*, the *China Energy Statistical Yearbook*, and the *China Environmental Statistical Yearbook*. A detailed explanation of each variable is shown below.

3.2.2. Explained Variable

CO_2 emissions per capita (CE). We use the unified standard technique proposed by the IPCC to calculate the CO_2 emissions of different provinces of China due to the dearth of official data on CO_2 emissions in various regions [49]. The formula can be given as follows:

$$CE_{energy} = \sum_{i=1}^{8} CE_i = \sum_{i=1}^{8} E_i \times NCV_i \times CEF_i \times COF_i \times \frac{44}{12} \quad (4)$$

where CE_{energy} is the CO_2 emissions from the consumption of fossil fuel i, and CE_i, NCV_i, CEF_i, and COF_i stand for the amount of fossil fuel i that was burned, the low calorific value, the CO_2 content, and the rate of CO_2 oxidation, respectively. Table 1 (the average low calorific value is provided in the appendix of the *China Energy Statistical Yearbook*, and the carbon content is derived from IPCC (2006)) lists the eight fossil fuels' CO_2 emission coefficients.

Table 1. CO_2 emission coefficients of various fossil fuels.

Fossil Fuels	Low Calorific Value (kJ/kg)	CO_2 Content (kgC/GJ)	Rate of CO_2 Oxidation	CO_2 Emission Coefficients (tC/t)
Coal	20,908	25.8	0.913	0.4925
Coke	28,435	29.2	0.928	0.7705
Crude oil	41,816	20.0	0.979	0.8187
Diesel	42,652	20.2	0.982	0.8461
Fuel oil	41,816	21.1	0.985	0.8691
Gasoline	43,070	18.9	0.980	0.7977
Kerosene	43,070	19.5	0.986	0.8281
Natural gas	38,931 (kJ/m^3)	15.3	0.990	0.5896 (tC/m^3)

3.2.3. Explaining Variables

Green finance development level (GF). To effectively assess the green financial development level in China, referring to the indicator system (Table 2) designed by Wu [50], we employ the entropy weight method to calculate the comprehensive evaluation index of green finance.

Table 2. Indicator system of green finance.

Target Layer	Criteria Layer	Index Layer	Unit	Attribute
Green finance (GF)	Green credit	Six energy-intensive industry total interest payments/industrial interest payments	%	−
	Green investment	Investment in environmental pollution control/GDP	%	+
	Green insurance	Agricultural insurance/total agricultural output value	%	+
	Government support	Official environmental protection expenditure/general budget expenditure	%	−

Industrial structure upgrading (ISU). The output value ratio of the tertiary industry to the secondary industry is adopted to measure the industrial structure upgrade, which amply demonstrates the direction of the industrial structure's progression [51].

3.2.4. Control Variables

The following control variables are selected in the light of previous research on the scale, structure, and technology effects [52] that influence carbon emissions to control for the effects of other factors on CO_2 emissions.

First, it is shown that the level of economic development [12], natural resource endowment [53], and human capital [54] can affect carbon emissions through scale and structural effects. Economic development is measured by GDP per capita. The proportion of mining fixed assets in the fixed assets of the whole industry is used to measure the regional natural resource endowment. Referring to the measurement method of Barro and Lee [55], the stock of human capital in each area is determined based on the level of education.

Second, technology advancement is essential for cutting energy use and minimizing carbon emissions [56], and significant R&D expenditures are necessary for technological progress; hence, R&D expenditure is selected as a control variable. In addition, knowledge and technology spillovers from FDI also reduce carbon emissions through the technology effect [57]. This paper uses the ratio of real yearly foreign investment to GDP to measure the level of FDI.

4. Results and Discussions

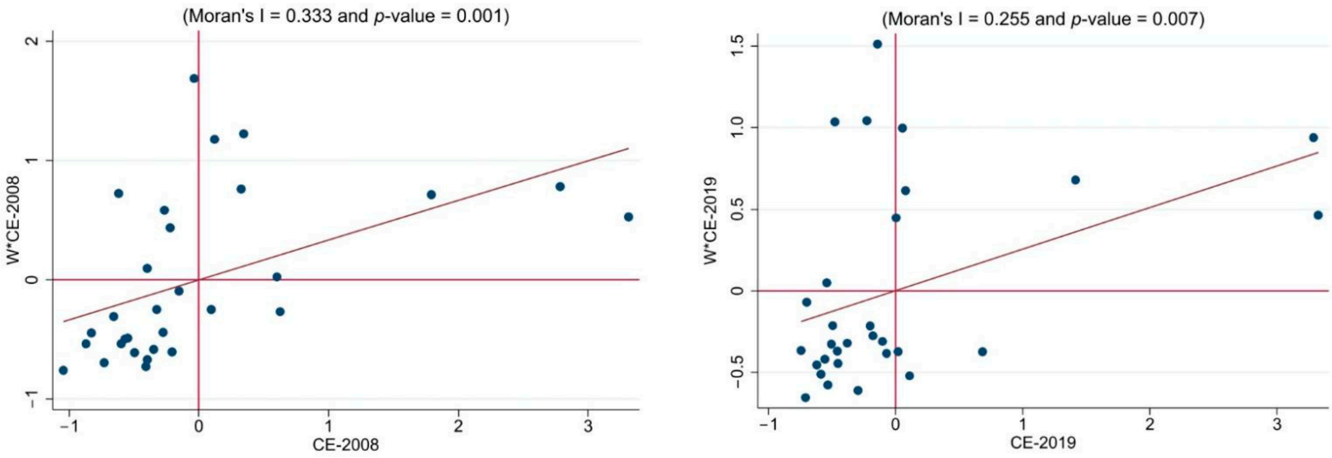
4.1. Spatial Correlation Analysis

Before examining the ripple effects of green finance, we employed spatial correlation testing to analyze the spatiotemporal characteristics of carbon dioxide emissions in China's provinces and the existence of spatial effects. As can be seen from Table 3, all Moran's I indices are positive, with a significance level of 1% from 2004 to 2019, indicating that China's provincial CO_2 emissions have a significant positive spatial correlation. Then, in order to more thoroughly examine the geographical correlation features of carbon emissions in each province, we integrated the data from Moran's I index with the scatter plot for each year. As can be seen in Figure 1, most of the observed values are distributed in the first and third quadrants, indicating that carbon emissions in the majority of provinces exhibit a positive spatial correlation of "high–high" agglomeration and "low–low" agglomeration. The result further confirms the positive spatial dependence of carbon emissions among China's provinces. This is consistent with the findings of many scholars, such as Liu and Song [58] and Guo et al. [17]. Therefore, it is an appropriate and reasonable option to empirically analyze the spatial effects through a spatial panel model.

Table 3. Moran's index of CO_2 emissions.

Year	I	P	Year	I	P
2004	0.311 ***	0.004	2012	0.302 ***	0.002
2005	0.324 ***	0.002	2013	0.294 ***	0.003
2006	0.314 ***	0.002	2014	0.292 ***	0.003
2007	0.319 ***	0.002	2015	0.278 ***	0.005
2008	0.333 ***	0.001	2016	0.271 ***	0.006
2009	0.317 ***	0.002	2017	0.253 ***	0.009
2010	0.314 ***	0.002	2018	0.250 ***	0.009
2011	0.299 ***	0.002	2019	0.255 ***	0.007

Note: *** indicates a significance level of 1%.



(**a**) (**b**)

Figure 1. Moran's I scatter plot of carbon emissions in 2008 (**a**) and 2019 (**b**).

4.2. Testing on the Existence of Ripple Effect

According to the estimation results displayed in Table 4, the coefficients of GF and W×GF are both significantly negative, with a confidence level of 1%, indicating that the ripple effect of green finance does exist; that is, the development of local green finance can not only curb local carbon emissions, but also contribute to reducing carbon emissions in neighboring areas. Thus, despite the different variable settings and analysis methods, the view that green finance is an important driver for achieving China's regional carbon reduction targets is largely consistent with the findings of many existing studies [15,43]. Besides, a province's carbon emissions are negatively related to the regional natural resource endowment, while positively related to the human capital structure and economic development level. Further, the spatial spillover effects of natural resource endowment are very prominent and significantly promote neighboring carbon emission reduction. Finally, the coefficients of Rho is significantly positive (0.257, $p = 0.000$), indicating that there is a significant spatial spillover effect of carbon emissions. In other words, the reduction of local CO_2 emissions will contribute to the carbon emission reduction in adjacent provinces.

Since the SDM is nonlinear, the regression coefficients estimated by SDM could not be enough to reflect the marginal impact of independent variables and various control variables on CO_2 emissions. Therefore, the partial derivative moment method of LeSage and Pace [48] is used to decompose the total model effect into direct and indirect effects. The direct effect refers to the impact of the independent variable on CO_2 emissions within the province, and the indirect effect, that is, the spatial spillover effect, refers to the impact of the variable on neighboring provinces. The total effect is the sum of the two, and the results of the respective effects are presented in Table 5.

Table 4. Spatial Durbin model estimation and test results.

Independent Variable	Coefficient	Std. Err	Z Variable	$p > \|z\|$
GF	−2.814 ***	0.424	−6.64	0.000
NR	−1.039 ***	0.231	−4.50	0.000
HC	1.103 *	0.644	1.71	0.087
ED	1.992 ***	0.395	5.04	0.000
RD	−0.246	0.225	−1.10	0.273
FDI	−0.297	0.247	−1.20	0.230
W × GF	−2.874 ***	0.875	−3.28	0.001
W × NR	1.024 *	0.534	1.92	0.055
W × HC	1.731	1.407	1.23	0.218
W × ED	−0.054	0.701	−0.08	0.938
W × RD	0.419	0.334	1.25	0.210
W × FDI	−0.559	0.547	−1.02	0.307
Rho	0.257 ***	0.063	4.07	0.000
Sigma2_e	4.494 ***	0.293	15.36	0.000

Note: *, *** represent significance levels of 10% and 1%, respectively.

Table 5. The test results of the carbon emission reduction effect of green finance.

Independent Variable	Direct Effect	Indirect Effect	Total Effect
GF	−3.038 ***	−4.616 ***	−7.654 ***
NR	−0.999 ***	0.962	−0.038
HC	1.316 **	2.813	4.129 *
ED	2.012 ***	0.622	2.634 **
RD	−0.222	0.442	0.220
FDI	−0.325	−0.759	−1.083

Note: *, **, *** represent significance at 10%, 5%, and 1% level respectively.

1. Direct effect analysis: According to the direct effect coefficient of each variable, it is found that the local CO_2 emissions are considerably negatively impacted by green financing and the abundance of natural resources, whereas the improvement of a local human capital structure and economic development level both exhibit the opposite effect. Among them, for every 1% increase in the level of green financial development, regional CO_2 emissions will decrease by 3.038%, which confirms the important role of accelerating the development of green finance in achieving emission reduction targets. Combined with previous studies, this paper suggests that the potential mechanism may be as follows: First, green financing may support the promotion and use of green technologies, as well as the green upgrading of company fixed equipment, which can assist in increasing production efficiency and lowering pollution emissions [29]. Second, it may contribute to deterring investments in polluting sectors and fostering the growth of green industries, which in part improves the industrial structure to a certain extent and, eventually, lowers energy consumption and CO_2 emissions [41,56]. The ensuing study will confirm the potential transmission pathway. The possible conduction mechanisms will be verified in the subsequent examination.
2. Indirect effect analysis: Indirect effects of green finance reflect spatial spillovers across provinces. As shown in Table 5, the coefficient of the indirect effect of GF (4.616) is significantly negative and larger than its estimated coefficient of the direct effect (3.038), indicating that green finance has a stronger inhibitory effect on carbon emissions in neighboring areas, which also confirms the existence of the ripple effect of green finance on carbon emission reduction. However, in a case study of the Yangtze River Economic Zone in China, Guo et al. [17] pointed out that the spatial spillover effects of green finance on CO_2 emissions in neighboring areas were not significant. This implies that differences in sample selection may lead to the bias of the research results and also reflects the realistic feature of the current asymmetric impact of green finance development on regional carbon emissions in China. Combining the results of indirect effects, we argue that the promotion of local green financing has resulted

in modifications to industrial layout and manufacturing processes, with neighboring provinces benefiting from the transfer of technology and experience [41]—the "free-rider" effect—and ultimately has achieved the synergistic reduction of CO_2 emissions. Furthermore, according to the statistical results of other variables, there is no significant correlation between the control variables and the CO_2 emissions of neighboring regions.

4.3. Testing on the Industrial Structural Upgrading Effect of Green Finance

To investigate the formation mechanism of the above ripple effect, we introduced the interaction term of green financing and industrial structural upgrading for mechanism analysis. The mechanism analysis process is divided into two stages in total, and the first stage is to test the industrial structure upgrading effect of green finance. As exhibited in columns 2–4 of Table 6, the coefficients of GF are considerably positive in each model, and the direct effect (0.535) is higher than the indirect effect (0.307). Consistent with the findings of Wang and Li [59] and Wang and Wang [41], green finance policy is a key force behind structural change and has improved the overall industrial structure by fostering the rapid growth of the tertiary sector.

Table 6. Results of the formation mechanism analysis.

	ISU			CE		
Independent Variable	**Direct Effect**	**Indirect Effect**	**Total Effect**	**Direct Effect**	**Indirect Effect**	**Total Effect**
GF	0.535 ***	0.307 ***	0.842 ***			
GF × ISU				−3.604 ***	−6.552 ***	−10.156 ***
NR	−0.081 ***	−0.146 ***	−0.227 ***	−1.153 ***	0.7961	−0.357
HC	−0.052	−0.329 ***	−0.381 ***	1.006	2.274	3.280
ED	−0.122 ***	0.175 ***	0.053	1.156 ***	−0.900	0.256
RD	0.012	0.007	0.019	−0.771 ***	−0.730 *	−1.500 ***
FDI	−0.013	−0.238 ***	−0.251 ***	−0.365	−1.000	−1.365
Rho		−0.421 ***			0.319 ***	
Sigma2_e		0.041 ***			4.739 ***	

Note: *, *** represent significance at 10%, and 1% level respectively.

In order to calculate the effect of green-finance-induced industrial upgrading on the CO_2 emissions among the "local-neighborhood" areas, we add the interaction term GF × ISU to the regression analysis model in the second stage of the formation mechanism test. According to the results in columns 5–7 of Table 6, the coefficients of GF × ISU in all models are significantly negative, indicating that the industrial structural upgrading caused by green finance has played a significant inhibitory role in carbon emissions in both local and neighboring areas. As mentioned above, by providing differentiated financial supply, green finance will flow more funds to green and environmental protection industries and, at the same time, impose financing constraints on "high-pollution, high-energy-consumption" industries to restrain their scale expansion, which effectively guides the transformation of a regional industrial structure toward a cleaner direction [41]. Concurrently, the adjustment of the local industrial structure will have a "radiation effect" on the industrial development of neighboring areas due to the policy imitation between local governments and the deeper development of the industrial division of labor between regions, thus realizing the coordinated upgrading of the industrial structure between regions [21]. Ultimately, the upgrading of an inter-regional industrial structure largely reduces CO_2 emissions and fosters the ripple effect. This is quite different from existing studies. On the one hand, we distinguish the direct impacts and spillover effects of policy implementation. On the other hand, this study accurately calculates the actual impact of the industrial structure upgrade induced by green finance on CO_2 emissions by introducing interaction terms, and thus explains the formation mechanism of the ripple effect.

5. Conclusions and Implications

5.1. Conclusions

This study uses panel data of 30 Chinese provinces from 2004 to 2019 to examine whether and how green finance influences the "local-neighborhood" carbon emission reduction. The potential spatial effects of the CO_2 emissions for Chinese provinces are first investigated by a spatial autocorrelation test. Then the spatial Durbin model (SDM) is employed to test the existence of the ripple effect of green finance. Lastly, the formation mechanism of the ripple effect of green finance on CO_2 emission reduction is analyzed.

The conclusions are threefold. First, the findings of the spatial correlation testing demonstrate that there is a substantial geographical correlation between the CO_2 emissions of Chinese provinces in both the time and space dimensions. Second, the ripple effect of green finance on CO_2 emission reduction does exist. In other words, green financial development has a stronger inhibitory effect on carbon emissions both in "local-neighborhood" areas. Third, the formation mechanism test of the ripple effect shows that the upgrading of the industrial structure will be stimulated by the development of green finance, which in turn will significantly curb carbon emissions in these regions, leading to a ripple effect on CO_2 emission reduction.

5.2. Policy Implications

For the purpose of reducing carbon emissions and realizing green and high-quality development, the following recommendations and policy implications are forwarded:

1. The growth of green finance in China is still in the early stages, and there is still a large gap between the transaction scale of green finance and the financing requirements of green enterprises. In order to give full play to the carbon emission reduction potential of green finance, relevant departments should further broaden the scope of green financial services and innovate green financial instruments to better support regional green and low-carbon development. First, at present, bank credit still dominates China's green financial business, and direct financing methods represented by green funds and green bonds have not yet played a real role in the market, and relevant institutions need to appropriately relax the sources of risk capital to bring more social capital together in the green field. Second, China's green SMEs generally have problems, such as difficulty in financing and expensive financing. Therefore, financial institutions have to increase the universality of green finance, strengthen green financing support for SMEs, and better serve the modernizing and transforming of SMEs.
2. Facilitate the effective alignment of green financial development with carbon emission reduction targets. First, increase financial support for low-carbon development and climate-related projects, and formulate preferential lending policies for green enterprises and projects that have the potential to significantly reduce greenhouse gas emissions and generate ecological benefits. Second, strengthen the supervision of the green finance market, improve the quality of information disclosure on corporate carbon emissions, and strictly regulate the interface between green finance funds and green projects to avoid "greenwashing". Finally, local governments should establish an inter-regional green finance and carbon information sharing mechanism so that the ripple effect of green finance in CO_2 emission reduction can be better exerted. This is to strengthen inter-regional communication and coordination on carbon emission reduction policies and avoid the phenomenon of "pollution transfer" caused by differences in policy formulation and implementation.
3. Both the development of green finance and CO_2 emission reduction targets will bring profound changes to the industrial structure in China. Therefore, local governments may give impetus to the deep integration of green finance and regional green industry development to facilitate the upgrading and adjustment of an industrial structure and ultimately achieve low-carbon economic transformation. On the one hand, by giving sufficient financial support to clean industries and high-value-added industries and

imposing strict financing restrictions, the development of industries that use a lot of energy and produce a lot of pollution should be curbed, thus changing the path dependence and eventually realizing the development toward a cleaner direction of an industrial structure. On the other hand, special funds should be set up to increase support for cutting-edge technologies, such as new energy technologies and negative emission technology. Combining the distribution characteristics of natural resources, such as wind and solar energy, in the region, green funds will be allocated reasonably to guide the layout of clean energy and the construction of low-carbon technology industries.

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References

1. Ren, X.; Shao, Q.; Zhong, R. Nexus between green finance, non-fossil energy use, and carbon intensity: Empirical evidence from China based on a vector error correction model. *J. Clean. Prod.* **2020**, *277*, 122844.
2. Wang, A.L.; Hu, S.; Lin, B.Q. Can environmental regulation solve pollution problems? Theoretical model and empirical research based on the skill premium. *Energ. Econ.* **2021**, *94*, 105068. [CrossRef]
3. Wu, X.; Pan, A.; Fei, R. Three-dimensional heterogeneity analysis of climate aid's carbon reduction effect. *J. Environ. Manag.* **2021**, *289*, 112524. [CrossRef] [PubMed]
4. Pei, Y.; Zhu, Y.; Liu, S.; Wang, X.; Cao, J. Environmental regulation and carbon emission: The mediation effect of technical efficiency. *J. Clean. Prod.* **2019**, *236*, 117599. [CrossRef]
5. Yao, S.; Pan, Y.; Sensoy, A.; Uddin, G.S.; Cheng, F. Green credit policy and firm performance: What we learn from China. *Energy Econ.* **2021**, *101*, 105415. [CrossRef]
6. Yu, C.H.; Wu, X.; Zhang, D.; Chen, S.; Zhao, J. Demand for green finance: Resolving financing constraints on green innovation in China. *Energ. Policy* **2021**, *153*, 112255. [CrossRef]
7. Chen, Y.; Cheng, L.; Lee, C.C.; Wang, C.S. The impact of regional banks on environmental pollution: Evidence from China's City commercial banks. *Energ. Econ.* **2021**, *102*, 105492. [CrossRef]
8. Chen, L.; Li, W.; Yuan, K.; Zhang, X. Can informal environmental regulation promote industrial structure upgrading? Evidence from China. *Appl. Econ.* **2022**, *54*, 2161–2180. [CrossRef]
9. Dong, Z.; He, Y.; Wang, H.; Wang, L. Is there a ripple effect in environmental regulation in China?–Evidence from the local-neighborhood green technology innovation perspective. *Ecol. Indic.* **2020**, *118*, 106773. [CrossRef]
10. Liu, Q.; Wang, W.N.; Chen, H.Y. A study of the impact of Green Credit Guidelines implementation on innovation performance in heavy polluting enterprises. *Sci. Res. Manag.* **2020**, *11*, 100–112.
11. Tamazian, A.; Rao, B.B. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energ. Econ.* **2010**, *32*, 137–145. [CrossRef]
12. Xu, X.; Li, J. Asymmetric impacts of the policy and development of green credit on the debt financing cost and maturity of different types of enterprises in China. *J. Clean. Prod.* **2020**, *264*, 121574. [CrossRef]
13. Chien, F.; Ngo, Q.T.; Hsu, C.C.; Chau, K.Y.; Iram, R. Assessing the mechanism of barriers towards green finance and public spending in small and medium enterprises from developed countries. *Environ. Sci. Pollut.* **2021**, *28*, 60495–60510. [CrossRef] [PubMed]
14. Zhang, D.; Zhang, Z.; Managi, S. A bibliometric analysis on green finance: Current status, development, and future directions. *Financ. Res. Lett.* **2019**, *29*, 425–430. [CrossRef]
15. Jiang, H.; Wang, W.; Wang, L.; Wu, J. The effects of the carbon emission reduction of China's green finance—An analysis based on green credit and green venture investment. *Financ. Forum* **2020**, *11*, 39–48.
16. Lee, C.C.; Lee, C.C. How does green finance affect green total factor productivity? Evidence from China. *Energ. Econ.* **2022**, *107*, 105863. [CrossRef]
17. Guo, C.Q.; Wang, X.; Cao, D.D.; Hou, Y.G. The Impact of Green Finance on Carbon Emission—Analysis Based on Mediation Effect and Spatial Effect. *Front. Environ. Sci.* **2022**, *10*, 844988. [CrossRef]

18. Wang, E.; Liu, X.; Wu, J.; Cai, D. Green credit, debt maturity, and corporate investment—Evidence from China. *Sustainability* **2019**, *11*, 583. [CrossRef]
19. Paramati, S.R.; Mo, D.; Huang, R. The role of financial deepening and green technology on carbon emissions: Evidence from major OECD economies. *Financ. Res. Lett.* **2021**, *41*, 101794. [CrossRef]
20. Wang, X.; Huang, J.; Xiang, Z. Nexus between green finance, energy efficiency, and carbon emission: COVID-19 implications from BRICS countries. *Front. Energ. Res.* **2021**, *9*, 786659. [CrossRef]
21. Gao, X.L.; Xu, Z.N.; Niu, F.Q.; Long, Y. An evaluation of China's urban agglomeration development from the spatial perspective. *Spat. Stat.* **2017**, *21*, 475–491. [CrossRef]
22. Hong, Y.; Lyu, X.; Chen, Y.; Li, W. Industrial agglomeration externalities, local governments' competition and environmental pollution: Evidence from Chinese prefecture-level cities. *J. Clean. Prod.* **2020**, *277*, 123455. [CrossRef]
23. Dou, J.; Han, X. How does the industry mobility affect pollution industry transfer in China: Empirical test on Pollution Haven Hypothesis and Porter Hypothesis. *J. Clean. Prod.* **2019**, *217*, 105–115. [CrossRef]
24. Ameyaw, B.; Yao, L.; Oppong, A.; Agyeman, J.K. Investigating, forecasting and proposing emission mitigation pathways for CO2 emissions from fossil fuel combustion only: A case study of selected countries. *Energ. Policy* **2019**, *130*, 7–21. [CrossRef]
25. Liu, X.; Liu, X. Can Financial Development Curb Carbon Emissions? Empirical Test Based on Spatial Perspective. *Sustainability* **2021**, *13*, 11912. [CrossRef]
26. Khan, M.T.; Yaseen, M.R.; Ali, Q. Nexus between financial development, tourism, renewable energy, and greenhouse gas emission in high-income countries: A continent-wise analysis. *Energ. Econ.* **2019**, *83*, 293–310. [CrossRef]
27. Charfeddine, L.; Khediri, K.B. Financial development and environmental quality in UAE: Cointegration with structural breaks. *Renew. Sustain. Energ. Rev.* **2016**, *55*, 1322–1335. [CrossRef]
28. Acheampong, A.O. Modelling for insight: Does financial development improve environmental quality? *Energ. Econ.* **2019**, *83*, 156–179. [CrossRef]
29. Yao, S.; Zhang, S. Energy mix, financial development, and carbon emissions in China: A directed technical change perspective. *Environ. Sci. Pollut.* **2021**, *28*, 62959–62974. [CrossRef]
30. Xiong, L.; Tu, Z.; Ju, L. Reconciling regional differences in financial development and carbon emissions: A dynamic panel data approach. *Energy Procedia* **2017**, *105*, 2989–2995. [CrossRef]
31. Salazar, J. Environmental finance: Linking two worlds. Proceeding of the Workshop on Financial Innovations for Biodiversity Bratislava, Bratislava, Slovakia, 1–3 May 1998; Volume 1, pp. 2–18.
32. Cowan, E. Topical Issues in Environmental Finance. Research paper was commissioned by the Asia Branch of the Canadian International Development Agency (CIDA). 1999. Volume 1, pp. 1–20. Available online: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.543.4768&rep=rep1&type=pdf (accessed on 3 November 1998).
33. Scholtens, B. Finance as a driver of corporate social responsibility. *J. Bus. Ethics* **2006**, *68*, 19–33. [CrossRef]
34. Liu, N.; Liu, C.; Xia, Y.; Ren, Y.; Liang, J. Examining the coordination between green finance and green economy aiming for sustainable development: A case study of China. *Sustainability* **2020**, *12*, 3717. [CrossRef]
35. Li, W.; Zheng, M.; Zhang, Y.; Cui, G. Green governance structure, ownership characteristics, and corporate financing constraints. *J. Clean. Prod.* **2020**, *260*, 121008. [CrossRef]
36. Li, W.; Zhao, T.; Wang, Y.; Guo, F. Investigating the learning effects of technological advancement on CO_2 emissions: A regional analysis in China. *Nat. Hazards* **2017**, *88*, 1211–1227. [CrossRef]
37. Su, D.; Lian, L. Does green credit policy affect corporate financing and investment? Evidence from publicly listed firms in pollution-intensive industries. *J. Financ. Res.* **2018**, *12*, 123–137.
38. Fan, H.; Peng, Y.; Wang, H.; Xu, Z. Greening through finance? *J. Dev. Econ.* **2021**, *152*, 102683. [CrossRef]
39. Huang, Z.; Liao, G.; Li, Z. Loaning scale and government subsidy for promoting green innovation. *Technol. Forecast. Soc. Chang.* **2019**, *144*, 148–156. [CrossRef]
40. Sun, H.; Chen, F. The impact of green finance on China's regional energy consumption structure based on system GMM. *Resour. Policy* **2022**, *76*, 102588. [CrossRef]
41. Wang, X.; Wang, Q. Research on the impact of green finance on the upgrading of China's regional industrial structure from the perspective of sustainable development. *Resour. Policy* **2021**, *74*, 102436. [CrossRef]
42. Zhang, R.; Cao, Y.H.; Wu, K.R.; Sun, H. Research on the effect of green credit on ecological welfare performance: Evidence from China. *Front. Environ. Sci.* **2022**, *10*, 950341. [CrossRef]
43. Wang, F.; Cai, W.; Elahi, E. Do green finance and environmental regulation play a crucial role in the reduction of CO_2 emissions? An empirical analysis of 126 Chinese cities. *Sustainability* **2021**, *13*, 13014. [CrossRef]
44. Meo, M.S.; Abd Karim, M.Z. The role of green finance in reducing CO2 emissions: An empirical analysis. *Borsa Istanb. Rev.* **2022**, *22*, 169–178.
45. Liu, H.; Yao, P.; Latif, S.; Aslam, S.; Iqbal, N. Impact of Green financing, FinTech, and financial inclusion on energy efficiency. *Environ. Sci. Pollut. R.* **2022**, *29*, 18955–18966. [CrossRef] [PubMed]
46. Rasoulinezhad, E.; Taghizadeh-Hesary, F. Role of green finance in improving energy efficiency and renewable energy development. *Energ. Effic.* **2022**, *15*, 14. [CrossRef] [PubMed]
47. Fong, L.S.; Salvo, A.; Taylor, D. Evidence of the environmental Kuznets curve for atmospheric pollutant emissions in Southeast Asia and implications for sustainable development: A spatial econometric approach. *Sustain. Dev.* **2020**, *28*, 1441–1456. [CrossRef]

48. LeSage, J.P.; Pace, R.K. The biggest myth in spatial econometrics. *Econometrics* **2014**, *2*, 217–249. [CrossRef]
49. IPCC. *Guidelines for National Greenhouse Gas Inventories*; Institute for Global Environmental Strategies (IGES): Kanagawa, Japan, 2006.
50. Wu, G. Research on the Spatial Impact of Green Finance on the Ecological Development of Chinese Economy. *Front. Environ. Sci.* **2022**, *10*, 887896. [CrossRef]
51. Li, T.; Ma, J.; Mo, B. Does environmental policy affect green total factor productivity? Quasi-natural experiment based on China's air pollution control and prevention action plan. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8216. [CrossRef]
52. Grossman, G.M.; Krueger, A.B. Economic growth and the environment. *Q. J. Econ.* **1995**, *110*, 353–377. [CrossRef]
53. Zhang, W.; Meng, Z.; Yang, J.; Song, Y.; Zhou, Y.; Zhao, C.; Yuan, J. Managing the phaseout of coal power: A comparison of power decarbonization pathways in Jilin Province. *Resour. Conserv. Recy.* **2022**, *180*, 106216. [CrossRef]
54. Bano, S.; Zhao, Y.; Ahmad, A.; Wang, S.; Liu, Y. Identifying the impacts of human capital on carbon emissions in Pakistan. *J. Clean. Prod.* **2018**, *183*, 1082–1092. [CrossRef]
55. Barro, R.J.; Lee, J.W. International comparisons of educational attainment. *J. Monet. Econ.* **1993**, *32*, 363–394. [CrossRef]
56. Cheng, Z.; Li, L.; Liu, J. Industrial structure, technical progress and carbon intensity in China's provinces. *Renew. Sust. Energ. Rev.* **2018**, *81*, 2935–2946. [CrossRef]
57. Malik, M.Y.; Latif, K.; Khan, Z.; Butt, H.D.; Hussain, M.; Nadeem, M.A. Symmetric and asymmetric impact of oil price, FDI and economic growth on carbon emission in Pakistan: Evidence from ARDL and non-linear ARDL approach. *Sci. Total Environ.* **2020**, *726*, 138421. [CrossRef]
58. Liu, H.; Song, Y. Financial development and carbon emissions in China since the recent world financial crisis: Evidence from a spatial-temporal analysis and a spatial Durbin model. *Sci. Total Environ.* **2020**, *715*, 136771. [CrossRef]
59. Wang, W.; Li, Y. Can green finance promote the optimization and upgrading of industrial structures?—Based on the intermediary perspective of technological progress. *Front. Environ. Sci.* **2022**, *10*, 919950. [CrossRef]