

Does Financial Development Promote Carbon Reduction in China? A Non-Linear Test Based on The Role of Structural Optimization

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Abstract: In the context of green transformation, both financial development and structural adjustment are considered as means to achieve carbon neutrality in China. A model is constructed based on dynamic panel data of 285 cities and 30 provinces in China from 2003 to 2019 to measure the impact of financial development on carbon emissions from the perspectives of financial efficiency, financial scale, and financial structure, while considering the industrial structure, factor endowment structure, and energy consumption structure as moderating variables to examine the direct and indirect effects of financial development on carbon emission reduction. The results showed that the impact of different dimensions of financial development on carbon emissions showed an “inverted U-shaped” non-linear relationship, showing a tendency to promote and then inhibit carbon emissions. When considering the regulation effect, the different structural breakdown dimensions do not change the shape of the curve. The results of the heterogeneity analysis showed that this effect is more pronounced in resource cities than in non-resource cities. Based on this, macroeconomic regulation and structural optimization are proposed from the perspective of the government and enterprises, to contributing to an earlier crossing of the financial development threshold and the achievement of carbon neutrality.

Keywords: Financial development, Industrial structure, Elemental endowment structure, Energy consumption structure, Carbon emissions.

1. Introduction

With the climate crisis becoming a non-traditional risk to global sustainable development, countries around the world have been exploring ways to address the pressure of carbon emissions and the climate crisis. 2015 saw more than 140 countries around the world negotiate the Paris Agreement in response to the severe global warming trend. In October 2022, at the opening ceremony of the 20th National Congress, General Secretary Xi focused on implementing the new concept of development, promoting the construction of a new development pattern, and making efforts to promote high-quality economic development. It is also mentioned that a good ecological environment is fundamental to the sustainable development of people and society, and that blue skies and green mountains are the greatest capital for long-term development. As China enters a new era of economic development, the “two mountains” conflict has come to the fore, bringing China's high-quality economic development and ecological environment improvement to a critical opportunity. At present, China's energy consumption structure is still dominated by coal consumption, which is unable to meet the central document's requirement that the proportion of non-fossil energy consumption should reach over 80% by 2060. To achieve this goal, China needs to clarify the path of carbon emissions and take active and feasible policy measures to push China towards high-quality economic development and achieve the vision of “carbon peaking and carbon neutrality” at the same time. To achieve this goal, China needs to clarify its carbon emissions pathway and take proactive and feasible policy measures to move China onto a high quality economic development path, while at the same time achieving

the vision of “peak carbon and carbon neutral”.

The early literature focused on the Environmental Kuznets Curve (EKC), demonstrating that the environment and economic development have an “inverted U-shaped” curve (Grossman and Krueger, 1991). The relationship between financial development and carbon emissions has been studied in a variety of ways. The main reason for the positive relationship is that financial development can increase the amount of assets by widening access to finance, stimulating and supporting the development of the real economy, and the expansion of the economy will increase carbon emissions. Scholars who support a negative relationship believe that as foreign investment increases and brings more space for the development of talent and capital, it will lead to green technological progress and financial development can reduce energy consumption through industrial structure upgrading and other means, thus achieving carbon emission reduction. The explanation for the non-linear correlation between financial development and carbon emissions is that at the early stage of industrial structure development, a large amount of energy is consumed, leading to an increase in carbon emissions, while the development of low-carbon industries through industrial structure upgrading can relatively suppress carbon emissions, thus showing different effects of financial development on carbon emissions at different stages of economic development.

China's financial development is at a preliminary stage and still faces many problems, but some studies have concluded that financial development is conducive to reducing carbon emissions and that there is a threshold effect at different stages of economic development and levels of financial development. It has also been shown that structural

adjustment can effectively achieve carbon emission reduction, and that there are time lags and thresholds in the relationship between industrial restructuring and carbon emissions (Zhou et al, 2013). In recent years, scholars have found a non-linear relationship between industrial structure and carbon emissions, with Yang et al (2022) suggesting that the evolution of industrial structure at this stage has obvious developmental characteristics, with its impact on carbon emissions showing an inverted “V” trend of acceleration followed by inhibition.

The optimization of factor endowments can bring more competitive advantages to enterprises' production, such as foreign direct investment, technological progress, scientific research and innovation, and higher education levels, etc. Enterprises can continuously improve their infrastructure construction based on these factors, and achieve green development while improving production efficiency and expanding production scale. Shao et al. (2022) mentioned that the carbon emission reduction effect and factor saving effect play a key role in the improvement of carbon emission performance. The optimization of factor endowments provides China with a competitive advantage for economic development, and therefore their adjustment plays an important role in China's financial development and even in the operation of the national economy. Therefore, the impact of factor endowment structure on carbon emissions cannot be ignored.

China's total energy consumption in 2021 will be 5.24 billion tonnes of standard coal, more than half of the total energy consumption, and the increase in the coal-based energy mix will have a significant impact on carbon emissions in resource-based provinces. A slower growth rate of energy consumption and a low-carbon energy mix can enable the peak to occur earlier and also reduce the peak level (Xu et al, 2020). In domestic studies, most scholars emphasize that optimizing the current energy mix is one of the main effective ways to achieve carbon reduction. A part of scholars believed that the impact of the energy mix on carbon emissions is linear and contributory (Wu et al, 2021). Zeng et al (2021) believed that China's energy consumption structure is being optimized and the share of coal consumption is declining, but the magnitude of the decline is gradually decreasing. In addition, some scholars have proposed a different trend from that of

coal consumption. In addition, some scholars have proposed a different view from the above: Wang and Jia (2022) suggested that a coal-based energy consumption structure will significantly increase carbon emissions. Therefore, adjusting energy prices through carbon emission reduction policies to induce enterprises to optimize the input patterns of energy factors can help China change its energy consumption structure and can fundamentally reconcile the current relationship between China's economy, energy, and environment to achieve the goal of carbon neutrality.

Most of the current research on financial development on carbon emissions considers financial development as an indispensable tool in the process of achieving carbon neutrality, but less from the perspective of structural change. To achieve carbon neutrality, we must adjust and optimize the traditional industrial structure, factor endowment structure, and energy consumption structure, and accelerate the construction of a greener and more efficient structural system. Structural optimization is an important path for China to achieve carbon neutrality, while the allocation of financial resources will directly change the industrial structure, factor endowment structure, and energy consumption structure. Based on a literature review to sort out the mechanism of the role of financial development on carbon neutrality, this paper analyses the impact of financial development on carbon emissions from the perspectives of financial efficiency, financial scale, and financial structure by constructing a theoretical model.

2. Mechanistic Analysis

The study of the relationship between financial development and carbon dioxide emissions is essentially a discussion of the relationship between economic growth and the environment, and in recent years China, which is actively involved in the global response to reducing carbon emissions, has increasingly become a leader and promoter of international cooperation in green finance. Figure 1 illustrates that financial development, which is the focus of this paper, all affects carbon emissions directly and has a moderating effect on carbon emissions through three pathways: industrial structure, factor endowment structure, and energy consumption structure.

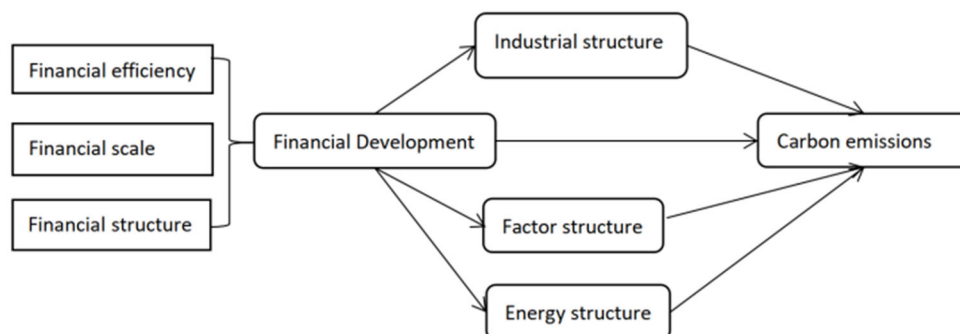


Figure 1. Framework

This paper will use theoretical analysis to investigate whether financial development can contribute to the early achievement of carbon emission reduction in China and to examine whether financial development can have an indirect effect on carbon emissions through the pathways of industrial structure, factor endowment structure, and energy

consumption structure.

2.1. Direct effects

The three main measures of financial development are often defined as financial efficiency, financial scale, and financial structure, and financial development will improve

the efficiency of financial resource allocation, which in turn can have an impact on China's carbon emissions.

First, improved financial efficiency can reduce transaction costs and frictional costs due to information asymmetry, and the rapid flow of funds will not only improve the efficiency of credit between banks and enterprises, but also make the allocation of resources in the green sector more efficient, which will help enterprises to further increase investment and expand production scale, which will increase CO₂ emissions; However, as financial deepening continues to deepen and various policies are supported, companies can break down information barriers and use more efficient financial products and tools to ensure sufficient funds for adjustment and reform, providing financial support for companies to improve their productivity, thus enabling companies to obtain funds at a lower cost and shorten the cycle of obtaining funds to speed up the completion of green projects, which can achieve carbon emission reduction while expanding the scale of companies, implying that carbon emission intensity will be curbed with financial deepening (Mo and Wang, 2022).

Second, the rapid expansion of the financial scale will increase the proportion of deposits and loans in banks, and the flow of funds to the corresponding green industries will increase, which can provide more financial support for the development of related enterprises, and more funds will flow in to guarantee the development of enterprises. The expansion of the financial scale will lead to an increase in carbon emissions (Zhao et al., 2020); Financial development is the key driving force to support the transformation of enterprises in the era of the low-carbon economy. The expansion of financial scale, with the support of policies, can flow capital to high-tech industries with a high return on investment in the production factors and clean energy, to upgrade the industrial structure, which can promote enterprises to promote technological innovation, adjust the use of factors and improve the energy consumption structure, which in turn can drive carbon emission reduction in China.

Thirdly, the development of the financial structure can promote the further improvement of the financial system. With the improvement of financial efficiency and the expansion of the financial scale, the increase in production of enterprises will inevitably increase carbon emissions, while the improvement of the financial structure will, to a certain extent, affect the use of credit instruments and interest rate adjustment. Interest rate adjustments will bring policy dividends to the relevant green enterprises, which will help them attract capital and rationalize the use of technology, thereby reducing pollution emissions and promoting the development and early realization of a low-carbon economy. Although carbon emissions will gradually increase during the period, the effect of curbing carbon emissions will eventually be achieved. Based on the above analysis, this paper proposes hypothesis 1.

Hypothesis 1: Financial development has an inverted U-shaped non-linear relationship that promotes and then inhibits CO₂ emissions.

2.2. Indirect effects

In general, the promotion of industrial upgrading, the restructuring of factor endowments and the optimization of energy consumption structures will inevitably have an impact on carbon emissions. In this paper, we will distinguish the pathways affecting carbon emissions and explain the relevant mechanisms of action in the following three aspects.

From the viewpoint of industrial structure, financial development promotes the optimization of industrial structure, the upgrading of industrial structure will face a large amount of capital demand, so it needs the investment of government and social capital, when the capital flows to the green industry can enable enterprises to obtain the capital needed for further development, on the one hand, optimize the proportion of primary, secondary and tertiary industries, on the other hand, gradually eliminate the high energy consumption and high pollution enterprises, the upgrading of industrial structure makes the resource allocation efficiency increase. The upgrading of the industrial structure makes the allocation of resources more efficient, thus achieving an efficient allocation of production factors on a larger scale, thereby enhancing its competitive advantage. The optimization and upgrading of the industrial structure has led to the gradual elimination of energy-intensive enterprises and the gradual increase in the market size of low-carbon enterprises, ultimately promoting the improvement of energy efficiency and the reduction of carbon emissions. In particular, during the period of low financial development, financial development will prompt enterprises in the green industry to improve their business management mode and promote enterprises to reset their initial production equipment thus achieving industrial structure integration and optimization, when carbon emissions increase due to the increased use of resources and energy consumption by enterprises to expand their production scale. Zhou et al. (2021) and Sun et al. (2018) both suggested that changes in industrial structure significantly affect carbon emissions, and that both rationalization and advanced industrial structure are conducive to reducing carbon emissions. When the economy develops to a higher level, pollution levels can be reduced by means of high technology, increasing the cost of treatment while reducing carbon dioxide emissions.

In terms of factor endowment structure, factor endowment structure is an important factor affecting carbon productivity, and its improvement will facilitate carbon productivity growth (Li et al., 2016). Financial development promotes the growth of green industries by improving the efficiency of the use of capital and labour. In terms of capital, the rational use of capital can break the financing constraints commonly faced by enterprises, reverse the difficult financing situation caused by the small scale of business entities, unstable operations and poor risk resistance, improve production processes, optimize management processes and increase production efficiency, financial development can broaden investment and financing channels, and enterprises have more diversified fund-raising channels to obtain investment for production expansion, thus This has a catalytic effect on carbon emissions. On the other hand, through China's continuous investment in education and scientific research, China's education resources are constantly enriched and education infrastructure is gradually improved, cultivating more talents will have a significant effect on the production process of enterprises, thus ultimately realizing the impact of factor endowment restructuring on carbon emissions. In the early stages of financial development, the factor input structure is relatively homogeneous and has a lagging effect. When factors are invested in enterprises, the increase in the amount of capital and labour will bring more profit output, thus attracting more capital and talent to green enterprises. When the factor input reaches a certain level, it will promote the further improvement and optimization of the carbon trading system

and carbon financial market, so as to effectively use the financial market, improve the financing structure, promote technological innovation and achieve the goal of economic growth while reducing energy consumption and pollution emissions, and at the same time achieve the effect of energy saving and emission reduction.

From the perspective of energy consumption structure, the current use of coal for power generation in China is extensive, and the amount of electricity consumption to meet the demand for China's economic development will have a negative externality effect on the environment, leading to an increase in carbon emissions. In the early stage of China's economic development, a large amount of energy resources were consumed for the development of China's industrial infrastructure construction. Zhong et al. (2015) concluded through empirical evidence that the structure of energy consumption has an impact on carbon emissions, and the efficiency of energy use is mainly influenced by the secondary industry. If financial development only increases the economic growth rate without changing the industrial structure, it will intensify energy consumption. By adjusting and optimizing the industrial structure and energy consumption structure, the purpose of reducing carbon emission intensity can be effectively achieved. Financial development promotes the optimization of the energy consumption structure, and governments can understand energy market trends and take measures such as pricing and cross-subsidies to steer energy consumption in a cleaner direction, thereby reducing the negative environmental issues arising from resource consumption. Moreover, financial development provides financing support for efficient, low-pollution and low-energy industries and related enterprises, which allows more capital to flow to green industries to promote their development and promote the optimization and upgrading of industrial structures, thus promoting the achievement of carbon neutrality.

In summary, not only does financial development have a direct effect on carbon emissions, but the carbon emission effect may be influenced by the moderating effects of industrial structure, factor endowment structure and energy structure. Since the above three pathways exist simultaneously for financial development on carbon emissions, based on the above analysis, this paper proposes hypothesis 2:

Hypothesis 2: Industrial structure, factor endowment structure and energy consumption structure have a moderating effect on carbon emissions.

3. Model Construction and Data Selection

3.1. Model design

To examine the impact of financial development on carbon emissions, this paper takes carbon dioxide emissions ($\ln\text{CO}_2$) as the explanatory variable and the level of financial development (FD) as the core explanatory variable. Among them, the three major factors of financial development, namely financial efficiency, financial scale, and financial structure, are incorporated into the model in the form of core explanatory variables to obtain the relationship between financial development and carbon emissions. As structural adjustment requires a certain period, the current year's carbon emission level is often influenced by the previous year's policy situation, so this paper adds the carbon emission level

with a lag of one period into the model, and eliminates the influence of many factors affecting the level of financial development, which has a serious bias on the validity of the empirical results. The squared financial development term is used to test whether the mechanism of financial development on carbon emissions is in an "inverted U-shaped" relationship. A dynamic panel regression model (1) was developed as follows:

$$\ln\text{CO}_{2i,t} = \beta_0 + \beta_1 \ln\text{CO}_{2i,t-1} + \beta_2 \text{FD}_{i,t} + \beta_3 \text{FD}_{i,t}^2 + \gamma X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

where i and t in the model denote region and year respectively, $\ln\text{CO}_{2i,t}$ is the current period emission, and $\ln\text{CO}_{2i,t-1}$ are the first-order lagged terms of the current period emissions of CO denotes the city's level of green financial development in the year, $\text{FD}_{i,t}$ including financial deepening (FDE), financial interrelationship ratio (FIR), and financial intermediaries (FID). $X_{i,t}$ Covers control variables and aims to control for bias in omitted variables. δ_i and λ_t measure area fixed effects and time fixed effects, which $\varepsilon_{i,t}$ are random errors.

Industrial structure (IS), factor endowment structure ($\ln\text{FS}$), and energy consumption structure (MC) are introduced here to examine the structural adjustment effects of financial development. Here, interaction terms are set to investigate the moderating effects of industrial structure, factor endowment structure, and energy consumption structure. Therefore, the following moderation effects are modeled (2):

$$\begin{aligned} \ln\text{CO}_{2i,t} &= \beta_0 + \beta_1 \ln\text{CO}_{2i,t-1} + \beta_2 \text{FD}_{i,t} + \beta_3 \text{FD}_{i,t}^2 \\ &\quad + \beta_4 \text{FD}_{i,t} * \text{IS}_{i,t} + \gamma X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \\ \ln\text{CO}_{2i,t} &= \beta_0 + \beta_1 \ln\text{CO}_{2i,t-1} + \beta_2 \text{FD}_{i,t} + \beta_3 \text{FD}_{i,t}^2 \\ &\quad + \beta_4 \text{FD}_{i,t} * \ln\text{FS}_{i,t} + \gamma X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \\ \ln\text{CO}_{2i,t} &= \beta_0 + \beta_1 \ln\text{CO}_{2i,t-1} + \beta_2 \text{FD}_{i,t} + \beta_3 \text{FD}_{i,t}^2 \\ &\quad + \beta_4 \text{FD}_{i,t} * \text{MC}_{i,t} + \gamma X_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \quad (2) \end{aligned}$$

Compared to the linear model, the moderating effect of the non-linear model is mainly manifested in the fact that the moderating variable can change the location of the critical point and the moderating factor can change the shape of the curve (Haans et al, 2016). The moderating factors can change both the instantaneous rate of change of X to Y, i.e. they can change the steepness of the curve when it is at different levels; and they can change the node at which the relationship between X and Y reverses, so that the reversal point occurs at a higher or lower level (Lin, 2022).

3.2. Data selection and description

The current state of research at home and abroad shows that carbon emissions refer to the emission of greenhouse gases (mainly carbon dioxide), which is expressed in this paper as the logarithm of per capita carbon dioxide emissions ($\ln\text{CO}_2$).

In general, the increase in the level of financial development is often attributed to the increase in the efficiency of financial services, the expansion of the overall scale of finance, and the optimization of the composition of the financial structure. This paper uses urban panel data to comprehensively document the characteristics of financial development. Given the availability of data and the research objectives of this paper, the impact of financial development

on carbon neutrality is also examined from the perspective of financial development, with the main independent variables being financial deepening (FDE), financial interrelationship ratio (FIR) and financial intermediation development (FID) to measure financial efficiency, financial scale, and financial structure respectively.

Financial efficiency (FDE) represents the depth of financial institutions and to a certain extent the efficiency of financial resource allocation in a region, and is expressed as the ratio of loan balances of financial institutions to GDP. Financial size (FIR), the “financial-related ratio”, is the ratio of the value of a country's total financial assets to its national wealth, reflecting the degree of financial of the economy, and is expressed as the ratio of total deposits and loans of financial institutions to GDP. Financial Intermediary Development (FID) describes the structure of financial development in an economy. Resident personal savings deposits reflect how much intermediation is carried out by the banking system and measure the conversion function of financial intermediaries on resident savings, approximated here as the ratio of resident savings deposits to GDP as an indicator of financial structure.

The upgrading of industrial structure is an important means to achieve a coordinated allocation of resources between industries as well as to achieve high-quality economic development. This paper uses the output value of the secondary industry/GDP to measure industrial structure upgrading (IS).Factor endowment structure (lnFS) is an indicator measured by the ratio of factors of production such as labour and capital stock. The indicator is based on a study by Li et al. (2021) and is reflected by taking the logarithm of the ratio of capital to labour. The larger the capital-labour ratio, the more the region tends to have a capital-intensive factor endowment structure. Energy consumption structure (MC) Considering the availability of data and the accuracy of the

research methodology, this paper uses the share of coal consumption in total energy consumption to measure the provincial energy consumption structure by doing group regressions to match other data.

Control variables:

Based on the existing literature, a variety of factors were considered control variables covering: foreign direct investment (lnFDI), population density (lnDENSITY) (Liu and Song, 2020), proportion of government expenditure (PGOV), education per capita (lnEDU), science and technology expenditure (lnRD), and income per capita (lnPGDP) and its squared term (lnPGDP²). In particular, we note here that the large consumption of energy (especially fossil energy) caused by the expansion of the economy is the main cause of the rapid increase in CO₂ emissions. Given that it is not possible to directly count the total amount of energy consumed, we examine here the inclusion of income per capita (lnPGDP) as one of the factors influencing carbon emissions, while taking into account the environmental “Kuznets curve”. Given the existence of the environmental “Kuznets curve”, we will introduce both the logarithm of per capita income and its squared term into the model.

The research period of the article is 2003-2019, a period of rapid economic transformation and booming financial development in China, which provides sufficient data for the conduct of this study. The data are sourced from the China Urban Yearbook, China Regional Economic Statistical Yearbook, China Financial Statistical Yearbook, China Industrial Economic Statistical Yearbook, China Energy Statistical Yearbook and relevant websites. Data with significant anomalies were also Winsor-processed in this paper, and descriptive statistics for all major variables are detailed in Table 1.

Table 1. Variable descriptive statistics

Symbols	Observations	Average	Stv	Min	Max
lnCO ₂	4845	6.2443	1.2793	2.0923	9.8399
FDE	4845	0.2073	0.5135	0	7.3824
FIR	4845	0.5042	1.3231	0	23.7925
FID	4845	0.1313	0.2399	0	3.7310
IS	4836	47.5192	11.1801	10.6800	90.9700
lnFS	4560	13.1050	0.8767	8.6291	15.1424
MC	4845	0.7158	0.1096	0.2141	0.9458
lnFDI	4318	11.5672	1.9395	2.8066	16.8347
lnDENSITY	4845	5.7244	0.9155	1.5476	7.9227
PGOV	4844	0.6167	0.6708	0.0300	10.9377
lnEDU	4837	12.2633	1.2126	6.7262	16.2456
lnRD	4831	9.4366	2.0992	3.5264	16.0820
lnPGDP	4845	10.1532	0.9125	7.5369	13.1851
lnPGDP ²	4845	103.9193	18.6786	56.8051	173.8458

4. Empirical Analysis and Discussion

4.1. Basic model results

The results of the regression in Table 2 show that the coefficient of the squared term between financial development and carbon emissions is significantly negative, and the impact of financial development on carbon emissions shows an open downward curve, indicating that as the level of financial development increases, carbon emissions will also increase, but the higher the level of financial development after turning past the apex, carbon emissions

will decrease, indicating that financial development has a positive effect on the achievement of carbon neutrality in the long term, and this conclusion is consistent with Zhu et al. (2018), which demonstrates the credibility of this paper's research on the impact of financial development on carbon emissions. The reason for this may be that the period chosen for this paper is a critical period of China's industrial structure transformation, where China's economic development has made outstanding achievements and the level of financial development has been improving to provide financial support for the expansion of enterprises' production scale, and enterprises' carbon emissions have increased due to the

expansion of production scale, but the credit efficiency in the process of financial development has increased to speed up the flow of funds and promote enterprises to reduce production costs, which is conducive to achieving carbon neutrality. Thus, hypothesis 1 is initially verified. Based on this, this paper argues that financial development can promote China's

early achievement of the “double carbon” target, which is the intrinsic motivation for the ultimate achievement of carbon neutrality, and that future financial development should continue to be optimized in three aspects: improving financial efficiency, expanding the scale of finance and optimizing the financial structure.

Table 2. Baseline regression

Variables	OLS			FE			SYS—GMM		
	FDE	FIR	FID	FDE	FIR	FID	FDE	FIR	FID
L.lnCO2	0.7091*** (0.0136)	0.7067*** (0.0136)	0.7101*** (0.0135)				0.2109*** (0.0791)	0.1846** (0.0748)	0.2886*** (0.0710)
FDE	0.6511*** (0.1444)			1.8832*** (0.3665)			2.6140*** (0.7566)		
FDE2	-0.7156*** (0.1224)			-1.7968*** (0.2985)			-	2.0105***(0.6445)	
FIR		0.3709*** (0.0685)			0.9424*** (0.1731)			1.1358*** (0.3266)	
FIR2		-0.1669*** (0.0249)			-			-	
FID			1.7774*** (0.2654)			3.4225*** (0.6488)			4.9210*** (1.1928)
FID2			-3.0714*** (0.4297)			-			-
_cons	0.6669 (1.0105)	0.5123 (1.0189)	0.6545 (1.0032)	-3.3926 (2.2863)	-3.5063 (2.2804)	-2.6251 (2.2613)	-6.1852 (8.1480)	-7.6624 (7.8983)	7.3895*** (1.8907)
City-FE	1	1	1	1	1	1	1	1	1
Year-FE	1	1	1	1	1	1	1	1	1
Adj R-squared	0.9558	0.9559	0.9559	0.7428	0.7439	0.7411			
F	287.53 [0.0000]	288.22 [0.0000]	288.29 [0.0000]	98.33 [0.0000]	97.47 [0.0000]	94.77 [0.0000]	4891.95 [0.0000]	4970.20 [0.0000]	4484.17 [0.0000]
N	4040	4040	4040	4307	4307	4307	4040	4040	4040
AR(1)							0.000	0.000	0.000
AR(2)							0.892	0.754	0.944
Hansen							0.219	0.246	0.187

Model (2) was used to further investigate the mechanism of action of the impact of financial development on carbon emissions after the inclusion of structural adjustment. industrial structure (IS), factor endowment structure (lnFS), and energy structure (MC) were selected to explore the impact of financial development on carbon emissions through different structural paths, and the regression results are presented in Table 3. The estimation results show that under the three different paths and moderating effects, the three indicators of financial development The squared terms of all three indicators are significantly negative. The regression coefficients for each interaction term have different characteristics, but either the curve becomes smooth or steep, or the direction of change of the inflection point of the curve shifts to the left or right. In terms of the moderating effect, there is at least a linear or non-linear relationship in the significant cases, indicating that China can change the impact of financial development on carbon emissions through the moderating effect of structural adjustment. It is suggested that in the path of the impact of financial development on carbon neutrality, the different industrial structure sub-dimensions show an increasing and then weakening the moderating effect, and that financial development on carbon emissions does not change the results of the baseline regression under the moderating effect of industrial restructuring. We can see from the calculations that there are more leftward shifts in the inflection point of the curve (columns 1, 2, 5, 7, 8, and 9) than rightward shifts (columns 3, 4, and 6). In the path of the influence of financial efficiency (FDE) on carbon emissions, the inflection point can be shifted to the left through the adjustment of industrial structure and factor endowment structure. Through these paths we can help China achieve the carbon peak as soon as possible by formulating policies that help improve financial efficiency and upgrade the industrial structure and optimize the adjustment of factor endowment structure; while the adjustment of energy consumption structure will shift the inflection point to the right, with the

expansion of financial scale and The adjustment of the energy consumption structure will shift the inflection point to the right, with an increase in the scale of finance and more energy consumption, which will delay the carbon peak, to the detriment of China's achievement of the “double carbon” target. In the path of the influence of financial scale (FIR) on carbon emissions, only the path of structural adjustment of factor endowments can move the inflection point to the left, while for the adjustment of industrial structure and energy consumption structure, the inflection point moves to the right, indicating that the expansion of China's financial scale will result in an increase in carbon emissions, and at this time energy consumption will also continue to increase, even if China's carbon emissions reach the inflection point will also make the carbon peak increase. The inflection points are all shifted to the left in the path of financial structure (FID) on carbon emissions but are not significant in the regulation process of industrial structure and factor endowment structure. The reason for this may be that the financial structure is lagging due to the different mechanisms established by the financial development of each province and city in China, the relatively small share of deposits in commercial banks, or the insufficient upgrading of industrial structure and insufficient factor liquidity in different transmission paths, all of which may inhibit to a certain extent the role in the optimal allocation of resources in regulating the effect. Therefore, the current industrial structure and factor endowment structure, which are lagging in development, are not yet sufficient to create an intrinsic incentive to reduce carbon emissions. Based on this, this paper argues that future structural optimization will help China to achieve the “double carbon” target as soon as possible and that it is necessary to accelerate the upgrading of China's industrial structure and factor market reform to further release market dynamics, as well as to adjust the energy consumption structure and reduce pollution emissions caused by energy consumption through green technology and clean energy. This will be done through green

technology and clean energy to reduce pollution emissions caused by energy consumption.

Table 3. Mechanisms of regulatory effects

Variables	FDE			FIR			FID		
	IS	LnFS	MC	IS	LnFS	MC	IS	LnFS	MC
L.lnCO2	0.3107*** (0.0632)	0.2038** (0.0797)	0.5165*** (0.0609)	0.2904*** (0.0634)	0.2926*** (0.0677)	0.2778*** (0.0650)	0.3477*** (0.0670)	0.4733*** (0.0617)	0.4741*** (0.0621)
FDE	10.5611*** (2.3079)	12.9830*** (3.5739)	4.0518* (2.2711)						
FDE2	-6.2281*** (1.0353)	-3.6855*** (0.8498)	-6.8685*** (1.1428)						
FIR				2.9003*** (0.5450)	9.9112*** (2.2568)	2.5467** (1.0838)			
FIR2				-1.1636*** (0.2013)	-1.5311*** (0.2682)	-1.1997*** (0.2109)			
FID							27.8049*** (5.6557)	26.7876*** (7.5478)	20.3960*** (4.7278)
FID2							15.9023*** (4.5649)	22.7029*** (3.5888)	20.7662*** (3.6439)
IS	0.0206*** (0.0079)			0.0141* (0.0076)			0.0507*** (0.0113)		
LnFS		0.0814 (0.1790)			0.2523* (0.1385)			-0.0616 (0.1055)	
MC			-0.0732 (0.5866)			1.1110 (0.8359)			2.1387*** (0.6621)
Primary interaction item	-0.0916** (0.0388)	-0.6767*** (0.2316)	3.7185 (2.7218)	0.0038 (0.0172)	-0.4969*** (0.1457)	0.4963 (1.2726)	-0.3992*** (0.1056)	-1.0277** (0.4842)	-10.7103** (5.1572)
Secondary interaction item	0.0009** (0.0004)	-0.0017** (0.0007)	0.0904* (0.0494)	0.0001** (0.0001)	0.0002* (0.0001)	0.0098** (0.0048)	-0.0068 (0.0046)	0.0078 (0.0063)	0.4405* (0.2493)
_cons	4.2968 (8.1825)	7.1235 (8.5788)	-9.4938* (5.1753)	1.9003 (8.1470)	0.9709 (8.3801)	-3.8971 (8.2563)	21.5820** (9.8269)	-5.4074 (5.3588)	-13.2193** (5.7513)
Control variables	1	1	1	1	1	1	1	1	1
N	4035	4040	4040	4035	4040	4040	4035	4040	4040
City-FE 和 Year-FE	1	1	1	1	1	1	1	1	1
AR(1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2)	0.136	0.938	0.141	0.176	0.372	0.182	0.284	0.121	0.185
Hansen	0.284	0.175	0.217	0.292	0.299	0.323	0.219	0.230	0.246

4.2. Heterogeneity analysis

Resource-based cities and non-resource-based cities have long had large differences in financial development standards due to differences in the industrial structure, financial policies, and resource endowments of each region, which have hindered cross-regional flows and cooperation in green finance, and there may also be large gaps in financial development levels. Resource-based cities have made historic contributions to the establishment of China's economic development and industrial construction, while non-resource cities are inferior to resource-based cities in terms of regional location, level of science and education, and size, which can also affect the benefits of structural adjustment on the regulation of financial development affecting carbon emissions. To verify the difference in the impact of financial development on carbon emissions due to this difference, this paper further divides resource cities and non-resource To verify the difference in the impact of financial development on carbon emissions due to this difference, this paper further divides resource and non-resource cities to analyze the heterogeneity of the impact of green financial development on carbon emissions. The classification of resource and non-resource cities is based on the State Council's National Sustainable Development Plan for Resource-based Cities (2013-2020), which further improves the policy system for promoting the sustainable development of resource-based cities and is a strong guarantee for China to eventually achieve carbon neutrality.

The results, as shown in Tables 4 and 5, show that there are significant differences between resource and non-resource

cities in terms of the moderating effect of financial development on carbon emissions through structural adjustment. Specifically, almost all of the quadratic interaction terms for resource cities are significant, with the inflection points shifting to the left, indicating that the non-linear adjustment of financial development through structural adjustment helps China to achieve carbon neutrality, while none of the quadratic interaction terms for non-resource cities are significant, with only a few showing either increasing or decreasing linear adjustment effects. The reason for such a large difference may be that the country has selected typical resource-rich areas to carry out pilot projects, and resource cities have thus become early demonstration zones for sustainable development by their rich geographical resources and location advantages, making high-energy-consuming, high-polluting and high-emission projects better developed than those in non-resource cities. In contrast, non-resource cities have a single industrial cultivation structure, imperfect infrastructure, and low overall resource utilization, which cannot support the green transformation of the city. Based on this, this paper argues that financial institutions in resource cities can be guided and encouraged to increase their lending support for sustainable development on the premise of risk prevention; actively explore diversified and distinctive development models, and increase policy support for non-resource cities will play a greater role in enhancing non-resource cities. By adjusting the financial structure and improving the efficiency of energy use, it may be possible to improve the problem of the non-linear adjustment effect of energy consumption restructuring in resource cities.

Table 4. Tests for moderating effects in resource cities

Variables	FDE			FIR			FID		
	IS	LnFS	MC	IS	LnFS	MC	IS	LnFS	MC
L.lnCO2	0.8118*** (0.0823)	0.7862*** (0.0747)	0.7919*** (0.0780)	0.7466*** (0.0848)	0.7825*** (0.0696)	0.8012*** (0.0637)	0.8044*** (0.0777)	0.8195*** (0.0695)	0.8266*** (0.0866)
FDE	15.5161** (4.2943)	10.8341 (9.2534)	5.8262 (4.8796)						
FDE2	-	-16.6777* (9.9477)	-11.7929* (6.5935)						
FIR				1.0514 (0.9148)	6.1385* (3.4098)	1.2269 (1.9689)			
FIR2				-0.9621 (1.1176)	-2.6373 (1.8577)	-0.7468 (1.2024)			
FID							37.2188** (9.5121)	25.0527** (9.9834)	7.6666 (5.1547)
FID2							-64.7202** (26.1643)	-27.7593* (15.4528)	-6.5546 (11.4855)
IS	0.0100 (0.0070)			-0.0053 (0.0071)			0.0250*** (0.0075)		
LnFS		0.0296 (0.1061)			0.0511 (0.0983)			0.2721** (0.1349)	
MC			0.5173 (0.6564)			0.4527 (0.6342)			
Primary interaction item	0.1848*** (0.0502)	-0.4153 (0.5016)	-2.2838 (6.6892)	0.0013 (0.0178)	-0.3191* (0.1681)	-0.7860 (2.1273)	-0.3890*** (0.1198)	-1.3195*** (0.4954)	-1.9263** (5.4041)
Secondary interaction item	0.0209*** (0.0066)	-0.0767*** (0.0271)	-1.2193*** (0.4215)	-0.0045** (0.0022)	-0.0179*** (0.0060)	-0.2592** (0.1138)	0.0036 (0.0842)	-0.1387** (0.0645)	-1.9263** (0.8346)
_cons	18.8602** (8.9937)	23.0491*** (7.0052)	22.5984*** (6.6652)	22.2174*** (6.0514)	28.6813*** (7.3053)	27.7786*** (7.6961)	15.2602* (7.9523)	28.7207*** (8.0864)	27.5067*** (7.6554)
Control variables	1	1	1	1	1	1	1	1	1
Year-FE	1	1	1	1	1	1	1	1	1
AR(1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR(2)	0.264	0.244	0.232	0.233	0.238	0.227	0.273	0.182	0.181
Hansen	0.814	0.987	0.974	0.946	0.848	0.935	0.762	0.872	0.947

Table 5. Tests for moderating effects in non-resource cities

Variables	FDE			FIR			FID		
	IS	LnFS	MC	IS	LnFS	MC	IS	LnFS	MC
L.lnCO2	0.0498 (0.1084)	0.1379 (0.1090)	0.1520 (0.0984)	0.0598 (0.1047)	0.1453 (0.1081)	0.1452 (0.1008)	0.0553 (0.0987)	0.1395 (0.1151)	0.1671* (0.0996)
FDE	5.2369 (3.5081)	10.6780 (7.0507)	9.8095*** (3.4689)						
FDE2	-1.7426* (1.0495)	-2.7380* (1.5030)	-2.0560 (0.8058)						
FIR				2.2283** (0.9691)	4.1400 (4.0143)	6.5752*** (2.2498)			
FIR2				-0.5313* (0.2959)	-0.6550* (0.3506)	-0.5685*** (0.2151)			
FID							24.9858*** (7.4852)	-29.6543 (19.8468)	11.3775 (7.8763)
FID2							-16.5690*** (5.8878)	-8.0253 (6.9061)	-12.2346** (5.2021)
IS	0.0499** (0.0209)			0.0441** (0.0183)			0.0509* (0.0278)		
LnFS		0.4626* (0.2557)			0.4894 (0.3142)			0.2223 (0.3084)	
MC			1.9160 (1.6024)			3.4385* (2.0576)			1.6395 (2.0120)
Primary interaction item	-0.0369 (0.0701)	-0.4337 (0.3894)	-8.4779** (4.2359)	-0.0116 (0.0286)	-0.1213 (0.2364)	-6.3126** (2.9062)	-0.2793** (0.1284)	2.7637* (1.4005)	-2.9228 (10.3780)
Secondary interaction item	-0.0023 (0.0016)	-0.0047 (0.0040)	-0.1322 (0.0988)	-0.0002 (0.0002)	-0.0004 (0.0005)	-0.0111 (0.0139)	0.0002 (0.0058)	0.0045 (0.0186)	-0.1813 (0.4679)
_cons	9.0809 (17.4967)	-22.3685 (15.2054)	-20.7040 (14.8211)	9.4960 (19.0349)	-19.9656 (16.0981)	-13.0768 (15.1504)	23.8170 (19.8750)	-12.4954 (16.7758)	-1.2127 (17.5188)
N	2443	2448	2448	2443	2448	2448	2443	2448	2448
Control variables	1	1	1	1	1	1	1	1	1
Year-FE	1	1	1	1	1	1	1	1	1
AR(1)	0.000	0.000	0.000	0.001	0.003	0.001	0.000	0.000	0.000
AR(2)	0.221	0.193	0.329	0.296	0.217	0.345	0.518	0.691	0.698
Hansen	0.250	0.170	0.178	0.238	0.165	0.211	0.679	0.339	0.148

4.3. Robustness tests

The results of this paper are shown in Table 6 by replacing the measurement of the explanatory variables with LnPCO2 instead of LnCO2 and adding the measurement of the control variable (LnK). The impact of green financial development on

carbon emissions all show an “inverted U-shape”, and there is no significant difference between the estimated results and significance of all variables, only minor changes in specific values, which shows that the empirical results of this paper are reliable.

Table 6. Robustness test

Variables	LnPCO2			+LnK		
	FDE	FIR	FID	FDE	FIR	FID
L.	0.2806*** (0.0670)	0.2717*** (0.0659)	0.2722*** (0.0679)	0.5299*** (0.0580)	0.5022*** (0.0610)	0.4999*** (0.0600)
FDE	5.1713*** (1.4398)			5.1556*** (0.9513)		
FDE2	-5.0470*** (1.3699)			-		
FIR		3.0096*** (0.6403)		5.0618*** (0.8691)	2.9195*** (0.4917)	
FIR2		-1.1793*** (0.2570)			-	
FID			10.3885*** (2.1671)		1.1827*** (0.1898)	
FID2			-			10.1110*** (1.6851)
			15.6413*** (4.2271)			15.9918*** (2.8112)
_cons	-	-	-16.7343** (7.3853)	-	-	-11.8082** (4.6583)
	17.9036*** (6.3122)	18.1798*** (6.6185)		10.3806** (4.9284)	11.5338** (5.2782)	
Control variables	1	1	1	1	1	1
Year-FE	1	1	1	1	1	1
AR (1)	0.000	0.000	0.000	0.000	0.000	0.000
AR (2)	0.217	0.187	0.164	0.157	0.138	0.115
Hansen	0.162	0.136	0.153	0.238	0.259	0.204
N	4040	4040	4040	4040	4040	4040

5. Conclusion and Recommendations

Achieving carbon neutrality will not only help China achieve the ecological and environmental goals of green water and green mountains but also help China achieve structural transformation, which is crucial for China to achieve sustainable economic development. This paper constructs a model based on dynamic panel data of 285 cities in 30 provinces in China from 2003 to 2019, and conducts regressions using a systematic GMM approach to measure financial development from the perspectives of financial efficiency, financial scale, and financial structure, and considers the industrial structure, factor endowment structure, and energy consumption structure as moderating variables to explore the impact, mechanism of action and heterogeneity of financial development on carbon neutrality, followed by threshold regression analysis, and three main conclusions are drawn: (1) Not only does financial development directly affect the level of carbon dioxide emissions, but the three pathways of industrial structure, factor endowment structure and energy consumption structure can regulate the impact of financial development on carbon dioxide emissions. The significant and “inverted U-shaped” effect of financial development on China's carbon emissions indicates that financial development can effectively contribute to China's carbon neutrality in the long run; (2) structural adjustment has a moderating effect on the impact of financial development on carbon emissions, with different structural sub-dimensions not changing the curve of the impact of financial development on carbon emissions. (3) There is regional heterogeneity between resource cities and non-resource cities, and the impact of financial development on carbon emissions is more significant in resource cities than in non-resource cities. The impact of financial development on carbon emissions has a double threshold, when the level of financial development crosses the corresponding threshold, its effect on carbon

emissions will successively appear inflection point significantly weakened, until finally producing an inhibitory effect.

Although the moderating effect is not entirely statistically significant, it can be said that the impact of green financial development on carbon emissions differs under different impact paths, and we still need to tailor our policies to local conditions and precise measures and implement different policies for different regions or industries. As the world's largest emitter of carbon dioxide, China is now faced with many difficulties in the implementation of carbon emission reduction, and the implementation of strong macroeconomic policies is crucial to achieving carbon neutrality. Based on the above findings, this paper will propose the following suggestions for optimizing financial development and policies related to industrial structural change from both government and enterprise perspectives.

The government should continuously improve the financial development system and use economic policies to guide the transformation and upgrading of enterprises and consumer preferences to change the layout of financial development, such as improving the efficiency of financial development, expanding the scale of financial development, and improving the structure of financial development as mentioned in this paper, to realize the coupling between financial development and structural adjustment.

In the process of achieving carbon emission targets, we have to consider the relationship between the whole and the local. On the whole, we call for a joint national effort to achieve carbon emissions and carbon neutrality, consider the overall picture to do a good job of co-ordinated planning of green policies, accelerate the construction of a green financial standards system, strengthen the green regulation of the financial structure, improve the green information disclosure system applicable to the current development, and policy incentives and constraints to ensure the coordinated progress

of various industries. At the national level, the government has formulated fiscal and monetary policies in favor of the green direction; fiscal policies support the development of low-carbon industries and provide financial subsidies, tax concessions, etc.; monetary policies provide preferential interest rates on loans and green credit for relevant enterprises; at the same time, financial policies are used to help in the capital market, encourage enterprises to use green bonds, replace traditional energy structures with green technologies, clean energy, and other elements, and The government should also encourage enterprises to use green bonds, replace traditional energy structures with green technologies and clean energy, and improve industrial structures and factor endowment structures. At the same time, the “double carbon” target should adopt a differentiated control policy, combining regional characteristics to formulate industrial policies, strengthen cooperation and exchange between regions, and form an industrial circle with complementary advantages to promote the transformation and upgrading of industrial structures. As individual industries may encounter bottlenecks or take a wrong turn in the process of restructuring and reform, simultaneous carbon peaking may have an energy rebound effect, causing more uncertainty and damage to China's sustainable economic development. According to the findings of this paper resource cities and non-resource cities in different areas and at different stages of financial development, we need to develop different mechanisms to promote financial development, in resource city areas in terms of policy, financial support has tended to saturate, can give full play to the efficiency, scale, and structure of financial development to promote the role of exemplary leadership through the implementation of industrial transfer, enhance energy consumption structure, etc. In non-resource cities, efforts should be made to focus on technological innovation to reduce emissions, eliminate outdated industries, and find ways to cross the threshold, to better promote the achievement of the “double carbon” goal.

To create a higher level of profit, enterprises need to transform their industrial structure, upgrade their factor endowment structure and optimize their energy structure, and through the effective improvement of these three structural adjustments, they will upgrade their production technology, factors of production, and energy power, and therefore financial development can contribute to the achievement of the carbon neutrality target. Enterprises can consider the purchase of environmentally friendly production equipment, carbon emission allowances, or capacity reduction to achieve industrial structure optimization; promote factor endowment structure optimization to upgrade production equipment, optimize production processes, and improve organizational management; replace traditional energy structures with green technology, clean energy, and other elements, thus promoting the transformation and upgrading of traditional high energy consumption, high pollution, and high emission industries, as a means to achieve the carbon neutrality target The paper concludes by arguing that we need to look beyond the traditional energy consumption and emission industries.

Finally, this paper argues that we need to think beyond carbon reduction, as the fundamental goal behind carbon emissions is sustainable development, and that a comprehensive and profound transformation is needed under the overall layout of ecological civilization. Only through concerted efforts in the fields of industrial structure upgrading, factor market improvement, and energy structure

optimization can we effectively promote the ultimate realization of the great goal of “double carbon”.

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