

# Study on the Impact of Financial Development on Carbon Emissions: Empirical Tests Based on Provincial Panel Data in China

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**Abstract.** With the goal of “carbon peaking” and “carbon neutrality”, an effective financial system can guide the allocation of funds to green industries, accelerate the adjustment and optimization of industrial and energy structures, and achieve green development. Based on the panel data of 30 provinces in China from 2003 to 2019, this paper constructs a two-way fixed-effect panel model to investigate the impact of China's financial development level on carbon emissions and the differences between regions with different economic conditions and stages of financial development. The following conclusions are obtained from the empirical tests: In general, China's financial development suppresses on carbon dioxide emissions. The impact of financial development on carbon emissions is also regionally heterogeneous within China. The financial development exerts a more significant inhibitory effect on carbon emissions in the western region, which has relatively poorer economic conditions and higher levels of carbon emissions, but not in the eastern region. After China experienced the financial crisis in 2008, thanks to the reform and improvement of the financial system, the suppression effect of financial development on carbon emissions is more significant and stronger.

**Keywords:** Financial Development; Carbon Emission Intensity; Heterogeneity Impact; Two-way Fixed Effect.

## 1. Introduction

With the social and economic development, global warming caused by carbon dioxide emissions not only affects the sustainable development of economy and society, but also threatens the living conditions of human beings. Preventing climate change, improving the ecological environment and safeguarding the living conditions have become urgent issues for human beings to solve. In September 2020, General Secretary Xi Jinping solemnly announced to the world at the United Nations General Assembly that "China's carbon dioxide emissions will strive to peak by 2030, and it will strive to achieve carbon neutrality by 2060. " How to achieve high-quality economic development under the constraints of "double carbon" is an issue that China needs to explore in depth. Finance is the blood of modern economy and plays an important role in the allocation and optimization of resources. An effective financial system can guide the allocation of funds to green industries, accelerate the adjustment and optimization of industrial structure and energy structure, and thus achieve green development.

There has been a wealth of previous research on the topic of the key factors affecting carbon emissions. Panayotou (1993) first introduced the concept of "Environmental Kuznets Curve (EKC)", which suggests that environmental pollution and economic growth are in an "inverted U-shaped" curve [1]. Tamazian et al. (2009) focused on financial development as a key factor affecting environmental quality and showed that financial development can reduce pollutant emissions and improve environmental quality [2]. Salahuddin (2015) studied some countries in the Middle East and found that financial development can help promote technological progress and improve energy efficiency, thus reducing environmental pollution emissions [3]. Jalil and Feridun (2011) also found that financial development can reduce carbon dioxide emissions by analyzing Chinese panel data and demonstrated the existence of an environmental Kuznets curve in China [4]. He Jun. et al. proposed that credit size of financial institutions, financial market financing size and environmental pollution are negatively correlated and technology effect plays a mediating role [5]. Shahbaz et al. (2013) also

argued that financial development will achieve a curbing effect on carbon emissions by motivating enterprises to upgrade their technology and increase the importance of environmental protection [6]. However, Salahuddin et al. (2018), based on data from 1980 to 2013 in Kuwait, found that both FDI (foreign direct investment) and financial development promote carbon emissions [7]. Sadorsky (2010) and Sorrell (2009) also believed that financial development has contributed to the increase in carbon emissions and that the increase in the level of financial marketization has contributed to the increase in the level of technology through the introduction of R&D investment and foreign direct investment [8]. The rapid growth of the economy and society through the effects of technological progress generates a larger demand for energy consumption, leading to an increase in energy consumption and carbon emissions [9]. Similarly, Dogan & Seker (2016) pointed out that a country's financial development will be accompanied by an increase in its level of economic development, which inevitably generates a greater demand for resources and thus an increase in carbon emissions [10]. Zhang (2011) also found that China's financial development is a major driver of carbon dioxide emissions [11]. Hu Zongyi et al. (2019) argued that there are two types of financial development on environmental pollution, namely scale effect and technology effect, and the final impact depends on the relative size of the two. When the scale effect is greater than the technology effect, financial development presents a promoting effect on carbon emissions, and vice versa, a suppressing effect [12]. Xiong Ling (2016) found that financial development plays a negative role on carbon emissions in China's provinces and regions, both from the perspective of per capita carbon emissions and carbon emission intensity [13]. Hu Jianbo (2020) believed that the effect of money and credit on carbon emissions is inverted U-shaped and there is a threshold effect of environmental regulation [14].

In summary, the academic community can confirm that financial development in China has an impact on carbon dioxide emissions, but the direction of the impact is still open to debate. Moreover, China has only been reforming and opening-up for more than 40 years, and the economic system and financial system are still in the stage of maturity. However, there are still big differences between different regions within China, and regional heterogeneity may still exist. Therefore, this paper will study the following issues: What is the impact of China's financial development status on carbon emissions at this stage? Does the financial development status of different regions with different levels of economic development have different effects on carbon emissions? Do different stages of financial development have different effects on carbon emissions? The scientific and reasonable answers to the above questions are of theoretical and practical significance for the use of finance to achieve carbon emissions reduction.

## 2. Model Construction and Data Description

### 2.1 Measurement of Model Setting

Based on the above theoretical analysis, this paper establishes a two-way fixed-effect benchmark panel regression model to empirically analyze the impact of financial development on carbon emissions. The benchmark model is set as follows.

$$\text{Strength}_{it} = \alpha_0 + \beta_1 FD_{it} + \beta_2 GDP_{it} + \beta_3 Pop_{it} + \beta_4 Open_{it} + \beta_5 TI_{it} + \beta_6 Is_{it} + \beta_7 Gov_{it} + \beta_8 Ec_{it} + \mu_i + \sigma_t + \varepsilon_{it}$$

In this equation,  $\text{Strength}_{it}$  represents the logarithmic value of the carbon dioxide intensity in province  $i$  in year  $t$ .  $FD_{it}$  represents the logarithm of financial development level.  $GDP_{it}$  represents the logarithm of GDP per capita level in the region.  $Pop_{it}$  represents the logarithm of population density.  $Open_{it}$  represents the degree of openness to the outside world.  $TI_{it}$  represents the level of technological innovation.  $Is_{it}$  represents the industrial structure.  $Gov_{it}$  represents the level of government intervention.  $Ec_{it}$  represents the structure of energy consumption.  $\mu_i$ ,  $\sigma_t$ ,  $\varepsilon_{it}$  are individual and time effects and random disturbance terms respectively.

## 2.2 Variable Selection

$$\text{Strength}_{it} = \frac{J_{it}}{GDP_{it}} = \frac{\sum_{s=1}^7 J_{it}^s}{GDP_{it}} = \frac{\sum_{s=1}^7 F^s \times E_{it}^s \times \frac{44}{12}}{GDP_{it}}$$

(1) Explained variable: carbon dioxide emission intensity. The carbon dioxide emission intensity is obtained by dividing the total carbon dioxide emissions of a region by the real GDP of that year. Since there is no data on carbon dioxide emissions at the provincial level, the carbon dioxide emissions of each province are calculated using the consumption of seven major fossil fuels, including coal, coke, gasoline, kerosene, diesel, fuel oil and natural gas, from the 2006 IPCC Greenhouse Gas Emission Guidelines Catalogue, considering that carbon dioxide in China mainly comes from the combustion of fossil energy. The specific formula for calculating carbon dioxide emission intensity is as follows.

Where:  $J_{it}$  denotes the total carbon dioxide emissions of province  $i$  in year  $t$  with respect to the real GDP,  $s=1, 2, 3, \dots, 7$  representing coal, coke, gasoline, kerosene, diesel, fuel oil and natural gas respectively.  $E_{it}^s$  denotes the consumption of energy  $s$  in standard coal in year  $t$  of province  $i$ .  $F^s$  denotes the carbon emissions factor of energy  $s$  in tons/ton of standard coal, and  $44/12$  is the conversion factor of carbon in carbon dioxide.  $GDP_{it}$  denotes the real GDP of province  $i$  in year  $t$ , calculated using constant prices in 2003.

(2) Explanatory variables: financial development. This paper measures the level of financial development in terms of financial deepening (Depth) and financial efficiency (FEF). The deepening of financial development is generally reflected in the scale of its capital financing, and the larger the scale of borrowed funds, the deeper the financial development. Therefore, the indicator of financial deepening is expressed by "total credit of regional financial institutions/GDP". In China, the state-owned sector has a key role in both politics and economy, and it has a higher voice in the financial system, which distorts the market allocation of financial resources to a certain extent and reduces the efficiency of the financial system. The efficiency of financial development in this paper is expressed by "(total loans/GDP)  $\times$  (1 - total fixed asset investment in the state-owned sector / total fixed asset investment in the whole society)".

(3) Control variables. Economic development (GDP): measured by the logarithm of GDP per capita of the province. Population density (Pop): measured by the logarithm of the ratio of total population to land area of the province. Openness to the outside world (Open): measured by the ratio of total imports and exports to GDP of each province. Technological innovation level (Ti): measured by the ratio of total number of patents to total population. Industrial structure (Is): measured by the ratio of added value of tertiary industry to added value of secondary industry. Government intervention (Gov): measured by the level of government fiscal expenditure to GDP; Energy consumption structure (Ec): measured by the ratio of coal consumption to energy consumption.

## 2.3 Data Sources

To ensure the continuity and availability of data, the data sample in this paper consists of panel data from 30 provinces in mainland China (Tibet and Hong Kong, Macao and Taiwan are excluded due to missing data) from 2003-2019. The data are mainly obtained from *China Statistical Yearbook*, *China Energy Statistical Yearbook*, *China Financial Statistical Yearbook*, and provincial statistical yearbooks. Table 1 shows the descriptive statistics of the main variables.

**Table1.** Descriptive statistics of the main variables

| Variables | Description                                  | Description | Average value | Standard deviation | Minimum value | Maximum value |
|-----------|----------------------------------------------|-------------|---------------|--------------------|---------------|---------------|
| Strength  | Carbon emission intensity (logarithmic form) | 510         | 1.078         | 0.704              | -0.843        | 2.879         |
| Depth     | Financial deepening (logarithmic form)       | 510         | -0.151        | 0.331              | -0.974        | 0.593         |
| FEF       | Financial efficiency (logarithmic form)      | 510         | -0.528        | 0.372              | -1.572        | 0.348         |
| GDP       | GDP per capita (logarithmic form)            | 510         | 0.835         | 0.669              | -0.998        | 2.436         |
| Pop       | Population density (logarithmic form)        | 510         | 5.436         | 1.278              | 2.000         | 8.278         |
| Open      | Openness to the outside world                | 510         | 0.653         | 1.146              | 0.011         | 7.223         |
| Ti        | Technology innovation level                  | 510         | 1.031         | 0.572              | 0.494         | 5.169         |
| Is        | Industry structure                           | 510         | 0.681         | 0.285              | 0.017         | 1.758         |
| Gov       | Government intervention                      | 510         | 6.54          | 9.675              | 0.13          | 60.144        |
| Ec        | Energy consumption structure                 | 510         | 0.216         | 0.097              | 0.077         | 0.628         |

### 3. Empirical Analysis

#### 3.1 Benchmark Regression Analysis

This paper investigates the linear relationship between financial development and carbon emissions in China by using two-way fixed-effect panel model constructed above, and the regression results are shown in Table 2. The regression results show that the two core explanatory variables on financial development and financial deepening (Depth) and financial efficiency (FEF) are significant at 5% with negative coefficients. It indicates that both financial deepening and efficiency in general in China can reduce carbon dioxide emissions per unit of GDP. The inhibitory effect of financial development on carbon emissions is mainly through promoting technological progress, promoting industrial structure transformation, and reducing energy consumption per unit of output, thus reducing carbon dioxide emissions.

As for the control variables, the regression results show that the coefficient of industrial structure on carbon emissions is negative and significant at 1%, indicating that carbon dioxide emissions have been decreasing with the optimization and upgrading of industrial structure. The main reason is that since the reform and opening-up, China's economy has relied on the "high emission, low output" secondary industry, and has developed the economy at the expense of the environment, resulting in a crude production method in the past. However, with the economic development and social changes, China's industrial structure continues to transform, and the contribution of the "low emission, high output" tertiary sector to the economy continues to grow, thus bringing less pollution emissions and higher economic value added. The coefficient of government spending on carbon emissions is positive and significant at 1% for both financial development indicators, indicating that the increasing government spending has exacerbated carbon dioxide emissions. The main reason is that the spending of our government is mainly through investments, and most of the investments go to high emission sectors such as transportation and real estate, thus leading to an increase in carbon dioxide emissions. Similarly, the coefficient of the effect of energy consumption structure on carbon emissions is positive and significant at 1%, indicating that the coal-based energy consumption structure should put a greater pressure on our environment.

**Table 2.** Benchmark regression results

| Variables       | Regression (1)       | Regression (2)       |
|-----------------|----------------------|----------------------|
| Depth           | -0.170**<br>(-2.29)  |                      |
| FEF             |                      | -0.179**<br>(-2.73)  |
| GDP             | -0.311*<br>(-1.71)   | -0.265<br>(-1.59)    |
| Pop             | 0.419<br>(1.11)      | 0.361<br>(1.06)      |
| Open            | 0.000<br>(0.11)      | 0.004<br>(0.42)      |
| Is              | -0.194***<br>(-6.49) | -0.181***<br>(-6.11) |
| Ti              | 0.000<br>(0.14)      | 0.001<br>(0.26)      |
| Gov             | 1.017***<br>(3.54)   | 0.974***<br>(3.94)   |
| Ec              | 1.279***<br>(10.41)  | 1.294***<br>(11.11)  |
| Constant term   | -1.816<br>(-0.88)    | -1.627<br>(-0.87)    |
| Time effect     | Control              | Control              |
| Regional effect | Control              | Control              |
| Sample size     | 510                  | 510                  |
| R <sup>2</sup>  | 0.9417               | 0.9433               |

### 3.2 Sub-sample Regression Analysis

Different regions in China are largely different, and in order to discuss the influence of spatial heterogeneity on financial development and carbon emissions, this paper classifies the above 30 provinces, cities and autonomous regions into the eastern coastal region (eastern region) and the central and western inland coastal region (central region and western region) according to the administrative division regions. Meanwhile, after experiencing the global financial crisis in 2008, China's financial system has also been reformed, and the impact of financial development on carbon emissions may also vary depending on the progress of the financial system. Therefore, this paper divides the sample into two stages according to the annual year: 2003-2008 and 2009-2019. According to the above division, the two-way fixed-effect panel model constructed in the previous section was used for sub-sample regressions, and the results are shown in Table 3.

The regression results for the sub-sample by region are shown in the first four columns of Table 3. The results show that the effect of financial development on carbon emissions is not significant in the eastern region, where the economic development conditions are better. In the central and western regions, both indicators of financial development have a significant and negative effect on carbon emissions at 1%, which is consistent with the regression results of the overall sample. The main reason may be that the more developed economic conditions in the eastern region, the carbon emissions sector has higher environmental awareness and more strict environmental regulation, which makes the local carbon emissions already face stronger constraints. At the same time, the carbon emissions sectors in the eastern region choose to migrate to the central and western regions when they face higher carbon emissions costs, thus the local carbon emissions sectors are fewer and have more advanced industrial structures, and financial support has less impact on carbon emissions. Therefore, the impact of financial development on carbon emissions in the eastern region is not significant. In the central and western regions, on the one hand, the original industrial structure is based on the "high emission, low output" crude production method, which has the characteristics of high carbon emissions, and after further taking over the transfer of high carbon emissions sectors

from the eastern regions, the transformation of the industrial structure is hindered, and the carbon emissions continue to grow. On the other hand, the conditions of education, technology and infrastructure are weaker in the central and western regions. With the guidance of national policies, the financial system continues to provide support to such sectors, and technological innovation leads to the improvement of production processes, while reducing the support to high carbon emissions sectors, thus the negative effect of financial development on carbon emissions is more significant.

**Table 3.** Sub-sample Regression Results

| Variable<br>s       | Eastern Region        |                      | Midwest Region       |                      | 2003-2008            |                      | 2009-2019          |                      |
|---------------------|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|--------------------|----------------------|
|                     | Regressio<br>n<br>(1) | Regressio<br>n (2)   | Regressio<br>n (3)   | Regressio<br>n (4)   | Regressio<br>n (5)   | Regressio<br>n (6)   | Regressio<br>n (7) | Regressio<br>n (8)   |
| Depth               | 0.053<br>(0.76)       |                      | -0.375***<br>(-3.63) |                      | -0.174*<br>(-1.95)   |                      | -0.210*<br>(-1.95) |                      |
| FEF                 |                       | 0.024<br>(0.51)      |                      | -0.287***<br>(-3.36) |                      | -0.091<br>(-1.26)    |                    | -0.282***<br>(-3.41) |
| GDP                 | -0.075<br>(-0.67)     | -0.076<br>(-0.66)    | -0.231<br>(-0.90)    | -0.226<br>(-0.89)    | -0.015<br>(-0.07)    | 0.005<br>(0.03)      | -0.334<br>(-1.21)  | -0.259<br>(-1.08)    |
| Pop                 | -0.612***<br>(-4.44)  | -0.606***<br>(-4.33) | 1.485**<br>(2.59)    | 1.204**<br>(2.23)    | -0.161<br>(-0.30)    | -0.270<br>(-0.51)    | 1.063*<br>(1.90)   | 1.091**<br>(2.36)    |
| Open                | -0.007*<br>(-2.19)    | -0.007*<br>(-2.20)   | 0.027<br>(0.53)      | 0.039<br>(0.78)      | 0.103<br>(1.02)      | 0.113<br>(1.05)      | 0.000<br>(0.04)    | 0.005<br>(0.64)      |
| Is                  | -0.058**<br>(-2.45)   | -0.057**<br>(-2.43)  | -0.139<br>(-1.52)    | -0.113<br>(-1.25)    | -0.203***<br>(-3.06) | -0.199***<br>(-3.00) | -0.066<br>(-1.16)  | -0.038<br>(-0.71)    |
| Ti                  | 0.001<br>(1.21)       | 0.001<br>(1.24)      | 0.003<br>(0.29)      | 0.004<br>(0.44)      | -0.004<br>(-0.64)    | -0.002<br>(-0.28)    | -0.002<br>(-1.13)  | -0.001<br>(-0.60)    |
| Gov                 | 0.881**<br>(2.99)     | 0.809**<br>(2.50)    | 0.747***<br>(2.96)   | 0.797***<br>(2.94)   | -0.594<br>(-1.17)    | 0.527<br>(-0.96)     | 0.669<br>(1.62)    | 0.396<br>(1.13)      |
| Ec                  | 1.528***<br>(14.05)   | 1.516***<br>(14.37)  | 1.197***<br>(13.47)  | 1.233***<br>(15.13)  | 1.099***<br>(7.33)   | 1.104***<br>(7.65)   | 1.066***<br>(7.48) | 1.101***<br>(9.72)   |
| Constant            | 3.899***<br>(4.08)    | 3.881***<br>(3.96)   | -6.634**<br>(-2.42)  | -5.520**<br>(-2.12)  | 1.658<br>(0.57)      | 2.179<br>(0.77)      | -5.139<br>(-1.61)  | -5.465**<br>(-2.05)  |
| Time                | Control               | Control              | Control              | Control              | Control              | Control              | Control            | Control              |
| Regiona<br>l effect | Control               | Control              | Control              | Control              | Control              | Control              | Control            | Control              |
| Sample              | 187                   | 187                  | 323                  | 323                  | 180                  | 180                  | 330                | 330                  |
| R2                  | 0.9862                | 0.9861               | 0.9449               | 0.9448               | 0.7077               | 0.6997               | 0.9331             | 0.9392               |

The regressions for the subsample by time period are shown in the last four columns of Table 3. The results show that before 2008, although the effect of financial development on carbon emissions is also negative, only financial deepening (Depth) is significant at 10%. Specifically, financial deepening (Depth) is a significant coefficient at 10%, while financial efficiency is a significant coefficient at 1%, and the absolute value of the coefficient will be higher than that of the previous stage. The main reason may be that after the financial crisis in 2008, China was also hit by a big shock and realized that our immature financial system still needed continuous reform. After that, the financial system was more perfect, financial instruments were more abundant, the efficiency of fund using was improved, and funds were efficiently used in sectors such as technology, education and the more innovative and dynamic private sector, technology effect is more obvious. At the same time, with the increasing awareness of environmental protection, the policy guidelines for green finance have become clearer and the financial support for each sector has become more precise. The financial support provided to the old "high energy consumption, high emission" sectors has been continuously weakening. Therefore, after 2008, the negative effect of financial development on carbon emissions will become more significant.

### 3.3 Conservatism Analysis

In order to improve the credibility of the empirical findings of this paper, the conservatism test is conducted by excluding municipalities under the premise that two different core explanatory variables have been taken as follows.

Due to the varying levels of development of Chinese cities, especially the municipalities directly under the central government, Beijing, Tianjin, Shanghai and Chongqing, which have much larger economic volumes than other cities, this paper excludes the samples of these municipalities and tests the impact of financial development on carbon emissions again, and the results are shown in Table 4. It can be seen that the two core explanatory variables indicating the level of financial development, financial deepening (Depth) and financial efficiency (FEF), are not significantly different from the previous regression results, confirming the conservatism of the previous empirical results.

**Table 4.** Conservatism test results

| Variable        | Regression(1)        | Regression(2)        |
|-----------------|----------------------|----------------------|
| Depth           | -0.247***<br>(-3.49) |                      |
| FEF             |                      | -0.201***<br>(-2.97) |
| GDP             | -0.062<br>(-0.29)    | -0.060<br>(-0.27)    |
| Pop             | 1.306***<br>(2.92)   | 1.144**<br>(2.70)    |
| Open            | -0.016<br>(-1.05)    | -0.012<br>(-0.80)    |
| Is              | -0.116**<br>(-2.40)  | -0.101*<br>(-1.95)   |
| Ti              | -0.001<br>(-0.44)    | -0.001<br>(-0.39)    |
| Gov             | 0.801***<br>(3.18)   | 0.824***<br>(3.51)   |
| Ec              | 1.178***<br>(10.94)  | 1.200***<br>(11.23)  |
| Constant term   | -6.219**<br>(-2.69)  | -5.530**<br>(-2.51)  |
| Time            | Control              | Control              |
| Regional effect | Control              | Control              |
| Sample          | 442                  | 442                  |
| R <sup>2</sup>  | 0.9398               | 0.9400               |

## 4. Conclusion and Insights

Based on the panel data of 30 provinces in China from 2003 to 2019, this paper constructs a two-way fixed-effect panel model with two indicators, financial deepening (Depth) and financial efficiency (FEF), representing the level of financial development as the core explanatory variables and carbon emission intensity as the explanatory variable, to investigate the impact of China's financial development level on carbon emissions and how that impact varies between regions with different economic conditions and stages of financial development. The following conclusions are finally obtained: In general, China's financial development suppresses on carbon dioxide emissions. The impact of financial development on carbon emissions is also regionally heterogeneous within China, with financial development having a more significant inhibitory effect on carbon emissions in the central and western regions, where economic conditions are relatively poor and carbon emissions levels are higher, but not in the eastern regions. After China experienced the financial crisis in 2008,

thanks to the reform and improvement of the financial system, the suppression effect of financial development on carbon emissions is more significant and stronger.

Based on this conclusion, this paper puts forward the following policy recommendations: First, we need to continuously promote the reform of the financial system, unblock the transmission mechanism of monetary policy, support the development of green finance, guide the transfer of funds to the low carbon and green sectors, and promote the structural transformation of China's economy. Secondly, we should accelerate the process of China's independent innovation, and promote the development of China's low carbon economy with innovation drive. It is supposed to provide fiscal tax and financial support for the corresponding sectors, encourage enterprises to accelerate technological innovation and low carbon technology research and development, and promote the application and promotion of advanced low carbon technologies. Third, the policy needs to consider the industrial structure, energy consumption structure and economic base of different regions, the essential characteristics of different industries, and differentiate the carbon constraints according to the situation of different regions or industries, so that carbon emissions reduction can be carried out under the premise of ensuring stable and efficient economic development. Fourth, with effective energy supply being ensured, we need to support new energy, reduce the use of traditional energy, accelerate the conversion of old and new energy, improve the energy structure, and thus carbon emissions can be reduced through the optimization of energy structure.

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