Research on the Impact of Financial Development on Carbon Emissions: Does Industrial Structure Upgrading Matter?

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Abstract. The purpose of the study tries to investigate the impact of financial development on carbon emissions. In addition, the study also examines the mediating effect of industrial structure upgrading on the relationship between financial development and carbon emissions. Using annual data of 283 cities in China over the period 2006 to 2019, the study employs natural logarithm of carbon emission as dependent variable and credits and deposits scaled by GDP as independent variable to financial development. The study also has mediator of industrial structure upgrading. In addition, the study adds FDI, government spending, fixed investment and population as control variables in estimation regression. The empirical results of the study reveal that financial development has a significant and negative impact on carbon emissions. The study also finds that industrial structure upgrading has a mediating effect on the relationship between financial development and carbon emissions.

Keywords: Financial Development · Carbon Emissions · Industrial Structure Upgrading · Greenhouse Gas Effect

1 Introduction

Recently, greenhouse gas effect has substantially caused environmental degradation, which indicates carbon emissions are a serious issue in global climate-change problem. Resulting from the rapid economic growth in the world, large amounts of carbon emissions have gradually increased, which leads to a negative impact on global economic activities and life quality of human being.

Prior studies have mentioned the main factors to affect environmental degradation. The hypothesis of Environmental Kuznets Curve (EKC) suggests that economic growth causes environmental degradation in the early stage of economic development, and then, economic growth reaching at the level of threshold leads to lower environmental degradation [1][2]. Some studies explore the factors affecting carbon emissions by using STIRPAT model modified from IPAT model, which indicates main factors of population, growth and technology affect environmental degradation [3]. In addition, decomposition index approach presents the factors of population, GDP per capita, energy intensity and carbon emissions intensity reduce carbon emissions [4].

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However. The issue on the relationship between financial development and carbon emissions has attracted increasing attention. First, some previous studies support that financial development has positive impact on carbon emissions [5][6]. On the other side, some studies show the negative impact of financial development on carbon emissions [7][8].

According to previous studies, there are lots of theoretic literature on the nexus of financial development and carbon emissions. For further extending research fields, the study tries to use annual data of 283 cities in China over the period 2006 to 2019 to explore the mediating effect of industrial structure upgrading as a transmission channel from financial development to carbon emissions.

The study has five sections. The first section is introduction. The second section describes the literature review and presents the hypotheses. The third section presents data and methodology. The fourth section shows empirical results. Final section presents conclusion.

2 Literature Review

The study discusses the empirical literature on the impact of financial development on carbon emissions and summarizes the transmission channels as moderating effects between financial development and carbon emissions.

2.1 Financial Development and Carbon Emissions

It exists relationship between financial development and carbon emissions [7][9]. Most studies conclude the positive impact of financial development on carbon emissions. In case of India, Boutabba [10] finds there is a long-run unidirectional causality running from financial development to carbon emissions and also finds the long-run cointegration between carbon emissions, financial development, economic growth, energy consumption and trade openness. Cetin and Ecevit [11] also find financial development, economic growth and trade openness have positively affect carbon emission in the long run, and the environmental Kuznets curve (EKC) hypothesis is valid for Turkey.

Conversely, some studies reveal the negative impact of financial development on carbon emissions. Saidi and Mbarek [12] employ the data of emerging countries over the period 1990–2013 to examine the impact of financial development and other factors on carbon dioxide emissions and reveal financial development has negative impact on carbon emissions. In Malaysian case, Maji et al. [13] use the Cobb-Douglas production function and Autoregressive Distributed Lag (ARDL) approach to examine the impacts of financial development on sectoral carbon emissions (CO2) and results reveal that financial development reduces CO2 emissions from manufacturing and construction sectors. Zhou et al. [14] utilize panel-threshold model and take technological progress, energy intensity, energy structure, and economic structure as threshold variables, and findings show that there is a threshold effect in the impact of financial development on carbon dioxide emissions and financial development can effectively promote carbon emission reduction.

Over the past several decades, China has experienced rapid economic growth, which leads to the one of largest carbon emitters in the world. Following the above situation, financial sectors have provided large amounts of capital for firms to purchase fixed equipment to produce goods, and also extended individual loans for consumers to buy cars and durable appliances. But, Chinese government has presented policy of green financing to direct green economic development, which mitigates carbon emissions. This may direct lots of carbon emissions.

According to the theoretical concept and facts, the study presents the following hypothesis:

H1: Financial development has negative impact on carbon emissions.

2.2 Mediators on the Relationship Between Financial Development and Carbon Emissions

The previous studies explore the linkage between financial development and carbon emissions. Furthermore, some studies argue that financial development may reduce carbon emission through economic growth [5][9][15], industrialization [16], FDI [9][16], income inequality [5][17], and technological innovation [16] and energy consumption [16].

In case of 29 Chinese provinces, Hao et al. [15] use the panel data from 1996 to 2012 to explore the relationship between financial development and environmental quality. The empirical results show that financial development and environmental performance are inverted U-shaped functions of GDP per capita. Xu et al. [16] use the sample of 42 countries and panel data 1990–2018, and research findings show that financial development affects CO2 emissions through three channels: industrialization, economic growth, and energy consumption. The study confirms three relationships. (1) the impact of financial development on CO2 emissions changes from negative to positive as industrialization and energy consumption increase. (2) financial development has a positive impact on CO2 emissions when per-capita income is between $1100 and $8100 but a negative impact when per-capita income is less than $1100 or greater than $8100. (3) the economic growth channel is the Granger cause of the energy consumption and technological progress channels.

According to the theoretical concept and facts, the study presents the following hypothesis:

H2: Industrial structure upgrading has mediating effect on the relationship between financial development and carbon emissions.

3 Data and Methodology

3.1 Data and Sample

The annual data of the study over the period from 2006 to 2019 are selected from Statistic Bureau of China. The samples of the study include 283 cities in China and the study has totally 3760 observations.

3.2 Research Variables

3.2.1 Dependent Variable

Researchers have commonly used carbon emissions, carbon emissions intensity, and carbon emissions per capita to measure the environmental degradation. Thus, the study employs carbon emissions as the dependent variable to measure environmental degradations, which is:

$$\mathrm{CE} = \mathrm{LN}(\text{Carbon emissions}) \tag{1}$$

3.2.2 Independent Variable

The study employs credits and deposits to private sector scaled by GDP to measure financial development as independent variable. The measurement is as follows:

$$\mathrm{FD} = \frac{\text{Creidts and Deposits}}{\text{GDP}} \tag{2}$$

3.2.3 Mediating Variable

The study uses industrial structure upgrading as a mediating variable, which is measured as follows:

$$\begin{aligned}\mathrm{ISUP} = & \frac{\text{output velue of the first industry}}{\text{GDP}} * 1 \\ & + \frac{\text{output value of the second industry}}{\text{GDP}} * 2 \\ & + \frac{\text{out value of the tertiary industry}}{\text{GDP}} * 3\end{aligned} \tag{3}$$

3.2.4 Control Variable

The study adds FDI, government spending, fixed investment and population as control variables into estimation regression.

The summary of all variables is shown in Table 1.

3.3 Mediation Analysis

The study examines relationship between financial development and carbon emissions through mediating variables and direct relationship between financial development and carbon emissions. Referring to study of Baron and Kenny [18], the study proposes the following regression equations:

$$\mathrm{CO}_2 = \mathrm{a}_0 + \mathrm{a}_1\,\mathrm{FD} + \gamma + \varepsilon_1 \tag{4}$$

Table 1. Research variables

Variables	Name	Code	Measure
Dependent variable	Carbon emissions	CO_2	$CO_{2ti} = \sum_{j=1}^{16} CO_{2tij} = \sum_{j=1}^{16} E_{tij} \times CEF_j$
Independent variable	Financial development	FD	LN(Credits and Deposits from financial institutions)
Moderating variable	Industrial structure upgarding	ISUP	$\frac{I}{GDP}*1 + \frac{II}{GDP}*2 + \frac{III}{GDP}*3$
Control variable	Foreign direct investment	FDI	FDI/GDP
	Government spending	GS	GS/GDP
	Fixed investment	FI	FI/GDP
	population	POP	LN(POP)

$$MV_{it} = b_0 + b_1\,FD + \delta + \varepsilon_2 \tag{5}$$

$$CO_2 = c_0 + c_1\,FD + c_2\,MV + \zeta + \varepsilon_3 \tag{6}$$

where, CO_2 is per capita carbon emissions in metric tons. FD is measured as domestic credits provided by financial institutions scaled by GDP. MV is measured by different variables of GDP, Technology, FDI, and Industrial Structural Upgrading. γ, δ and ζ are control variables, a_0, b_0 and c_0 are constant items and ε_1, ε_2 and ε_3 are error items.

If coefficient of c_1 is significant, this reveals total effect of FD on CO_2. As FD has significant effect on MV and MV has significant effects on CO_2 in Eq. (4) and (5), this exists indirect effect. In addition, in the Eq. (6), coefficient of c_1 is significant, this indicates there exists partial mediating effect, while coefficient of c_1 is insignificant, this shows there exists full mediating effect. In summary, total effect of a_1 equals to the sum of direct effect of c_1 and indirect effect of b_1*c_2.

By controlling error items, the study adds control variable of population, income, FDI, fixed assets openness, and formation into estimated model.

3.4 Research Models

To test the hypothesis of the impact of financial development on carbon emissions, the study constructs the estimated model as follows:

$$CE_{it} = \alpha_0 + \alpha_1\,Credit_{it} + \alpha_2\,POP_{it} + \alpha_3\,INC_{it} + \alpha_4\,FDI_{it} + \alpha_5\,OPEN_{it} + \alpha_6\,FCF_{it} + \alpha_n \sum year + \varepsilon_{it} \tag{7}$$

Further to test the hypothesis of the indirect effect of industrial structure upgrading on relationship between financial development and carbon emissions, the study constructs the estimated models as follow:

$$CE_{it} = a_0 + a_1\,Credit_{it} + a_2\,POP_{it} + a_3\,INC_{it} + a_4\,FDI_{it} + a_5\,OPEN_{it}$$

Table 2. Results of Description Analysis

Var	Obs.	Mean	Max	Min	Std
CO_2	3,961	6.153	9.603	2.019	1.210
FD	3.960	2.249	21.297	0.235	1.214
ISUP	3,962	2.263	2.832	1.831	0.144
FDI	3,768	0.003	0.042	2.62e-07	0.003
GS	3,961	0.183	2.074	0.039	0.116
FI	3,954	0.736	7.653	0.087	0.354
POP	3,961	5.863	7.653	2.868	0.696

$$+ a_6 \, FCF_{it} + a_n \sum year + \varepsilon_{it} \tag{8}$$

$$ISUP_{it} = b_0 + b_1 \, Credit_{it} + b_2 \, POP_{it} + b_3 \, INC_{it} + b_4 \, FDI_{it} + b_5 \, OPEN_{it} + b_6 \, FCF_{it} + b_n \sum year + \varepsilon_{it} \tag{9}$$

$$CE_{it} = c_0 + c_1 \, Credit_{it} + c_1 \, ISUP_{it} + c_2 \, POP_{it} + c_3 \, INC_{it} + c_4 \, FDI_{it} + c_5 \, OPEN_{it} + c_6 \, FCF_{it} + c_n \sum year + \varepsilon_{it} \tag{10}$$

4 Empirical Results

4.1 Description Analysis

Table 2 indicates the characteristics of all variables. Referring to the Table 2, the value of CO_2 is between 9.603 and 2.019, which is more stable. The value of FD is between 21.297 and 0.235, which is not stable.

4.2 Correlation Analysis

Table 3 shows the correlation relationship of any two variables among all independent and control variables. The correlation coefficients of any two variables are less than 0.7, which indicates any one of independent and control variables can explain dependent variable independently.

4.3 Regression Results

According to Table 4, the results of the study show that FD has significant and negative impact on CO_2, which does not support the hypothesis 1.

Based on Table 4, Z-value in Sobel test on model 2–1, 2–2 and 2–3 is 30.81 and is significant in the level of $p = 0.000$. It indicates ISUP has a mediating effect on the

Table 3. Results of Correlation Analysis

Corr.	FD	IS	FDI	GS	FI	POP
FD	1.000					
IS	0.615***	1.000				
FDI	0.196***	0.252***	1.000			
GS	0.346***	-0.122***	-0.050***	1.000		
FI	0.212***	-0.018	0.163***	0.542***	1.000	
POP	0.069**	0.081***	0.065***	-0.127***	-0.045**	1.000

*** p < 0.01,** p < 0.05,* p < 0.1, values in () are Std. Err.

Table 4. Results of Estimation Regression

Var	Model1 CO_2	Model 2–1 CO_2	Model 2–2 ISUP	Model 2–3 CO_2
FD	-0.074*** (0.015)	0.524*** (0.014)	0.090*** (0.002)	0.103*** (0.017)
ISUP				4.684*** (0.129)
FDI	6.481* (3.513)	38.486*** (5.293)	4.223** (0.576)	18.707*** (4.586)
GS	0.743*** (0.153)	-4.800*** (0.194)	-0.555*** (0.021)	-2.199*** (0.182)
FI	0.080** (0.031)	-0.022 (0.054)	0.008 (0.006)	-0.061 (0.046)
POP	0.047 (0.115)	0.365*** (0.024)	-0.005** (0.003)	0.388*** (0.020)
C	5.333*** (0.676)	3.608*** (0.147)	2.172*** (0.016)	-6.566*** (0.307)
Year	Yes	Yes	Yes	Yes
Obs.	3,760	3,760	3,760	3,760
R-squared	0.659	0.395	0.515	0.553
Fixed effect	Yes	Yes	Yes	Yes
Sobel-test	Z = 30.81, P = 0.000			
Mediating effect	mediating effect/total effect = 80.43%			

*** p < 0.01,** p < 0.05,* p < 0.1, values in () are Std. Err.

relationship between FD and CO_2. In model 2–1, FD has significant positive impact on CO_2 with coefficient of 0.524, which represents the total effect of FD on CO_2. In model 2–3, FD has significant positive impact on CO_2 with coefficient of 0.103, which represents the direct effect of FD on CO_2. In addition, FD has significant impact on ISUP

Table 5. Robustness Test of Estimation Regression

Var	Model 1 CO_2	Model 2–1 CO_2	Model 2–2 ISUP	Model 2–3 CO_2
FD	-0.277*** (0.064)	1.290*** (0.051)	0.090*** (0.002)	0.307*** (0.066)
ISUP				10.921*** (0.504)
FDI	-19.299 (14.452)	47.042** (18.884)	4.223*** (0.576)	0.922 (17.933)
GS	-0.056 (0.631)	-8.658*** (0.693)	-0.555*** (0.021)	-2.594*** (0.711)
FI	-0.794*** (0.128)	-1.519*** (0.191)	0.008 (0.006)	-1.608*** (0.181)
POP	-2.583*** (0.473)	-2.005*** (0.085)	-0.005* (0.003)	-1.952*** (0.080)
C	16.774*** (2.781)	14.012*** (0.523)	2.172*** (0.016)	-9.712*** (1.201)
Year	Yes	Yes	Yes	Yes
Obs.	3,760	3,760	3,760	3,760
R-squared	0.324	0.253	0.515	0.336
Fixed effect	Yes	Yes	Yes	Yes
Sobel-test		Z = 20.3, P = 0.000		
Mediating effect		mediating effect / total effect = 76.20%		

*** $p < 0.01$,** $p < 0.05$,* $p < 0.1$, values in () are Std. Err.

with coefficient of 0.090 in model 2–2, while ISUP has significant impact on CO_2 with coefficient of 4.684 in model 2–3. This indicates there is an indirect effect with value of 0.4215 (= 0.090*4.684). The ratio of indirect effect to total effect is 80.43%. Thus, this supports the hypothesis 2.

4.4 Robustness Test

For examining the robustness of model, the study replaces dependent variable of $LN(CO_2)$ with CO_2 per capita. According to Table 5, it shows that FD has significant and negative impact on CO_2, which does not support the hypothesis 1. In addition, according to Table 4, Z-value in Sobel test on model 2–1, 2–2 and 2–3 is 30.81 and is significant in the level of $p = 0.000$. It indicates ISUP has a mediating effect on the relationship between FD and CO_2. Eventually, this gives evidence that the model is robustness.

5 Conclusion

The purpose of this study employs annual data of 283 cities in China over the period 2006 to 2019 to investigate the effect of financial development on carbon emissions and whether mediating effect of industrial structure upgrading on the relationship between financial development and carbon emissions.

According to the empirical results, the study concludes that financial development has a significant and negative impact on carbon emissions. The study also finds that industrial structure upgrading has a mediating effect on the relationship between financial development and carbon emissions with indirect effect.

The study would suggest that financial sector should operate in compliance with the policy of green financing set by government, which mitigates carbon emissions. In addition, it is suggested to adjust industrial structure in transmission from energy consumption-based industries to clean energy consumption-based industries.

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