

Research Article

Financial Development and Carbon Emissions: Analyzing the Role of Financial Risk, Renewable Energy Electricity, and Human Capital for China

Yiping Guo 

School of Finance and Trade, Zhengzhou Shengda University of Economics, Business & Management, Zhengzhou, China

Correspondence should be addressed to Yiping Guo; guo_yiping66@hotmail.com

Received 24 May 2021; Revised 29 June 2021; Accepted 9 July 2021; Published 27 July 2021

Academic Editor: Ahmed Farouk

Copyright © 2021 Yiping Guo. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

This study introduces the role of financial risk index and renewable energy electricity output along with financial development and human capital as new determinants of carbon emissions and uses updated time-series data from 1988–2018 for China, employing novel econometric approaches, i.e., Narayan and Popp unit root test with structural breaks, Maki cointegration, and frequency domain causality test for long, short, and medium run causality. The empirical outcome shows that improvement in human capital index and rising shares of renewable energy in electricity output help to limit carbon emissions. In contrast, gross domestic product, financial risk index, and structural break of 2001 increase carbon emissions. Moreover, structural break year of 2008 and financial development index reduces carbon emissions. The negative association between financial development and carbon emissions supports the positive school of thoughts of financial development which promotes sustainable environment. This study recommends promotion of quality human capital and green financial development along with increasing the shares of renewable energy in electricity for achieving China 2030 climate targets of reducing pollution.

1. Introduction

One of the most severe challenges the contemporary world is facing over the years is climate change, which has affected the sustainability of life on Earth. The increasing trend in global atmosphere has created unprecedented problems for the human lives and other lives on Earth. It is widely recognized that due to rapid industrialization, emissions of CO₂ in the recent decades has increased to an unprecedented high level, which has caused the global temperature on rise. The worldwide CO₂ emissions have increased from 22,149.4 million tons in 1990 to 36,390.3 million tons in 2018 [1]. In recent years, the rapid growth in economic activities, along with population growth and globalization, has caused an increase in CO₂ and other greenhouse gas emissions, posing a severe threat to the ecosystem [2]. Continuous rise in global economy with a 3 to 4 percent annual growth rate poses a severe risk to the environmental sustainability due to high-energy demand. These factors, along with globalization

and urbanization, cause the temperature to rise by 4–6°C. The total particles of CO₂ have reached 413 parts per million in air, which has increased the Earth's temperature by 1.9 Fahrenheit in the last 50 years [3]. Despite several global negotiations and accords, the level of greenhouse gases is on the rise. In this pursuit, countries are implementing strategies to restrict the emission level [4]. Being the largest carbon emitter, China's continuous economic growth may inevitably cause more carbon emissions in the future [5]. In 2016, China's share in worldwide CO₂ emissions was 27.3% [6]. However, in line with Paris Climate Agreement, the country is expected to control its CO₂ emissions by switching the industrial structure to more sustainable energies.

The literature on the responsible factors of environmental degradation is quite rich. Income is the most discussed factor of environmental degradation [7]. The relationship between income and environment is empirically tested by the environmental Kuznets curve (EKC)

hypothesis, which demonstrates an inverted U-shaped relationship between the level of income and CO₂ emissions. The EKC hypothesis is extensively validated by majority of empirical studies. However, these studies are criticized on the ground of incomplete model specification and incomprehensive proxies used for environmental degradation. Hence, researchers included other important variables while testing the EKC hypothesis. In the literature, several determinants of environmental degradation have been highlighted. The most widely identified determinants of environmental degradation are income, industrialization, international trade, urbanization, deforestation, population, energy consumption, etc. [8]. Moreover, renewable energy consumption, eco-innovation, energy efficiency, and human capital are considered important factors for improving environmental quality [9]. Researchers such as Tamazian et al. [10] and Shahbaz et al. [11] included financial development as an important factor of environmental degradation. Later on, a series of studies were carried out to examine the influence of the financial system on environmental quality. The possible relationship between financial development and CO₂ emissions is still debatable and researchers have not been reached to a clear conclusion that whether the later positively related with the former or the other way round. On the effect of financial development on CO₂ emissions, three different outcomes such as positive, negative, and insignificant are reported in [12]. It is argued that financial development affects environment via energy consumption [13]. On the one hand, due to the improved financial system, households get more financial products, which enable them to have access to high-energy demanding products. On the other hand, firms can afford to buy more high-energy products, which increase the energy consumption. An increase in households' and firms' demand for energy leads to more CO₂ emissions. Hence, financial development positively affects CO₂ emissions [14]. Moreover, financial development may affect environmental degradation by boosting industrialization and generating wealth by increasing risk diversification, which in turn affects CO₂ emissions. However, Tamazian et al. [10] argues that financial development attracts foreign direct investment (FDI), which has positive impact on environmental quality. Knowledge spillovers through FDI and international trade are the most effective way to transfer green technologies from one country to another. Hence, FDI strengthens the positive relationship between financial development and environmental quality. Since, foreign firms invest more in R&D, which improves the environmental quality, because of high R&D expenditures, firms may adopt energy efficient and eco-innovative production methods. These eco-innovative methods switched the industrial structure from less efficient energy production to high-energy efficient production and, hence, have strong positive impact on environmental sustainability [15]. Financial development enables firms and government to invest more in eco-innovative and energy efficient methods, which improve environmental sustainability [16]. This study analyzes the financial development-environment nexus in the case of China over the period of 1988–2018. Previous studies were

carried out to examine the financial development-environment nexus keeping in account FDI, R&D, energy consumption, and governance of the country. However, to the best of our knowledge, no study has been carried out to include financial risk and renewable energy electricity in financial development-environment nexus of China.

2. Literature Review

Due to the catastrophic effects of climate change on human lives, the determinants of heat-trapping gases, especially CO₂ emissions is the topic of great interest for academia, researchers, and environmentalists. The issue has received growing attention of researchers in recent years due to the various climate agreements which took place. The issue of possible determinants of environmental degradation is extensively discussed in [7, 17–20] and [4, 21, 22]. The literature on the impact of financial development on economic growth and other macroeconomic indicators is quite rich [23, 24]. Moreover, the relationship between financial development and environmental quality is widely studied with contradictory empirical evidences [13, 25–32]. The literature in this regard can be divided into three major schools. The first school of thought backed by Dasgupta et al. [33], Claessens and Feijen [34], Tamazian and Rao [25], Tamazian et al. [10], and Khan et al. [35] argues that the relationship between financial development and CO₂ emissions is negative, i.e., an improvement in the financial system improves the environmental quality by enabling firms to adopt energy efficient and eco-innovative production methods. Financial development reduces carbon emissions by declining production cost, enhancing products competitiveness, using energy efficient technology, and controlling energy cost. Projects related to financial development are in line with carbon reduction goals and most focus is given to cleaner energy. Moreover, financial institutions finance those projects which are environmentally friendly and do not increase emissions [36, 37]. Dasgupta et al. [33], in case of developing countries, Acheampong [13], in case of 46 sub-Saharan Africa countries, Ali et al. [30], in case of Nigeria, Baloch et al. [29], in case of Saudi Arabia, Çetin and Ecevit [38] and Cetin et al. [28], in case of Turkey, Charfeddine and Kahia [31], in case of MENA region, and Jiang and Ma [36], in a global perspective, found a negative association between financial development and CO₂ emissions. These authors suggest that, in order to restrict carbon emissions, a strong financial system is a prerequisite.

The second school of thought backed by Abbasi and Riaz [39] and Sadorsky [14] argues that FD positively affects CO₂ emissions. Abbasi and Riaz [39], in case of emerging economies, Karimzadeh et al. [37], in case of Iran, and Sadorsky [14], in case of emerging economies, found that the relationship between financial development and CO₂ emissions is positive.

The existing literature provides deep insight into the dynamics of the financial development-environment nexus. First, previous studies have used incomprehensive proxies for financial development. For instance, to measure financial development, several authors have used the ratio of the sum

of deposits and loans to GDP. Moreover, several authors have proxied financial development by financial intermediation efficiency, financial scale development, and financialization [40]. However, these proxies are greatly criticized on the ground of weak and incomplete nature. For example, in case of China, 20–35% of deposits are not transferred into loans in the past decade, and hence, there is widespread difference between the deposits and loans. Henceforth, the ratio of deposits to GDP is an incomprehensive proxy of financial development.

In case of China, several studies have been carried out to examine the financial development-environment nexus [40–42]. These empirical studies mostly involve cointegration and causality methods. It is argued that the relationship between FD and CO₂ emissions depends on the proxy used for financial development. For instance, Huang and Zhao [42] and Jalil and Feridun [43] argue that financial efficiency and financialization as proxies for financial development are negatively related with CO₂ emissions, while financial scale development as proxy of financial development exacerbates CO₂ emissions in case of China. The present study uses the most comprehensive proxy for financial development, which takes into account the financialization and efficiency.

To sum up, the existing literature on the relationship between FD and CO₂ emissions is rich. However, the role of financial development in the presence of financial risk, renewable energy electricity, and human capital has never

been studied before. This study introduces renewable energy electricity as new determinant of CO₂ emission in the case of China.

3. Methodology and Theoretical Framework

3.1. Theoretical Framework, Model, and Data. This study empirically analyzes the relationship between CO₂ emissions with its determinants including financial development, GDP, financial risk, renewable energy electricity and human capital in case of China over the period from 1988 to 2018. The dependent variable used in the empirical models is carbon emissions (CO₂), measured in million tons and obtained from [46]. We use the production-based measures of CO₂ emissions. Financial development is proxied by Financial Development Index (FDI) of IMF (2019). Financial risk is proxied by an index, which measures the overall financial risk of a country and its financial system ability. The FRI ranges from 0–50. Renewable energy electricity (REE) is calculated by renewable electricity as a percent of total electricity generation. The data on REE is taken from World Bank [45]. The data of human capital index is taken from Penn World. The basic model to estimate the impact of financial development, GDP, financial risk, renewable energy electricity, and human capital on CO₂ emissions is given as

$$\begin{aligned} \text{CO}_{2t} &= \pi_1 \text{FDI}_t + \pi_2 \text{FDI}_t + \pi_3 \text{GDP}_t + \pi_4 \text{REE}_t + \pi_5 \text{FRI}_t + \pi_6 \text{HC}_t + \varepsilon_t, \\ \text{CO}_{2t} &= \pi_1 \text{FDI}_t + \pi_2 \text{FDI}_t + \pi_3 \text{GDP}_t + \pi_4 \text{REE}_t + \pi_5 \text{FRI}_t + \pi_6 \text{HC}_t + D2001 + \varepsilon_t, \\ \text{CO}_{2t} &= \pi_1 \text{FDI}_t + \pi_2 \text{FDI}_t + \pi_3 \text{GDP}_t + \pi_4 \text{REE}_t + \pi_5 \text{FRI}_t + \pi_6 \text{HC}_t + D2008 + \varepsilon_t. \end{aligned} \quad (1)$$

On the effect of financial development on CO₂ emissions, we expect a negative impact of FD on CO₂ emissions. FD enables firms and government to invest more in eco-innovative and energy efficient methods, which improve environmental sustainability. An increase in economic activities (represented by GDP) is expected to increase CO₂ emissions. There is a common consensus among researchers regarding the positive effect of GDP on CO₂ emissions. Furthermore, renewable energy in electricity and human capital development are expected to abate CO₂ emission in China. An improvement in human capital enables countries to implement the eco-friendly technologies to switch the industrial structure to more sustainable energies. Moreover, the use of renewable energies in electricity generation is important in abating CO₂ emissions in the atmosphere. Hence, renewable energy in electricity generation may be considered as an optimal solution to energy security and environmental sustainability. Furthermore, improvement in financial risk is expected to deteriorate the environmental quality in China. The theoretical rationale for the negative impact of financial risk on CO₂ emissions is that since improvement in financial risk is associated with several factors such as curbing foreign debt service, improvement in

net international liquidity and stability of exchange rate is strongly related with economic activities. Hence, an improvement in financial risk leads to rise in different economic activities which in turn cause energy consumption from fossil fuel to rise and increase carbon emissions.

We include the structural break for the years 2001 and 2008. The structural break year 2001 and 2008 are linked with China inclusion into the world trade organization (2001) and the financial crises (2008). Hence, this study examines the impact of financial development, GDP, financial risk, renewable energy electricity, and human capital on CO₂ emissions keeping in account the structural breaks of 2001 and 2008. Table 1 provides descriptive analysis of all variables included in this study. The average value of carbon emissions is 6.70 kt, financial development index is 0.690, GDP 12.47 US dollars, financial risk index is 40.74, human capital index is 2.21, and renewable energy electricity output is 1.27% of the total. Moreover, the volatility is indicated through standard deviations. Similarly, the normality of the data is confirmed using Jarque–Bera (JB) test. The null hypothesis of the JB test is accepted, which supports that data are normally distributed [46].

TABLE 1: Descriptive statistics.

	CO ₂	FDI	GDP	FRI	HCI	REE
Mean	6.701275	0.690934	12.47480	40.74194	2.212740	1.271154
Median	6.657096	0.732926	12.46299	45.29167	2.246171	1.257401
Maximum	7.012497	0.790875	13.03635	48.00000	2.566427	1.408900
Minimum	6.374657	0.509210	11.88344	23.00000	1.825441	1.177162
Std. dev.	0.236087	0.086320	0.367684	9.010722	0.220368	0.062061
Jarque–Bera	3.292653	4.474465	2.069934	3.451729	1.525213	3.515126
Probability	0.192757	0.106754	0.355238	0.665490	0.466449	0.172465

Note: $P \leq 0.01$, $<0.05^{**}$, and 0.1^* , respectively.

3.2. Analytical Techniques

3.2.1. Narayan and Popp [47] Unit Root Test. Before examining the long run relationship among variables in models 1 to 3, we employ Narayan and Popp (NP) unit root test to check the integration order of variables. The NP test is based on the methodology of augmented Dickey–Fuller (ADF) test. The main reason of using the NP test is that it takes into account the structural break. Due to its high power in accurately identifying the structural breaks, the test is considered superior over other conventional unit root tests. NP test can trace up two structural breaks in the data series both in level and difference form. Identifying the structural breaks is important due to the fact that ignoring these may provide biased and inconsistent results [47].

3.2.2. Bayer and Hanck (BH) Cointegration Test (without Structural Breaks). To check the cointegration among variables in models, this study employs Bayer and Hanck cointegration test, popularized by Bayer and Hanck [48]. The test is based on the methodologies of Johansen (J), Engle-Granger (EG), Boswijk (Bo), and Banerjee (Ba) tests. The necessary condition for employing BH test is that all variables must be first-difference stationary. The test equation is given as

$$\begin{aligned} EG - J &= -2 \left[\ln(P^{EG}) + \ln(P^J) \right], \\ EG - J - Bo - Ba &= -2 \left[\ln(P^{EG}) + \ln(P^J) + \ln(P^{Bo}) \right. \\ &\quad \left. + \ln(P^{Ba}) \right], \end{aligned} \quad (2)$$

where P is for p values of each cointegration test.

3.2.3. Maki Cointegration Test with Structural Breaks. This study also employs the Maki cointegration test, which tests the long-run relationship among variables in the presence of structural breaks. Maki cointegration is superior to other cointegration methods due to its power to identify more than two structural breaks. The Maki test equation for regime shift and trend is given as

$$\begin{aligned} FD_t &= \alpha + \sum_{i=1}^k \pi_i D_{i,t} + \beta' X_t + \gamma t + \sum_{i=1}^k \delta_i t D_{i,t} \\ &\quad + \sum_{i=1}^k \beta'_i Z_t D_{i,t} + \varepsilon_t, \end{aligned} \quad (3)$$

where, in equation (3), X is for all explanatory variables such as FDI, GDP, FRI, REE, and HCI. Similar to the BH test, the prerequisite for the Maki test is that all variables must be first-difference stationary. α is drift and γ is for the trend coefficient.

3.2.4. Fully Modified Ordinary Least Square (FMOLS) and Frequency Domain Causality Test. For long-run association between variables in models 1–3, this study uses the FMOLS method. It is intuitively clear that FMOLS is an asymptotically unbiased and efficient estimator. To overcome the problem of correlation between explanatory variables and cointegration equations, FMOLS is the superior to other estimators. Moreover, to test the causal relationship among the variables, this study uses frequency domain causality test. Frequency domain causality test finds out the short-, medium-, and long-run causal relationship among the variables. The method is superior to other causality tests due to its power in removing the seasonal variations in dataset with short period of time.

4. Results and Discussion

Table 2 provides results of Narayan and Popp [47] unit root test with structural breaks. The results indicate that all variables are nonstationary at the level. It indicates that the mean and variance for these variables fluctuate overtime. It also indicates that the conditional probability distribution changes over time for CO₂, GDP, FDI, REE, FRI, and HCI. Moreover, after taking first difference, the data are stationary and the condition probability distribution for variables does not change over time. This suggests that all variables, i.e., FDI, CO₂, REE, HCI, and GDP, are stationary at $I(1)$. The Narayan and Popp [47] test also detects possible structural breaks in the data. The key structural breaks are 2001 and 2008. The structural break year 2001 is linked with China inclusion into the world trade organization (WTO) [8]. Similarly, the structural break for the year 2008 is for the financial crises. For the economy, both these structural break years, i.e., 2001 and 2008, have both long-lasting positive and negative impacts on the economy. Post 2001, China exports grew faster and post 2008 China economy suffered due to financial crises [15].

Table 3 provides the long-run cointegrating association among financial risk index, financial development, human capital index, GDP, renewable energy electricity output, and carbon emissions is confirmed through Bayer–Hanck and

TABLE 2: Narayan and Popp [47] unit root test.

Variables	<i>I</i> (0)		<i>I</i> (1)		Breaks
	Breaks in level	Breaks in level and trend	Breaks in level	Breaks in level and trend	
CO ₂	-4.306*	-0.795	-5.725***	-44.20***	2003–2005
GDP	-3.669	-4.433	-6.483***	-14.002***	2001–2008
FDI	-2.755	-3.871	-7.870***	-1.0554***	2001–2004
HCI	-3.124	-4.718	-6.254***	-9.347***	1995–2005
REE	-3.324	-4.571	-7.534***	-8.097***	2000–2002
FRI	-3.019	-3.292	-8.687***	-9.646***	2005–2008

Note: $P \leq 0.01$, $< 0.05^{**}$, and 0.1^* , respectively.

TABLE 3: Cointegration analysis using Maki and Bayer–Hanck approaches.

	<i>Bayer–Hanck</i> [48]			
	Engle Granger	Johansen	Banerjee	Boswijk
Statistics (<i>P</i> values)	-6.8819*** (0.0026)	84.5881*** (0.000)	-5.1755*** (0.0028)	125.1155*** (0.0000)
Combined statistics	Engle Granger–Johansen 57.890*** (0.000)		Engle Granger–Banerjee–Boswijk 124.908*** (0.000)	
Results	<i>Maki</i> [49]			
	Regime shift	Statistics Regime shifts with trend	Key structural breaks	
	-9.52**	-11.107**	2001–2008–2014	

Note: $P \leq 0.01$, $< 0.05^{**}$, and 0.1^* , respectively.

Maki cointegration tests. The results of Bayer–Hanck and Maki cointegration confirmed that there is a long-run cointegrating relationship between financial risk index, financial development index, human capital index, GDP, and renewable energy electricity output with carbon emissions for China. Moreover, Maki cointegration also provides multiple structural breaks, i.e., 2001, 2008, and 2014. However, the most important structural breaks associated with different real economic events, i.e., 2001, when China joined WTO, and 2008, for the global financial crises. In order to analyse the effect of these two structural breaks, this study used dummy variables in the main regression analysis to empirically test its effect on carbon emissions.

Table 4 shows results obtained from both fully modified and dynamic ordinary least square, i.e., FMOLS and DOLS. The results are divided into two parts: first, without considering structural breaks, and second, considering structural breaks and introducing dummy variables. The empirical results confirmed that 1% rise in financial development causes carbon emissions to decline by -0.191%, -0.159%, -0.128%, -0.117%, -0.169%, and -0.129%, respectively, for China. The effect of FDI on CO₂ emissions is similar to the empirical outcomes of Tamazian et al. [10] and Khan et al. [35]. The negative effect of FDI on carbon emissions is justified due to declining production cost, enhancing products’ competitiveness, using energy-efficient technology, and controlling energy cost. Project-related financial development is in line with carbon reduction goals, and most focus is given to cleaner energy. Moreover, financial institutions finance those projects which are environmentally friendly and do not increase emissions. Furthermore, the results suggest that increasing economic growth causes carbon emissions to rise in China. This

indicates that increasing carbon emissions in China is mostly associated with rise in economic activities. China transformation from a low-income country to an emerging economy causes carbon emission to rise extensively since the last few decades. Starting from economic regulations of the 1990s and later joining world trade organization (WTO) cause emissions to increase. China is the largest carbon emitter and contributes 27.3% to worldwide CO₂ emissions [6]. Due to the process of industrialization and globalization, continuous increase in economic activities, the economy is expected to continuously grow in the next decades, which has serious implications for the environmental sustainability of the country.

In contrast, increasing financial risk index (improvement in financial risk index) for China is positively related with CO₂ emissions. The rise in carbon emissions from financial risk index improvement is associated with many factors. These factors include curbing foreign debt service and current account services such as percentage of goods and service exports, improvement in net international liquidity, and stability of the exchange rate. Most of these factors are associated with rise in different economic activities which in turn cause energy consumption from fossil fuel to rise and increase carbon emissions [50].

Furthermore, the results show that human capital is negatively related with CO₂ emissions, which support the findings of Yang et al. [51]. Human capital is helpful in implementing the eco-friendly technologies, which enhance energy efficiency and hence improve the environmental quality. Similarly, renewable energy electricity output is also helpful to control carbon emissions. As increasing the shares of renewable energy in total electricity generation by 1% cause reduce in carbon emissions by -0.442%, -0.356%,

TABLE 4: Long-run results.

Variables	Without structural breaks		With structural breaks			
	FMOLS coefficients (std. er)	DOLS coefficients (std. er)	FMOLS coefficients (std. er)	DOLS coefficients (std. er)	FMOLS coefficients (std. er)	DOLS coefficients (std. er)
FDI	-0.191*** [0.0451]	-0.159*** [0.0350]	-0.128*** [0.0314]	-0.117*** [0.0314]	-0.169*** [0.0294]	-0.129*** [0.0310]
GDP	1.332*** [0.0980]	1.417*** [0.321]	1.230*** [0.0858]	1.257*** [0.1028]	1.355*** [0.134]	1.327*** [0.1546]
FRI	0.0044*** [0.0022]	0.00442* [0.0620]	0.0035* [0.0018]	0.0036* [0.0020]	0.0052** [0.0020]	0.0048* [0.0023]
HCI	-0.905*** [0.2112]	-0.873*** [0.2661]	-0.882*** [0.1696]	-0.918*** [0.1921]	-0.897*** [0.2319]	-0.892*** [0.2646]
REE	-0.442*** [0.1493]	-0.356** [0.1606]	-0.285** [0.1429]	-0.253*** [0.0561]	-0.488*** [0.1532]	-0.385** [0.1752]
D ₁ -2001	—	—	0.039** [0.0186]	0.030*** [0.0087]	—	—
D ₂ -2008	—	—	—	—	-0.0063*** [0.0011]	-0.0064*** [0.0019]
Constant	-1.051*** [0.2214]	-1.230*** [0.2712]	-1.121*** [0.2619]	-1.413*** [0.371]	-1.267*** [0.2089]	-1.101*** [0.331]
R-squared	0.971	0.963	0.982	0.962	0.951	0.967

Coefficient diagnostic tests

Normality test (Jarque–Bera)	Breusch–Pagan–Godfrey heteroscedasticity	Breusch–Pagan–Godfrey serial correlation LM
3.773 (0.151)	1.464 (0.2324)	1.021 (0.3764)

Note: $P \leq 0.01$, $< 0.05^{**}$, and 0.1^* , respectively.

TABLE 5: Frequency domain causality test.

Causality direction	Long run, $\omega = 0.05$	Medium run, $\omega = 1.5$	Short run, $\omega = 2.5$
GDP to CO ₂	13.586***	11.316***	13.275***
FDI to CO ₂	7.177**	5.332*	9.989***
HCI to CO ₂	7.602**	7.572**	5.721*
REE to CO ₂	6.432*	6.721**	4.126
FRI to CO ₂	9.217***	6.031**	6.451**

Note: $P \leq 0.01$, $< 0.05^{**}$, and 0.1^* , respectively.

-0.285%, -0.253%, -0.488%, and -0.385%. In the case of China, increasing shares of renewable energy in electricity is rising and causing emissions to decline. The use of renewable energies in electricity generation is helpful in restricting pollution in the atmosphere. Therefore, renewable energy in electricity generation may be considered as an optimal solution to energy security and environmental sustainability. Hence, without reducing the output level, generation of additional emissions can be reduced via development in environment-related technology by increasing the share of renewable energies in electricity generation. The structural break for the year 2001 (China entry into WTO) causes carbon emissions to increase by 0.039% and 0.030%. On the contrary, structural break for the year 2008 (global financial crises) causes carbon emissions to reduce by -0.0063% and -0.0064%. The overall results are significant with normal distribution and no autocorrelation and heteroscedasticity is detected.

The structural break for the year 2001 (China entry into WTO) causes carbon emissions to increase by 0.039% and 0.030%. On the contrary, structural break for the year 2008 (global financial crises) causes carbon emissions to reduce by -0.0063% and -0.0064%. The overall results are significant with normal distribution, and no autocorrelation and heteroscedasticity is detected.

Table 5 shows the outcome from frequency domain causality test and indicates that GDP, FDI, FRI, REE, and

HCI cause carbon emissions in the short run, medium run and long run. The results show that any policy targeting these factors shall affect carbon emissions for China [52].

5. Conclusion

On the nexus between financial development and carbon emissions, very few studies are available especially considering the role of financial risk index, renewable energy electricity, and human capital. Therefore, this study attempts to fill the gap by studying the impact of financial development on carbon emissions for China from 1988–2018. This study introduces novel variables in the model, i.e., financial risk index, renewable energy electricity, and human capital index by employing novel time-series econometric tests. This study used Narayan and Popp unit root test with structural breaks, Bayer–Hanck and Maki cointegration tests, and fully modified and dynamic OLS techniques for long-run results. Moreover, frequency domain causality test is employed for short-, medium-, and long-run causal relationship among the variables.

Narayan and Popp unit root tests detect important structural breaks linked with the structural changes in China economy, i.e., 1993, 2001, and 2008. The cointegration tests, i.e., Maki and Bayer–Hanck confirmed long-run cointegrating relationship for carbon emissions, financial risk index, financial development index, renewable energy

electricity, gross domestic product, and human capital index. Moreover, the empirical outcomes for FMOLS and DOLS indicate that financial risk index and gross domestic product cause carbon emissions to rise. In contrast, renewable energy electricity, financial development, and human capital index limited carbon emissions. Moreover, the structural break year 2001 causes to surge carbon emissions, and on the other hand, the break year 2008 helped to limit carbon emissions in China. Based on the outcomes from this study, the following policy implications are recommended: (1) promotion of financial development is in line with the goals set by China to achieve its target of limiting carbon emissions; (2) financial risk index improvement is indeed good for the overall economy; however, regulations should be encouraged to ensure that further expansion does not harm the environment and it should be environmental friendly with less use of fossil fuels; (3) shares of renewable energy should be increased in total electricity output especially through investment in energy industry; (4) more capital should be devoted towards human capital as controlling carbon emissions can only be done through quality human capital.

Data Availability

The data used to support the findings of the study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

- [1] World Bank, 2020, <https://www.worldbank.org/en/about/annual-report>.
- [2] D. Kirikkaleli, T. S. Adebayo, Z. Khan, and S. Ali, "Does globalization matter for ecological footprint in Turkey? Evidence from dual adjustment approach," *Environmental Science & Pollution Research*, vol. 28, no. 11, pp. 14009–14017, 2020.
- [3] NASA, 2020, <https://www.nasa.gov/content/2019-nasa-press-releases/>.
- [4] S. Ali, E. Dogan, F. Chen, and Z. Khan, "International trade and environmental performance in top ten-emitters countries: the role of eco-innovation and renewable energy consumption," *Sustainable Development*, vol. 29, no. 2, pp. 378–387, 2020.
- [5] L. Wang, C.-W. Su, S. Ali, and H.-L. Chang, "How China is fostering sustainable growth: the interplay of green investment and production-based emission," *Environmental Science and Pollution Research*, vol. 27, no. 31, pp. 39607–39618, 2020.
- [6] BP, The BP Statistical Review of World Energy, 2017.
- [7] S. Ali, M. Babi, and F. Rabbi, "A new economic dimension to the environmental Kuznets curve: estimation of environmental efficiency in case of Pakistan," *Asian Economic and Financial Review*, vol. 4, no. 1, pp. 68–79, 2014.
- [8] Z. Khan, S. Ali, M. Umar, D. Kirikkaleli, and Z. Jiao, "Consumption-based carbon emissions and international trade in G7 countries: the role of environmental innovation and renewable energy," *The Science of the Total Environment*, vol. 730, Article ID 138945, 2020.
- [9] X. Ji, M. Umar, S. Ali, W. Ali, K. Tang, and Z. Khan, "Does fiscal decentralization and eco-innovation promote sustainable environment? A case study of selected fiscally decentralized countries," *Sustainable Development*, vol. 29, no. 1, pp. 79–88, 2020.
- [10] A. Tamazian, J. P. Chousa, and K. C. Vadlamannati, "Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries," *Energy Policy*, vol. 37, no. 1, pp. 246–253, 2009.
- [11] M. Shahbaz, A. Kumar Tiwari, and M. Nasir, "The effects of financial development, economic growth, coal consumption and trade openness on CO₂ emissions in South Africa," *Energy Policy*, vol. 61, pp. 1452–1459, 2013.
- [12] A. Gök, "The role of financial development on carbon emissions: a meta regression analysis," *Environmental Science and Pollution Research*, vol. 27, no. 11, pp. 11618–11636, 2020.
- [13] A. O. Acheampong, "Modelling for insight: does financial development improve environmental quality?" *Energy Economics*, vol. 83, pp. 156–179, 2019.
- [14] P. Sadorsky, "The impact of financial development on energy consumption in emerging economies," *Energy Policy*, vol. 38, no. 5, pp. 2528–2535, 2010.
- [15] Z. Khan, M. Hussain, M. Shahbaz, S. Yang, and Z. Jiao, "Natural resource abundance, technological innovation, and human capital nexus with financial development: a case study of China," *Resources Policy*, vol. 65, Article ID 101585, 2020.
- [16] A. Safi, C. Chen, S. Wahab, S. Ali, X. Yi, and M. Imran, "Financial instability and consumption-based carbon emission in E-7 countries: the role of trade and economic growth," *Sustainable Production and Consumption*, vol. 27, pp. 383–391, 2020.
- [17] W. Yang, T. Li, and X. Cao, "Examining the impacts of socio-economic factors, urban form and transportation development on CO₂ emissions from transportation in China: a panel data analysis of China's provinces," *Habitat International*, vol. 49, pp. 212–220, 2015.
- [18] B. Dong, F. Wang, and Y. Guo, "The global EKC's," *International Review of Economics & Finance*, vol. 43, pp. 210–221, 2016.
- [19] M. Shahbaz, M. A. Nasir, and D. Roubaud, "Environmental degradation in France: the effects of FDI, financial development, and energy innovations," *Energy Economics*, vol. 74, pp. 843–857, 2018.
- [20] M. A. Destek and S. A. Sarkodie, "Investigation of environmental Kuznets curve for ecological footprint: the role of energy and financial development," *Science of the Total Environment*, vol. 650, pp. 2483–2489, 2019.
- [21] M. Bhattacharya, J. N. Inekwe, and P. Sadorsky, "Consumption-based and territory-based carbon emissions intensity: determinants and forecasting using club convergence across countries," *Energy Economics*, vol. 86, Article ID 104632, 2020.
- [22] Z. Khan, S. Ali, K. Dong, and R. Y. M. Li, "How does fiscal decentralization affect CO₂ emissions? The roles of institutions and human capital," *Energy Economics*, vol. 94, Article ID 105060, 2021.
- [23] F. Jawadi, B. Egert, and J. Botev, "The nonlinear relationship between economic growth and financial development: evidence from developing, emerging and advanced economies," *International Economics*, vol. 160, pp. 3–13, 2019.
- [24] S. Ali and Z. K. Malik, "Revisiting economic globalization led growth: the role of economic opportunities," *Journal of Public Affairs*, vol. 21, no. 2, 2020.

- [25] A. Tamazian and B. Rao, "Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies," *Energy Economics*, vol. 32, no. 1, pp. 137–145, 2010.
- [26] M. Abid, "Impact of economic, financial, and institutional factors on CO₂ emissions: evidence from sub-Saharan Africa economies," *Utilities Policy*, vol. 41, pp. 85–94, 2016.
- [27] M. Çetin and E. Ecevit, "The impact of financial development on carbon emissions under the structural breaks: empirical evidence from Turkish economy," *Journal of Economic Perspectives*, vol. 11, no. 1, pp. 64–78, 2017.
- [28] M. Cetin, E. Ecevit, and A. G. Yucel, "The impact of economic growth, energy consumption, trade openness, and financial development on carbon emissions: empirical evidence from Turkey," *Environmental Science and Pollution Research*, vol. 25, no. 36, pp. 36589–36603, 2018.
- [29] M. A. Baloch, F. Danish, F. Meng, J. Zhang, and Z. Xu, "Financial instability and CO₂ emissions: the case of Saudi Arabia," *Environmental Science and Pollution Research*, vol. 25, no. 26, pp. 26030–26045, 2018.
- [30] H. S. Ali, S. H. Law, W. L. Lin, Z. Yusop, L. Chin, and U. A. A. Bare, "Financial development and carbon dioxide emissions in Nigeria: evidence from the ARDL bounds approach," *GeoJournal*, vol. 84, no. 3, pp. 641–655, 2019.
- [31] L. Charfeddine and M. Kahia, "Impact of renewable energy consumption and financial development on CO₂ emissions and economic growth in the MENA region: a panel vector autoregressive (PVAR) analysis," *Renewable Energy*, vol. 139, pp. 198–213, 2019.
- [32] L. Charfeddine and K. Ben Khediri, "Financial development and environmental quality in UAE: cointegration with structural breaks," *Renewable and Sustainable Energy Reviews*, vol. 55, pp. 1322–1335, 2016.
- [33] S. Dasgupta, B. Laplante, and N. Mamingi, "Pollution and capital markets in developing countries," *Journal of Environmental Economics and Management*, vol. 42, no. 3, pp. 310–335, 2001.
- [34] S. Claessens and E. Feijen, *Financial Sector Development and the Millennium Development Goals*, World Bank, Washington, DC, USA, 2006.
- [35] Z. Khan, Z. Sisi, and Y. Siqun, "Environmental regulations an option: asymmetry effect of environmental regulations on carbon emissions using non-linear ARDL," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, vol. 41, no. 2, pp. 137–155, 2019.
- [36] C. Jiang and X. Ma, "The impact of financial development on carbon emissions: a global perspective," *Sustainability*, vol. 11, no. 19, p. 5241, 2019.
- [37] M. Karimzadeh, S. T. Bazkhaneh, H. K. Dalfardi, and M. Barakchian, "Studying the relationship between financial development and emissions of carbon dioxide in Iran: using autoregressive-distributed lag," *Journal of Resistive Economics (OAJRE)*, vol. 2, pp. 94–105, 2014.
- [38] M. Cetin and E. Ecevit, "The impact of financial development on carbon emission under the structural break: empirical evidence from Turkish economy," *International Journal of Economic Perspectives*, vol. 11, pp. 64–78, 2017.
- [39] F. Abbasi and K. Riaz, "CO₂ emissions and financial development in an emerging economy: an augmented VAR approach," *Energy Policy*, vol. 90, pp. 102–114, 2016.
- [40] H. W. Zhou and Y. H. Zhong, "China's financial intermediation development and regional economic growth: a multivariate VAR system analysis," *Journal of Financial Research*, vol. 6, pp. 130–137, 2004.
- [41] Y. Hao, Z.-Y. Zhang, H. Liao, Y.-M. Wei, and S. Wang, "Is CO₂ emission a side effect of financial development? An empirical analysis for China," *Environmental Science and Pollution Research*, vol. 23, no. 20, pp. 21041–21057, 2016.
- [42] L. Huang and X. Zhao, "Impact of financial development on trade-embodied carbon dioxide emissions: evidence from 30 provinces in China," *Journal of Cleaner Production*, vol. 198, pp. 721–736, 2018.
- [43] A. Jalil and M. Feridun, "The impact of growth, energy and financial development on the environment in China: a cointegration analysis," *Energy Economics*, vol. 33, no. 2, pp. 284–291, 2011.
- [44] D. Gilfillan, G. Marland, T. Boden, and R. Andres, "Global, regional, and national fossil-fuel CO₂ emissions," 2019, <https://energy.appstate.edu/CDIAC>.
- [45] World Bank, 2019, <https://www.worldbank.org/en/about/annual-report>.
- [46] K. B. Luintel, M. Khan, R. Leon-Gonzalez, and G. J. Li, "Financial development structure and growth: new data method and results," *Cardiff Economics Working Papers*, vol. 43, 2016.
- [47] P. K. Narayan and S. Popp, "A new unit root test with two structural breaks in level and slope at unknown time," *Journal of Applied Statistics*, vol. 37, no. 9, pp. 1425–1438, 2010.
- [48] C. Bayer and C. Hanck, *BAYERHANCK: Stata Module to Compute Test for Non-Cointegration*, Statistical Software Components S457061, Boston College Department of Economics, Boston, MA, USA, 2009.
- [49] D. Maki, "Tests for cointegration allowing for an unknown number of break," *Economic Modelling*, vol. 29, no. 5, pp. 2011–2015, 2012.
- [50] L. D. Howell, *International Country Risk Guide Methodology*, PRS Group, East Syracuse, NY, USA, 2011.
- [51] L. Yang, J. Wang, and J. Shi, "Can China meet its 2020 economic growth and carbon emissions reduction targets?" *Journal of Cleaner Production*, vol. 142, pp. 993–1001, 2017.
- [52] Y. Huang, X. C. Chen, H. Zhu, C. Huang, and Z. Tian, "Heterogeneous effect of FDI and foreign trade on CO₂ emission: evidence from China," *Mathematical Problem in Engineering*, vol. 2019, Article ID 9612492, 14 pages, 2019.