

# Could green finance facilitate low-carbon transformation of power generation? Some evidence from China

Some evidence  
from China

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## Abstract

**Purpose** – The decarbonization of power generation is key to achieving carbon neutrality in China by the end of 2060. This paper aims to examine how green finance influences China's low-carbon transition of power generation. Using a provincial panel data set as an empirical study example, green finance is assessed first, then empirically analyses the influences of green finance on the low-carbon transition of power generation, as well as intermediary mechanisms at play. Finally, this paper makes relevant recommendations for peak carbon and carbon neutrality in China.

**Design/methodology/approach** – To begin with, an evaluation index system with five indicators is constructed with entropy weighting method. Second, this paper uses the share of coal-fired power generation that takes in total power generation as an inverse indicator to measure the low-carbon transition in power generation. Finally, the authors perform generalized method of moments (GMM) econometric model to examine how green finance influences China's low-carbon transition of power generation by taking advantage of 30 provincial panel data sets, spanning the period of 2007–2019. Meanwhile, the implementation of the 2016 Guidance on Green Finance is used as a turning point to address endogeneity using difference-in-difference method (DID).

**Findings** – The prosperity of green finance can markedly reduce the share of thermal power generation in total electricity generation, which implies a trend toward China's low-carbon transformation in the power generation industry. Urbanization and R&D investment are driving forces influencing low-carbon transition, while economic development hinders the low-carbon transition. The conclusions remain robust after a series of tests such as the DID method, instrumental variable method and replacement indicators. Notably, the results of the mechanism analysis suggest that green finance contributes to low-carbon transformation in power generation by reducing secondary sectoral share, reducing the production of export products, promoting the advancement of green technologies and expanding the proportion of new installed capacity of renewable energy.

**Research limitations/implications** – This paper puts forward relevant suggestions for promoting the green finance development with countermeasures such as allowing low interest rate for renewable energy



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power generation, facilitating market function and using carbon trade market. Additional policy implication is to promote high quality urbanization and increase R&D investment while pursuing high quality economic development. The last implication is to develop mechanism to strengthen the transformation of industrial structure, to promote high quality trade from high carbon manufactured products to low-carbon products, to stimulate more investment in green technology innovation and to accelerate the greening of installed structure in power generation industry.

**Originality/value** – This paper first attempts to examine the low-carbon transition in power generation from a new perspective of green finance. Second, this paper analyses the mechanism through several aspects: the share of secondary industry, the output of exported products, advances in green technology and the share of renewable energy in new installed capacity, which has not yet been done. Finally, this study constructs a system of indicators to evaluate green finance, including five indicators with entropy weighting method. In conclusion, this paper provides scientific references for sustainable development in China, and meanwhile for other developing countries with similar characteristics.

**Keywords** Green finance, Low-carbon transformation, Power generation, GMM and DID methods, China

**Paper type** Research paper

## 1. Introduction

We are still facing severe global climate change problems. Despite international communities made a series efforts such as United Nations Framework Convention on Climate Change, the Kyoto Protocol in 1997 and the Paris Agreement in 2015, global energy-related CO<sub>2</sub> emissions in 2018 increased by 17% year-on-year, reaching a record peak of 33.1 billion tons (IEA, 2019). In particular, IEA report notes that coal-fired thermal power contributed most to CO<sub>2</sub> emission growth in 2018.

In China, due to the relative abundance of coal resources in its energy mix, it relies mainly on thermal power generation. According to a report by the China Thermal Power Association, thermal power companies accounted for nearly 88.6% of China's total installed electricity capacity in 2018 (Springer *et al.*, 2019). The cheap cost of thermal power and its stable supply for peaking and centralized heating are the major reasons why China heavily relies on thermal power. Although the Chinese government has intensified new energy sources (e.g. solar, nuclear, wind) in recent years, thermal power still takes up over 60% of China's all electricity generation. Hence, the largest producer of CO<sub>2</sub> is China's thermal power generation industry. President Xi, on September 22, 2020, proclaimed China's carbon target to peak its carbon emissions by 2030 then realize carbon neutral by the end of 2060 to the world.

Some scholars estimate that China needs more than RMB 127.2tn (US\$20tn) to achieve carbon neutrality (Xie and He, 2020). In fact, China's financial markets do have sufficient funds to meet these needs. The key issue is how to better shift the focus of investment from high-carbon to low-carbon power generation sectors. Traditionally, bank loans are the main resources for Chinese enterprises' external financing. To facilitating economic fast growth, banks intentionally allocated credit resources to high energy-consuming industries and resulted in their continuous expansions and corresponding CO<sub>2</sub> emissions. Actually, China's green credit has been the major instrument of green finance. In 2016, "Guidance on Green Finance" was jointly launched by China's departments, such as the People's Bank of China. Subsequently, China further clarified the importance of green finance. China's green credit balance has shown notable growth, with the balance from RMB 5.2tn in 2013 to over RMB 10tn (\$1.5tn) in 2019. China's green bonds accounted for 24.2% of the global total, ranking the second in 2018.

Recently, the environmental improvement effects of green finance have become important research filed. For instance, Zhou and Xu (2022) demonstrate that a U-shaped

relationship exists between green finance and ecological development. In addition, [Li and Huang \(2022\)](#) verify the negative effect of green finance on CO<sub>2</sub> emissions. Yet, there are few studies that examine the promoting effect on low-carbon transformation in power generation industry from a new perspective of green finance.

Therefore, this paper tries to investigate how green finance influences the low-carbon transition of power generation by applying generalized method of moments (GMM) models and using 30 provincial panel data sets, which span the period from 2007 to 2019. Meanwhile, the implementation of “Guidance on Green Finance” in 2016 is used as the time point to address the endogeneity issue by applying difference-in-difference (DID) approach. The findings demonstrate that the share of thermal power generation can be significantly reduced by green finance, which implies that China’s power generation tends to transform toward a low-carbon approach.

This paper makes contribution to the literature in three aspects: first, most of previous studies focus on energy consumption control, while ignoring the key issue reducing the share of coal-fired thermal power to total power generation because China is still developing country and energy consumption tends to be upward. China’s green finance market does have money; however, the key is to shift investment from coal-fired thermal power to low-carbon power generation. No such work has been done to examine the low-carbon transition in power generation from a new perspective of green finance. Second, this paper analyses the mechanism through several aspects: the share of secondary industry, the output of exported products, advances in green technology and the share of renewable energy in new installed capacity, which has not yet been done. Finally, this study constructs a system of indicators to evaluate the level of regional development of green finance, which includes five indicators with entropy weighting method. In conclusion, this paper provides scientific references for sustainable development in China, and meanwhile for other developing countries with similar characteristics.

The paper is organized as follows. Literature review is in Section 2. You can look through the research methodology, especially the empirical model in Section 3. Section 4 exhibits the empirical procedure and the main findings. In the end, some conclusions and policy recommendations are presented in Section 5.

## 2. Literature review

### 2.1 *Economic effects of green finance*

In response to climate warming, resource scarcity and environmental pollution, the concept of “green” was proposed by the United Nations in the early 1980s. Some scholars have answered that financial institutions have the responsibility to make selective investments to form green finance in society and to prompt enterprises to achieve green production ([Soundarrajan and Vivek, 2016](#)). At the beginning of the 21st century, with the Equator Principles release and global promotion, the Financial Action Facility of the United Nations Environment Program argued that green finance is not only an investment in environment-related fields but also an investment in the environment ([Jeucken \*et al.\*, 2017](#)). In August 2016, the central bank as the representative of seven Chinese ministries implemented the “Guidance on Green Finance,” which actively responded to climate warming and resource scarcity, and environmental protection. Green financial instruments include green credit, green securities, green insurance, green investment and carbon finance. Immediately afterward, at the G20 Summit in October 2016, it was further emphasized that green finance brings positive benefits to ensure sustainable development in the long run with optimizing resource allocation, mitigating environmental pollution and slowing down climate warming.

In terms of economic effects, scholars mainly argue that green finance brings external financing to green projects. [Kim et al. \(2016\)](#) conclude that financial institutions have an important role in promoting green industries. [Berensmann and Lindenberg \(2016\)](#) further find that green finance provides sufficient funds for the development of green enterprises. Similar conclusions are obtained by [ghisetti et al. \(2017\)](#) and [Wang and Wang \(2021\)](#). On the other hand, green finance can impose certain financing constraints on more polluting enterprises ([Gilbert and Zhao, 2017](#)). [Xian and Zhang \(2022\)](#) confirm that green finance significantly suppresses wastewater emissions, general industrial solid waste and sulfur dioxide emissions. Therefore, high pollution and high energy consumption projects should be progressively abandoned; meanwhile, environmentally friendly and ecological projects should be actively developed to establish new economic development mechanisms ([Volz, 2018](#)).

### *2.2 The drivers of low-carbon transition in power industry*

First, this paper focuses on carbon reduction in power generation industry. [Martins et al. \(2021\)](#), using G7 countries as a study, find that fossil fuel consumption significantly increases CO<sub>2</sub> emissions and, therefore, reducing coal consumption will reduce carbon emissions to some extent ([Li et al., 2022](#)). [Edianto et al. \(2022\)](#) find by comparison that countries with bilateral agreements for the development of the coal industry or weaker policy support for renewables, countries that received higher investments in coal power generation than renewables. Therefore, a low-carbon transition of the power mix is important if we want to reduce fossil energy consumption and the associated CO<sub>2</sub> emissions.

During power industry operation, the decision of power supply mix planning is of vital importance ([Joardar et al., 1998](#)). [Jiang et al. \(2010\)](#) suggest that China's future power supply restructuring should be based on coal power, with an increased proportion of renewable power generation to improve system stability and peak regulation. [Bhattacharya and Kojima \(2012\)](#) use Japanese data to analyze the impact of renewable energy inclusion on reducing system risk, and conclude that investors would benefit from reducing overall risk rather than simply controlling costs. In particular, thermal power generation is an important component of the global electricity sector and is critical to examining the greening of the electricity supply mix ([IEA, 2020](#)).

### *2.3 The influence of green finance on low-carbon transition in power industry*

In the transition to a decarbonized power supply mix, green finance plays an important role of motivation. [Wang et al. \(2018\)](#) focus on the influence of environmental policies on the electricity supply mix and argue that environmental and carbon tax policies can significantly improve power restructuring and power quality. [Levin et al. \(2019\)](#) apply an optimization model to a case study of electricity market data in Texas and show that carbon taxes is more systematically cost-effective for reducing emissions, while production and investment tax credits are more systematically cost-effective for increasing investment in renewable energy. In addition to forms of taxation, carbon trading mechanisms can also promote low-carbon electricity generation. [Kara et al. \(2008\)](#) conduct a low-carbon analysis of the Finnish electricity system and discover that developing low carbon in the electricity system can be facilitated by carbon trading mechanisms. [Streimikiene and Roos \(2009\)](#) conduct a quantitative analysis of the impact of carbon credits in the European Union (EU) carbon trading scheme on the electricity supply mix of the electricity system. quantitative analysis, showing that carbon trading promotes the clean-up of power supplies in the EU. In addition, [Chan et al. \(2022\)](#) reveal that coal-fired power plants get more financing from banks

through corporate finance rather than project finance, while [Yin et al. \(2021\)](#) predict that China needs RMB 400–700bn to orderly get out of current coal-fired power capacity.

To our knowledge, no such work has been done to investigate how green finance influences low-carbon transition in power generation with green development at its core. Based on an analysis of the above literature, financial policy incentives, financial mechanism support and financial resource inflows are needed to be able to restructure the long-standing thermal power dominated power supply mix. In theory, green finance, as a form of finance with green development at its core, can facilitate the transition of power generation in a low-carbon direction. Therefore, we propose *H1* as follows.

*H1.* Green finance can drive low-carbon transformation of China's power generation.

The channels through which green finance influences the transition are almost unknown; [Lin and Shi \(2022\)](#) suggest that industrial upgrading is still supported by a greater proportion of thermal power; [Feng et al. \(2022\)](#) show that green technological innovation is significantly advanced by digital finance; [Wang et al. \(2020b\)](#) reveal that excessive carbon emissions are generated by the increasing number of exports which have ultra-high economic efficiency and hinder harmony in both economic and environment; [Delarue et al. \(2011\)](#) find that, for a given cost, increasing wind power can reduce risk while differentiating between installed capacity and electricity generation. However, no such work has been done to explore the bridge between green finance and the low-carbon transition in electricity generation. Literally, green finance policies, such as green credits, can facilitate a low-carbon transition in power generation by providing low-cost financing for services, domestic production, green technologies and renewable energy facilities. Therefore, we propose *H2* as follows:

*H2.* Green finance influences the low-carbon transition in power generation by reducing the share of secondary industries, reducing the production of export products, promoting the advancement of green technologies and expanding the proportion of new installed capacity of renewable energy in China.

### 3. Data and methods

#### 3.1 Variable selection

*3.1.1 Explained variable.* Power supply structure (*PS*). The main source of CO<sub>2</sub> emissions is the consumption of fossil energy ([Secretariat, 2012](#)); thus, thermal power generation occupies a large percentage of CO<sub>2</sub> emissions ([Liu et al., 2015](#)). It is evident that the top task to make power generation low-carbon is to reduce the use of fossil energy for thermal power generation. Owing to the lacking data about renewable energy generation (water, nuclear, wind, solar), this paper will use the share of coal-fired power generation to all power generation as a reverse proxy for the low-carbon transition in power generation.

*3.1.2 Core explanatory variables.* Green finance index (*GFI*). [Clark et al. \(2018\)](#) measure a country's green finance development level in terms of several factors, such as the total number of banking institutions, their share and the scale of green loans, with reference to the equatorial principle commonly used in the banking industry; [Li and Xia \(2014\)](#), [Fu and Peng \(2020\)](#) use indicators such as green credit, green investment, green securities to construct evaluation index measuring green finance. So we base on China's "Guidance on Green Finance," constructing an index system containing five subsystems of green credit, green

insurance, green investment, green securities and carbon finance. By calculating the amount of information contained in the data of each index through the entropy weighting method, the objective weights of each evaluation index are determined, and the green financial evaluation index system and weights are shown in [Table 1](#).

3.1.3 Control variables.

- *Urbanization level (UR)*: represented by the share of urban population to total population. With urbanization, increased environmental protection requirements, regional energy restructuring and advances in technology lead to renewable energy generation increases, but fossil energy generation decreases ([Xie et al., 2014](#)). We, therefore, expect a negative impact from the level of urbanization on the share of coal-fired thermal power.
- *Economic development (ED)*: denoted by regional gross domestic product (GDP) per capita. [Rahman \(2020\)](#) displays a long-term positive relationship between electricity consumption and economic development. Because renewable energy generation in China is still at developing stage and cannot be scaled up significantly in the short-term, the higher electricity demand resulting from rapid economic growth will be met to a greater extent by conventional thermal power generation. So we expect a positive impact from the level of economic development on the share of coal-fired thermal power.
- *Research and development investment (RD)*: measured by regional R&D personnel in full-time equivalence. R&D investments in power generation technologies concentrate renovation and upgrading and energy saving of coal-fired thermal power on one side, and developing and using renewable energy sources on the other side ([Wang et al., 2020a, 2020b](#)). We, therefore, expect a negative impact from R&D investment on the share of coal-fired thermal power.

Criterion layer	System layer	Indicator layer	Unit	Type	Weights	
Green finance	Green credit	Ratio of industrial high-energy-consuming industries' interest residence to total industrial interest expenditure	%	-	0.0068	
	Green insurance	Ratio of agricultural insurance income to total insurance income	%	+	0.1720	
	Green investment	Ratio of energy conservation and environmental protection expenditure to total fiscal expenditure	%	+	0.2762	
	Green securities		Ratio of market value of high energy-consuming enterprises to the total market value of A shares	%	-	0.0211
			Ratio of market value of environmental protection companies to the total market value of A shares	%	+	0.5147
	Carbon finance		Carbon emissions as a percentage of loan balance	1 million tons per billion yuan	-	0.0091

**Table 1.**  
Evaluation index system for green finance



### 3.1.4 Mediating variables.

- Secondary industry structure (*IS*) measured by using the value added of the secondary industry over GDP;
- Foreign trade (*FT*) measured by using the total exports of domestic destinations and sources as a proportion of GDP;
- Green technology (*GT*) measured by the proportion of green invention patents to total invention patents; and
- Installed capacity structure (*ICS*) measured by the share of new installed capacity of China's clean energy to all new capacity.

### 3.2 Data information

This paper uses panel data about China's 30 provinces (except for Tibetan region, where data are seriously missing) from 2007 to 2019 for the empirical analysis. *PS* and *ICS* are secured from China's Electricity Statistical Yearbooks. China's Statistical Yearbooks, China Insurance Statistical Yearbook and China Stock Market and Accounting Research Database provide data sources for *GFI*, *UR*, *ED*, *IS* and *FT* are obtained from National Bureau of Statistics. Data about *RD* are received from China's Science and Technology Statistical Yearbooks, and data about *GT* are from China's Research Data Service Platform. Descriptive statistics are displayed in [Table 2](#).

### 3.3 Theoretical framework

So far, we cannot get a theoretical framework from the literature explicitly. Literally, its basic logic is that unlike traditional financial institutions, the profit function ( $\Pi_B$ ) of financial institutions (such as banks) pursuing business ethics or social responsibility is written as follows:

$$\Pi_B = \varphi R_C K_C + R_D K_D - C(K_C + K_D) \quad (1)$$

where  $R$  is revenue,  $C$  denotes marginal cost,  $\varphi$  represents bank credit preference coefficient for green and low-carbon projects (enterprises),  $K(t)$  is total capital,  $K_D(t)$  and  $K_C(t)$  represents the change rate of high carbon capital (high pollution investment and resource ecological destruction investment) and green and low-carbon investment, respectively. The

VarName	Obs	Mean	SD	Min	Median	Max
<i>PS</i>	390	0.753	0.237	0.081	0.833	1.000
<i>GFI</i>	390	0.109	0.090	0.015	0.074	0.570
<i>UR</i>	390	0.553	0.134	0.282	0.536	0.942
<i>ED</i>	390	1.326	0.556	-0.243	1.342	2.784
<i>RD</i>	390	10.963	12.664	0.126	6.510	80.321
<i>IV</i>	390	1.000	0.797	0.247	0.645	4.580
<i>PSI</i>	390	0.684	0.225	0.080	0.732	1.000
<i>GFI1</i>	390	0.224	0.075	0.085	0.204	0.561
<i>IS</i>	390	0.428	0.082	0.160	0.438	0.620
<i>FT</i>	390	0.292	0.313	0.011	0.152	1.617
<i>GT</i>	390	0.109	0.027	0.053	0.104	0.245
<i>ICS</i>	390	0.480	0.333	0.000	0.444	1.000

**Table 2.**  
Descriptive statistics

key problem is how to allocate capital elements to low-carbon capital ( $K_c$ ). One way to maximizing the profit function is to follow the framework of Nordhaus (1994) with a dynamic general equilibrium model. In this paper, we simply apply the literature (Acemoglu *et al.*, 2012) to infer our theoretical framework. Maximizing the profit function of green financial institutions depends on the relative expected profits of allocating capital to high carbon power generation or to low-carbon power generation. In the long-term, the relative expected profits seem to converge to a dynamic equilibrium point where the marginal income of polluting capital is equal to the marginal income of green capital, resulting in a win-win situation between economic development and carbon reduction. Therefore, we further infer our *H1*: green finance can drive low-carbon transformation of China's power generation.

### 3.4 Econometric model

**3.4.1 Generalized method of moments estimation method.** In the field of economics, we cannot avoid the problem of endogeneity. There are many reasons for endogeneity, such as missing variables, measurement error and explanatory variables that, in turn, affect explanatory variables. The dilemma is that there is no way we can solve all endogeneity problems at the same time with one method. In this paper, we use GMM because it has the advantage over other methods in that it can deal with dynamic endogeneity when one lag of the explanatory variable appears in equation (2) right-hand side. In addition, we use the stepwise method by increasing variables one by one gradually to avoid missing variables. Empirical model is constructed as follows:

$$PS_{i,t} = \alpha_0 + \alpha_1 PS_{i,t-1} + \alpha_2 GFI_{i,t} + \alpha_3 UR_{i,t} + \alpha_4 ED_{i,t} + \alpha_5 RD_{i,t} + \varepsilon_{i,t} \quad (2)$$

where  $i$  and  $t$  separately denote region and year, and  $\varepsilon$  stands for random error term.  $PS$  is the share of thermal power,  $GFI$  represents green finance index,  $UR$  denotes urbanization,  $ED$  is economic development and  $RD$  is technology input. This model is used to test the linear correlation between GFI and the share of thermal power.

**3.4.2 Difference-in-difference estimation method.** This study applies DID models to address the endogeneity problem. The underlying logic is that by comparing the difference in the impact of an event on economic agents in the experimental and control groups in a natural experiment situation, the double difference method can overcome the effects of other factors that interfere with causality or omitted variables, and thus determine the causal relationship between the variables we are interested in Qian and Fang (2017). Therefore, this paper applies the DID method for robust analysis with the following model:

$$PS_{i,t} = \beta_0 + \beta_1 DID (Policy \times Time) + \beta_2 Policy + \beta_3 Time + \beta_4 UR_{i,t} + \beta_5 ED_{i,t} + \beta_6 RD_{i,t} + \delta_i + \gamma_t + \varepsilon_{i,t} \quad (3)$$

Where DID stands for cross product of Policy  $\times$  Time, Policy means if the region belongs to the treatment group, it takes the value of 1, otherwise 0. Time means if the time is in the year of policy release (2016) and later years, time takes the value of 1, otherwise 0. The cross product can be used to measure  $GFI$  while avoiding endogenous problems.  $PS$  represents power supply structure,  $UR$  is urbanization level,  $ED$  is economic development level and  $RD$  is technology input.  $i$  and  $t$  denote region and year, respectively,  $\delta$  is individual fixed effect,  $\gamma$  is time fixed effect and  $\varepsilon$  stands for random error term.



## 4. Empirical results

### 4.1 Benchmark empirical regression

**4.1.1 Regression setting.** It is generally accepted that differential GMM estimation is better when the coefficient  $\rho$  of the first-order lag term of the explanatory variables is not very large, e.g.  $\rho < 0.8$ , while the systematic GMM is better when  $\rho > 0.8$ . By testing, this paper will use differential GMM for estimation. To better alleviate the endogeneity problems caused by control variable selection bias and omitted variables, this paper will adopt a stepwise estimation approach by adding control variables sequentially, which can improve the robustness of the core explanatory variable parameter estimates. This is done by first regressing the GFI directly on the power structure and then adding the three control variables of urbanization level, economic development level and R&D investment in turn. The estimated results of adopting stepwise approaches with GMM models are displayed in Table 3.

**4.1.2 Model testing.** In Table 3, AR(1) indicates that there exists first-order serial correlation in the residual series. AR(2) indicates that the difference equation does not have the second-order serial correlation. Hansen tests indicate this study does have valid instrumental variables (IVs). Hence, empirical results of difference GMM models are consistent.

**4.1.3 Analysis of results.** For the core explanatory variable GFI, empirical results in Column (1) demonstrate a significantly negative effects of GFI on the share of thermal power, implying that the share of thermal power in the region decreases significantly as GFI increases, proving *H1*. The regression coefficients of the GFI in Columns (2), (3) and (4), which are estimated by adding the control variables, in turn, are all significantly negative and close to each other, indicating a consistent and robust conclusion on the dampening effect of green finance on the share of thermal power.

For the control variable urbanization level (*UR*), the results in Column (2) show that the coefficient of urbanization is significantly negative, implying that regional share of thermal power significantly decreases as the level of urbanization increases. The possible explanation for this is that regions with higher urbanization have more awareness of environmental protection, environmental regulations and urban planning than those with

Variables	GMM (1)	GMM (2)	GMM (3)	GMM (4)
<i>GFI</i>	-0.528*** (0.192)	-0.260*** (0.098)	-0.310*** (0.116)	-0.325** (0.126)
<i>UR</i>		-0.493*** (0.101)	-1.268*** (0.446)	-1.438*** (0.463)
<i>ED</i>			0.101* (0.053)	0.147*** (0.057)
<i>RD</i>				-0.003** (0.001)
<i>LPS</i>	0.743*** (0.149)	0.214* (0.119)	0.234* (0.140)	0.285** (0.142)
Ar(1) Pr>z	0.018	0.031	0.018	0.005
Ar(2) Pr>z	0.089	0.09	0.089	0.079
Hansen test	0.534	0.217	0.534	0.893
Prob > chi2				
Observations	330	330	330	330
Number of pro	30	30	30	30

**Notes:** Robust standard errors in parentheses. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

**Table 3.**  
Regression results of  
the impact of *GFI* on  
*PS* by GMM models

lower levels of urbanization and have a higher awareness and ability of low carbonation, thus promoting the low carbonation of the regional Power supply structure. For the control variable economic development level (*ED*), the results in Column (3) demonstrate significantly positive effects of economic development, indicating that as the economy develops, the share of thermal power at region level increases significantly. The possible explanation for this is that, as China is an industrialized country, the level of secondary sector development largely represents economic development degree; hence, regional share of secondary sector with higher economic development is higher than that with lower economic development. This is because the demand for electricity in the secondary sector is high, while thermal power still dominates the domestic power supply structure and will, therefore, increase the regional share of thermal power. For the control variable technology input (*RD*), the results in Column (4) display significantly negative effects of R&D investment, suggesting that the share of thermal power in the region decreases significantly as the investment in R&D increases. The possible explanation for this is that regions with higher R&D investment have better technology for the use of nonfossil energy sources, improved technology for energy storage equipment and technology for controlling peaking capacity than regions with lower R&D investment, thus decreasing coal-fire power share at regional level.

4.2 Robustness analysis

4.2.1 Replacing the explained variable. Considering that the change in the share of thermal power generation mainly reflects the power supply structure in the current year, this paper introduces the ratio of thermal power installed capacity to all installed capacity as the power supply structure measure (*PS2*), and the measurement from generator type can also reflect the future power supply structure of the region to a certain extent. The regression results are presented in Table 4.

Empirical results in Table 4 show that the model passes the Arellano–Bond serial correlation test and the Hansen test, and therefore the differential GMM estimates are

Variables	GMM (1)	GMM (2)	GMM (3)	GMM (4)
<i>GFI</i>	-0.268 (0.171)	-0.099* (0.051)	-0.109* (0.064)	-0.162** (0.080)
<i>UR</i>		-0.394 (0.269)	-0.459* (0.255)	-0.930*** (0.348)
<i>ED</i>			0.017 (0.030)	0.089** (0.044)
<i>RD</i>				-0.003*** (0.001)
<i>L.PSI</i>	1.101*** (0.064)	0.828*** (0.191)	0.870*** (0.160)	0.740*** (0.168)
Ar(1) Pr>z	0.004	0.011	0.004	0.000
Ar(2) Pr>z	0.255	0.557	0.571	0.640
Hansen Test	0.218	0.305	0.658	0.911
Prob > chi2				
Observations	330	330	330	330
Number of pro	30	30	30	30

**Table 4.** Regression results of replacing the explained variable

**Notes:** Robust standard errors in parentheses. \*\*\**p* < 0.01, \*\**p* < 0.05, \**p* < 0.1

consistent and reliable. The coefficients of GFI are all significantly negative when control variables are added, strengthening the robustness of the benchmark analysis.

**4.2.2 Substitution of the core explanatory variable.** Considering that there are various ways of assigning indicators to the green finance indicator system, this paper adopts subjective and objective weighting methods to determine *GFI2*. The subjective weights are adopted from China's Green Finance Report by Li and Xia (2014). The objective weights were obtained by entropy weight method. The combined weights =  $0.5 \times$  subjective weight +  $0.5 \times$  objective weight. The specific weights are displayed in Table 5.

Empirical regression results are presented in Table 6.

Table 6 shows that our model passes the Arellano–Bond serial correlation test and the Hansen test, and therefore, the differential GMM estimates are consistent and reliable. The coefficients on the core explanatory variable, the *GFI2*, are all significantly negative except for Column (2), strengthening the robustness of the benchmark analysis.

#### 4.3 Endogenous analysis

**4.3.1 Instrumental variable method.** Referring to Fisman and Svensson (2007), this study applies the share of regional GFI to national GFI average for the year as an IV. Because government policies related to green finance are strongly policy-oriented and mostly implemented nationally, regional GFI is correlated with national average of GFI. The GFI is

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Weight type	Green credit	Green insurance	Green investment	Green securities	Carbon finance
Objective weights	0.0068	0.1720	0.2762	0.0211	0.5147
Subjective weights	0.2000	0.1000	0.3000	0.2000	0.2000
Combined weights	0.0534	0.1360	0.2881	0.1106	0.3573

**Table 5.**  
Comprehensive weighting of GFI system

Variables	GMM (1)	GMM (2)	GMM (3)	GMM (4)
<i>GFI2</i>	-0.722*** (0.193)	-0.198 (0.177)	-0.340** (0.170)	-0.373** (0.169)
<i>UR</i>		-0.511*** (0.125)	-1.157*** (0.445)	-1.316*** (0.461)
<i>ED</i>			0.091* (0.053)	0.133** (0.056)
<i>RD</i>				- 0.002** (0.001)
<i>LPSI</i>	0.576*** (0.123)	0.201* (0.115)	0.211 (0.133)	0.255* (0.138)
Ar(1) Pr>z	0.002	0.035	0.019	0.004
Ar(2) Pr>z	0.075	0.088	0.082	0.069
Hansen test	0.054	0.222	0.574	0.897
Prob > chi2				
Observations	330	330	330	330
Number of pro	30	30	30	30

**Table 6.**  
Regression results of replacement the core explanatory variable (*GFI2*)

**Notes:** Robust standard errors in parentheses. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

mainly oriented by regional attributes and national policies, and individual regions have little impact on the national green finance evaluation level, thus satisfying the exogenous requirement of the IV. Empirical findings are presented in [Table 7](#).

The findings of the first stage regression with a significantly positive IV coefficient and an *F*-value statistic much greater than 10 indicate that the IVs were chosen reasonably. The Kleibergen–Paap rk LM test (under-identification test) value was 55.3 and the Wald rk F test (weak identification test) value was 1,077.2 at the 1% level. In this case, original hypothesis was denied, proving the validity by using IVs. GFI remains the same sign as the benchmark analysis after using IVs to overwhelm endogenous, strengthening the robustness of our conclusion.

*4.3.2 DID method.* “Guidance on Green Finance” in 2016 is China’s first overall specific guidance program. This policy is equivalent to exogenous shocks for regions, which provides a relatively good quasi-natural experiment for this paper to mitigate endogeneity using the DID model. As the policy is implemented for all regions of the country, there is no explicit target of policy shocks. In this paper, we refer to the treatments of researchers such as [Vig \(2013\)](#) and [Campello and Larrain \(2016\)](#) to construct control and treatment groups regarding to differential impacts of the policy on regions with power supply structures. Based on the purpose that green finance will direct financial resources to green projects, regions with a higher share of thermal power will be affected by green finance policies more strongly than those with a lower share of thermal power.

Before using the DID method, this paper conducts a parallel trend test to see if there is a significant difference in the power mix before and after the release of this policy. The results in [Figure 1](#) show a downward trend in the share of thermal power in the treatment group

Variables	(1) <i>PS</i>	(2) <i>PS</i>	(3) <i>PS</i>	(4) <i>PS</i>
<i>GFI</i> <sub><i>it</i></sub>	-0.126** (0.062)	-0.124** (0.062)	-0.128** (0.062)	-0.120* (0.062)
<i>UR</i>		-0.167 (0.125)	-0.127 (0.137)	-0.031 (0.144)
<i>ED</i>			-0.026 (0.036)	-0.024 (0.036)
<i>RD</i>				0.001** (0.001)
Constant	0.823*** (0.011)	0.903*** (0.061)	0.901*** (0.061)	0.845*** (0.067)
Individual effect	YES	YES	YES	YES
Time effect	YES	YES	YES	YES
Observations	390	390	390	390
Number of pro	30	30	30	30
R-squared	0.371	0.374	0.375	0.382
<i>First stage regression results</i>				
<i>IV</i>	0.107*** (0.002)	0.107*** (0.002)	0.107*** (0.002)	0.107*** (0.002)
F	3,261.96	3,261.96	3,261.96	3,261.96
Prob > F	0.000	0.000	0.000	0.000

**Table 7.** Regression results of the impact of *GFI*<sub>*it*</sub> on *PS* by IV method

**Notes:** Robust standard errors in parentheses. \*\*\**p* < 0.01, \*\**p* < 0.05, \**p* < 0.1

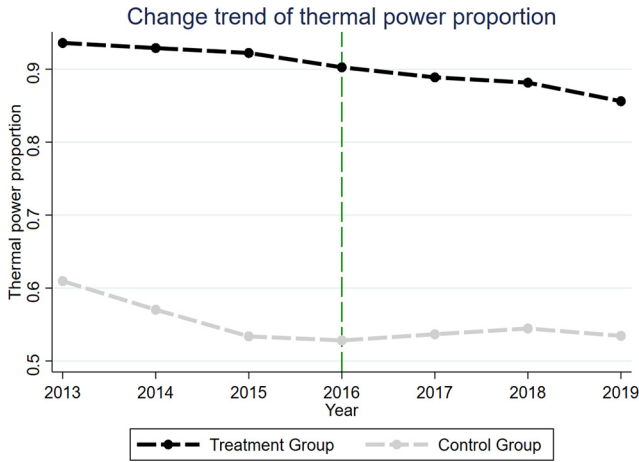


Figure 1. Parallel trend test

around 2016, while the trend of change in the control group is not significant. The results satisfy the hypothesis on which this paper will be based using the DID method.

We first divided the data set into a low group and a high group based on the average of the thermal power share of each region in the five years before the policy shock (2011–2015), using the median as the cutoff point. On this basis, high group was set as the treatment group, while low group was set as the control group. This paper also uses the 33% and 66% quartiles as cutoff points to divide the sample into low, medium and high groups. On this basis, medium group was set as the treatment group, while low group as the control group as a robustness reference. Empirical findings are displayed in Table 8.

Column (1) shows the results of the dichotomous DID estimation, the DID coefficient is significantly negative, implying that the policy shock significantly reduces regional share of thermal power. Column (2) shows that the estimated coefficient is still significant after adding control variables. Columns (3) and (4) show empirical findings with trichotomous method by setting middle group as the treatment group while low group as the control group. Columns (5) and (6) set high group as the treatment group while low group as the

Variables	(1) PS	(2) PS	(3) PS	(4) PS	(5) PS	(6) PS
DID	-0.067*** (0.019)	-0.067*** (0.019)	-0.082*** (0.026)	-0.085*** (0.028)	-0.062*** (0.020)	-0.064*** (0.021)
Constant	0.804*** (0.011)	0.817*** (0.166)	0.716*** (0.016)	0.305 (0.271)	0.778*** (0.012)	0.866*** (0.204)
Control Variables	NO	YES	NO	YES	NO	YES
Individual effect	YES	YES	YES	YES	YES	YES
Time effect	YES	YES	YES	YES	YES	YES
Observations	210	210	140	140	140	140
Number of pro	30	30	20	20	20	20
R-squared	0.428	0.429	0.440	0.474	0.489	0.501

Notes: Robust standard errors in parentheses. \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$

Table 8. DID regression results

control group on a comparison. In this case, all DID coefficients are significantly negative, strengthening our conclusion stability.

4.4 Mechanism analysis

This paper further discusses the mechanism through which green finance influences power supply structure. We explore four channels: industrial structure (*IS*), foreign trade (*FT*), green technologies (*GT*) and installed capacity structure (*ICS*). Empirical findings are displayed in Table 9.

4.4.1 Industrial structure. Based on China’s Electricity Statistics Yearbooks, electricity consumption in China’s secondary industry reached 79.69% in 2019, indicating that the secondary industry is the most important part of regional electricity demand. It is, therefore, believed that industrial structure transformation drives down the total electricity demand, thus reducing the reliance on thermal power and weakening the impediment to the greening process of the regional power supply structure. Comparing the results in Column (1) to Column (2), we find that green finance can contribute to a decrease in the share of secondary industry, while secondary industry significantly increases the share of thermal power. This finding implies that improving green finance tends to decrease regional secondary industry by directing financial resources from high carbon sector to green and low-carbon sector, which optimizes power supply structure, thereby promoting China’s low-carbon transformation of power generation.

4.4.2 Foreign trade. Along with the trend toward global economic integration, foreign trade has become increasingly prominent in China’s economic development, which contains hidden carbon emissions that are extremely easy to overlook. Implicit carbon is the carbon emissions generated directly or indirectly throughout the life cycle of a product (including its components) from raw materials, processing, transport to consumption. Since the production and transportation of foreign traded goods are accompanied by a significant use of electricity, it is argued that foreign trade contributes significantly to the total regional demand for electricity, which, in turn, increases regional dependence on thermal power. Comparing the results in Column (3) to Column (4), the findings demonstrate a declining effect of green finance on the degree of foreign trade, while the regression coefficient of the degree of foreign trade on the share of thermal power is significantly positive. Therefore,

Variables	(1) <i>IS</i>	(2) <i>PS</i>	(3) <i>FT</i>	(4) <i>PS</i>	(5) <i>GT</i>	(6) <i>PS</i>	(7) <i>ICS</i>	(8) <i>PS</i>
<i>GFI</i>	-0.079** (0.034)	-0.231* (0.130)	-0.264*** (0.058)	-0.155 (0.125)	0.035** (0.015)	-0.210 (0.136)	0.344** (0.164)	-0.127 (0.136)
<i>IS</i>		0.355** (0.145)						
<i>FT</i>				0.394*** (0.057)				
<i>GT</i>						-1.412*** (0.526)		
<i>ICS</i>								-0.354*** (0.035)
Constant	0.437*** (0.006)	0.626*** (0.073)	0.175*** (0.012)	0.712*** (0.025)	0.105*** (0.002)	0.930*** (0.054)	0.442*** (0.028)	0.935*** (0.017)
Observations	390	390	390	390	390	390	387	390
R-squared	0.007	0.025	0.020	0.087	0.014	0.035	0.009	0.254

**Table 9.**  
Regression results of  
mechanism analysis



this finding also suggests that green finance reduces power consumption in the manufacturing process of regional foreign trade goods by directing financial resources from the foreign trade manufacturing industry to green industry, which promotes the low-carbon transformation of power generation.

*4.4.3 Green technologies.* On the one hand, the clean energy generation industry requires long-term technological innovation and scale expansion to reduce prices and expand the scale of clean energy generation. On the other hand, hydropower, wind power and photovoltaic are all vulnerable to regional environmental and climatic constraints and thermal power's excellent peaking performance increases the dependence of the power mix on thermal power. Advances in green technology can solve the problem of China's dependence on thermal power at a technical level, thus contributing to the transformation and optimization of the power mix. Comparing the results in Columns (1), (6) and (7), we can see that green finance tends to promote green technology that further reduces the share of thermal power. Therefore, it proves that improving green finance drives green technology and thereby reducing the reliance on thermal power and contributing to the process of power structure optimization.

*4.4.4 Installed capacity structure.* In addition to the decline in thermal power, the rise in nonthermal power generation can visually optimize the power supply structure from the other side, which is microscopically reflected in the structure of the installed capacity of regional generators. It is, therefore, argued that the greening of the installed capacity structure can optimize the power supply structure starting from the underlying structure of electricity production. Comparing the results in Columns (1), (8) and (9), we find that green finance tends to promote greening of installed capacity, while installed capacity structure significantly reduces the share of thermal power. Thus, it proves that green finance expands the size of green sector, directing the installed structure of new generators toward nonfired power, which, in turn, optimizes the power supply structure from the base.

## 5. Conclusion and policy recommendations

With the overall increase in global low-carbon awareness, various industries are exploring the ways to green their power supply structures to achieve sustainable development. This study assesses green finance's role in driving greening of power generation and its mechanisms by applying panel data set for China's 30 provinces with spanning time from 2007 to 2019. Empirical findings demonstrate that green finance development can significantly reduce the share of coal thermal power generation, implying that China tends to be on the way of low-carbon transformation of power generation. Urbanization level and R&D investment are major driving factors affecting the low-carbon transformation, while economic development level hinders the low-carbon transformation. By using "Guidance on Green Finance" in 2016 as a quasi-natural experiment with DID model, we confirm the dampening effect of green finance policy on the share of thermal power. Mechanism analyses reveal that green finance tends to reduce the share of thermal power through declining the proportion of the secondary industry, reducing the production of export products, advancing green technology and expanding new installed capacity in renewable energy industry.

Empirical findings provide policy recommendations for China's sustainable development. First, by tilting financial resources to green sectors and allowing low interest rate for renewable energy power generation, facilitating market function, using carbon trade market and constructing green financial system, local governments can damp the share of thermal power in the region. Besides, mechanism should be developed to promote high quality urbanization and increase R&D investment while pursuing high quality economic

development. The last implication is to develop mechanism to strengthen the transformation of industrial structure, to promote high quality trade with low-carbon manufactured products, to stimulate investments in green technology innovation and to accelerate the greening of installed structure in power generation industry.

This study benefits both sustainable development in China and overseas, especially in developing countries experiencing the same strategies to mitigate climate change due to low-carbon transformation of power generation in China. However, it should be kept in mind that the results from this study need to be interpreted with caution due to data availability and the limitation of empirical analysis technology. Nevertheless, this study is helpful in understanding the effects of green finance on low-carbon transformation of power generation and its mechanism, and the results should be interesting to those who are interested in green finance development and low-carbon transformation. Spatial spillover effects should be considered in further research because of large variations in green financial market in the context of China.

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