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The mechanism of China's green financial policy on renewable energy industry

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[Abstract]

In this paper, we propose the mechanism of China's green financial policy on renewable energy industry development implemented in different pilot zones. By utilizing the synthetic control method, this paper examines the differences in the effect of green financial policy before and after its implementation. The results demonstrate that green financial policy can significantly reduce traditional energy consumption while promote the renewable energy industry development simultaneously. Furthermore, the effects across different regions reveal that the impacts of green financial policy are pronounced in selected pilot zones, with Shanghai and Chongqing standing out the most while Gansu province performs the worst. The analysis also figure out that green financial policy stimulates the expansion of regional financing scales, resource endowment, and technological innovation as well.

▸ **Key words**: Green financial policy, renewable energy industry, Synthetic control method, energy consumption

[요 약]

이 논문은 중국 시범지구에서 시행된 녹색금융정책이 신재생에너지산업 발전에 미치는 메커니즘을 탐구한 연구이다. 녹색금융은 환경보호에 대한 금융지원뿐만 아니라 에너지소비 및 산업발전까지 추진하는 새로운 정책수단이라고 볼 수 있다. 통제집단합성법을 활용하여 녹색 금융정책의 잠재적 경제효과를 측정하고 연구 결과에 따른 녹색 금융정책은 신재생에너지 산업발전을 촉진 시키는 효과를 발견한다. 지역별 분석결과에 따른 상하이시와 충칭시가 더 뚜렷한 녹색금융정책 효과를 보이는 반면, 간쑤성은 효과가 미흡한 것으로 나타난다. 장기적으로 녹색금융 활성화를 위한 정부의 지원은 시장 안정화될 때까지 이루어져야 하고 금융정책을 통해 산업구조변화, 녹색기술혁신, 자원배분 및 지역규모확대 등 분야에 자금이 공급되도록 해야 할 것이다.

▸ **주제어**: 녹색금융정책, 신재생에너지 산업, 통제집단합성법, 에너지소비

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I. Introduction

As the world's largest emitter of greenhouse gases and a major global economic power, China holds a significant role in global energy carbon transition towards a sustainable economic pattern. Energy industry, which contributes to China's economic development, plays a crucial role in country's economic growth. However, China's traditional over-reliance on fossil energy consumption has led to huge challenges and problems for sustainable development. Under the analysis of energy consumption structure, in 2020, China remains one of the world's largest fossil energy consumers, accounting for 26% of global energy consumption while renewable resources account for a smaller share. To achieve carbon neutrality 2050, China has already adjust its traditional energy structure and promote renewable energy industry development since 2016.

Industrial development always relies on the support of economic policies. According to the guidance of China Ministry of Environmental Protection (MEP) in 2016, green finance system was first designed to facilitate the transition of traditional fossil energy towards clean and renewable industry. In 2017, China initiated a five-year green finance reform and innovation policy in five selected pilot zone to advance environmental governance and energy structure innovation. Some green financial products were published first such as green bonds, green funds, carbon finance, green credit and insurance as well As a result, it is necessary to analyze the implementation situation of green economic policies and evaluate its effect on the renewable energy industry and environmental protection.

Currently, the relevant research on green economic policy mainly focuses on international experiences and its green effects on innovation, environmental protection, regional economic growth and carbon emission reduction. Due to difficulty of data collection, policy diversity and completeness of policy implementation, empirical studies on the impact of green financial policy on energy structure change remains scare. Therefore, this study aims to enrich and deepen the green finance policy mechanism and analyze its effect on regulating renewable energy industry.

When considering methodology, previous studies primarily focused on comparative analysis or difference in differences (DID) approach which offer simplicity and ease of implementation while the strong assumptions that may not always be held. This research adopt synthetic control method(SCM), a more flexible approach that can better account for selected complexity to evaluate the impact of green financial policy mechanism on renewable energy industry based on the selected pilot zone panel data in China from 2013 to 2021. Furthermore, the robust test of estimation also emphasize policy effect and figure out that green financial policy stimulates the expansion of regional financing scales, resource endowment, and technological innovation as well.

The structure of this research is as follows: The second part focuses on theoretical analysis related to the effect of green finance policy and industrial transformation. Part three introduces new pilot zones selected under China green finance policy landscape. Part four analyzes methodology, variables and data while part five presents the empirical results and conducts robustness tests. Finally, part six explains the conclusions and policy implications.

II. Literature reviews

Previous studies analyzed the basic definition of green finance policy from various perspectives. Salazar(1998) first proposed the concept of green finance and emphasized the integration of environmental consideration into financial practices. Recently, Wu, et al.(2019) analyzed effect of green finance policy from enterprise perspective

and conducted that green credit policy could exert positive influence on renewable energy sources. Xu, et al.(2023) explained the emergence of green finance and figured out financial development must be tied to environmental and climate risks when confronting the real economy. Zhang and Li(2022) suggested that green finance is a financial form to promote environment-friendly investments and emphasized the important relationship between green-oriented credit, green securities, green insurance and green investment as well as green bond. Batrancea(2020) analyzed the synergistic degree of green finance policy and showed that in order to increase economic growth while reducing global warming issues and climate change, financial sector should assume a greater role in funding green investments. Liu and Wang (2023) defined green finance as a financial innovation to support the green transformation and development of the national economy, which can rationally allocate and maximize the guidance of limited resources to the direction of environmental protection. Lee and Lee(2022) explained green finance policy from the perspective of carbon emission trading policy in China and the results showed that improvements in green finance development index as well as the use of non-fossil energy contributed to a reduction in carbon emission intensity. Ma, et al.(2023) introduced that green bonds are the main source of financing policy and it can be used to remove the financing barriers for green industry and economic sustainability.

Besides the basic definition explanation, some findings explore the green financial policy evaluation and its effect on industries. Zhang (2022) analyzed Chinese industry-level data and showed that carbon emission intensity of high pollution industries decreased sharply compared to non-high pollution industries after the implementation of green credit policy. Su(2022) provided evidence from perspective of traditional fossil industry and analyzed that green finance policy exhibits energy saving effect on enterprises. Gu, et al. (2023) pointed out green finance development has a positive effect on the energy consumption structure transformation, which is revealed through the construction of intermediary effect and threshold effect models. Tang, et al.(2023) constructed the green innovation level indicator and explored the implementation effect of China's green finance pilot policy from a green innovation perspective.

At the same time, some researches dedicated to explore the relationship between green finance policy and energy structure transformation by using different models. Huang(2021) conducted a different-in-different propensity score matching (PSM-DID)model and investigate the differences of green financial policies from environmental perspective. The result showed that green finance policy can reduce environmental pollution and improve environmental enhancement as well. Sun(2022) covered panel data spanning from 2007 to 2020 from 30 province in China and applied sys-GMM model to demostrate that the green finance strategy in renewable energy can reduce the carbon emission amount. Cui and Mao(2023) adopted synthetic control method to analyze the impact of green financial policy and its effect on energy consumption structure. The results showed that green financial policy significantly promote the transformation of traditional energy structure while the regional differences also be implemented as well.

Although some literature has discussed the relationship between green finance policy and traditional energy consumption, empirical evidence on the mechanism of green financial policy on renewable industry remains limited. Therefore, this research try to explore the impact through empirical analysis.

III. Green financial policy situation in China

The establishment of China's pilot zones for green finance reform and innovation aims to apply green financial practices with new policies, regulations, and financial instruments which intended to promote green investments and support the energy transition to a low-carbon economy under the Carbon Neutrality Plan 2030.

In 2017, the State Council of China initiated the first step of development of pilot zones in five provinces (Guangdong, Zhejiang, Jiangxi, Guizhou, and Xinjiang). After 2 years of practice, China is vigorously promoting a new branch of financial pilot reform zones in other cities, which were chosen as models for scaling up green finance initiatives nationwide, driving sustainable development and contributing to global efforts to combat climate change. Figure 1 illustrates the new regional distribution of four pilot zones(Gansu province, Chonqing, Shanghai and Shandong province) selected in 2019, which also emphasize the geographical differences among them.

Shanghai aims to establish green financial ecosystem along with banking and insurance sectors. The balance of green financing are expected to surpass 1.5 trillion yuan by 2025. Shanghai also promote steady growth in green insurance, bonds, funds, trusts, asset management and leasing businesses. Recently, over 90% of the nation's green bonds are issued and more than 60% of equity financing for green and environmental protection enterprises takes place in Shanghai.

Chongqing is actively promoting financial pilot reforms and innovations by increasing the proportion of green assets and the scale of green credit issuance. The city aims to achieve a green loan balance of over 600 billion yuan by the end of 2025, doubling the figure from 2020, with an average annual growth rate of over 20%. By 2025, Chongqing aims to quadruple its green bond issuance scale compared to 2020, reaching over 90 billion yuan.

Shandong Province has been closely monitoring the "dual carbon" goal orientation in recent years. It introduced China's first local carbon account system to encourage residents to adopt green lifestyle. Currently, over 1,200 individual carbon accounts have been registered in Shandong, contributing 30% of the total amount.

Gansu Province continuously intensified efforts to innovate over 50 green financial products which focused on fiscal and tax support, industrial incentive and green platform development. Gansu government have issued over 4.6 billion new green bonds. Furthermore, the innovative green financial products and services such as "Silk Road Carbon Trading + Green Insurance" have been introduced, facilitating the implementation of green financial products.

The main characteristics of green financial pilot zones in China can be summarized as followed. (1) Incentive Mechanisms: The pilot zones offer a range of financial incentives, including subsidies and risk compensation to stimulate investment in green projects. (2) Green Financial Products and Services: The pilot zones facilitate the advancement of green financial products and services through green loans, green bonds, green insurance, and green funds. (3) Risk Management: The pilot zones enhance the risk management of green finance by establishing green finance risk evaluation system. (4) Information Disclosure: The pilot zones mandate companies to disclose their environmental information, which aims to aiding investors in evaluating environmental risk associated with investments. (5) Integration, Cooperation and exchange: the pilot zones foster cooperation and exchange at both domestic and international levels together.

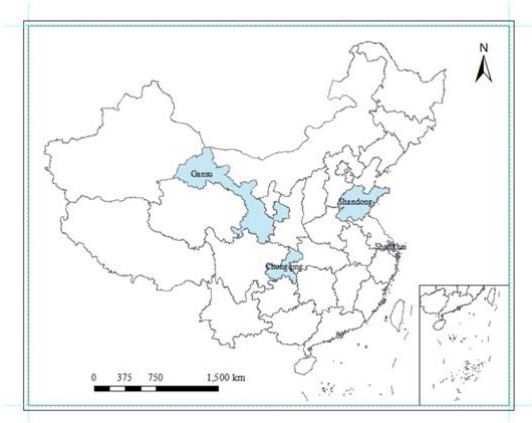

Fig. 1. China's new green financial policy pilot zones (source: Ministry of Ecology and Environment of China)

IV. Methodology and data

1. Synthetic control method

Synthetic control method(SCM) is a powerful tool used for evaluating the effect of policies and interventions. Compared with other comparative analysis and DID approach, SCM constructs a synthetic control group that closely resembles the characteristics of the treatment group to compare against the actual group. It generally utilizes an extensive time series of outcomes prior to the intervention in order to ensure that control group closely reflect the treatment group. Furthermore, traditional methods often require large sample size whereas SCM can analysis reliable statistical results even with smaller data source. By comparing changes before and after the policy implementation, SCM can clearly identify the policy's effects and figure out the actual regions where the policy was implemented efficiently. The methodology has been employed in previous research such as smoking regulations in California(Abadie, et al., 2010), the effects of Cuban immigration in Florida, and the reunification of East and West Germany in 1990(Abadie,et al., 2015).

The principle of SCM is that central weights are determined to minimize the discrepancy between control group and experimental group, ensuring that the synthetic control group exhibits characteristics similar to those of the experimental group prior to policy implementation. The process of minimizing the discrepancy between two groups is known as iterative optimization algorithm(Abadie, et al., 2010). The basic outline of SCM equation and the explanation of its components can be represented by equation 1.

$$\sum_{i=1}^{t} = v_i (X_{ti} - X_{(t-1)i} W)^2 \quad (1)$$

For the predictor variables from i to t, X_{ti} represents the i-th predictor variable of the experimental group, while $X_{(t-1)i}$ represents the i-th predictor variable of the potential control group. The predictor variables for both groups correspond to explanatory variables in a regression analysis, which are expected to influence the outcome variable that reflects the policy effect. The control group is assigned with a weight vector W, based on its similarity to the experimental group, and v_i is a weight vector reflecting the relative importance of the predictor variables.

After constructing the synthetic control group, the effect of the policy can be measured by equation 2, Subsequent to policy implementation, the outcome variable m for the experimental group is represented as Y_{tm}, while the outcome variable for the synthetic control group is denoted as $Y_{(t-1)m}$. W represent a weight vector for control group. The disparity in outcome variables between the two groups represents the policy effect.

$$\min_{w} \| Y_{tm} - Y_{(t-1)m} W \| \quad (2)$$

$$\text{subject to } \sum_{i=1}^{t} w_i = 1, w_i \geq 0, i = 2, \ldots, T$$

2. Variables and data resource

This research selects the ratio of renewable energy consumption to total energy consumption as dependent variable, which illustrate the impact of green financial policy. Government policy dummy variable is chosen as explanatory variable which representing the new pilot zones of green finance

reform and innovation from 2019. Here we assumed if the pilot year is after 2019, the time dummy variable is set to 1; otherwise it is set to 0. Meanwhile, if selected province is a pilot zone, the regional dummy variable is set to 1; otherwise it is set to 0.

Table 1. Variable definitions

Variable	Variable name	Abbreviation	Variable definition
Dependent variable	Renewable energy consumption	Rec	ratio of renewable energy consumption to total consumption
Explanatory variables	Regional dummy variable	Treat	A dummy variable is set to be one for provinces is pilot zone and zero for those with non-pilot zones.
	Time dummy variable	Post	A dummy variable. It is set to be one if year is after 2019 (including 2019)and zero before 2019.
Control variables	Population	Pop	natural average population indicator
	GDP	GDP	GDP indicator
	Foreign trade	Ftrade	proportion of total foreign trade in each district's Gross Regional Production
	Industrial structure	Is	proportion of the secondary industry's added value in gross regional product
	Energy price	Ep	provincial fossil fuel price index with the base year of 2000
	Environmental regulation	Ecost	ratio of fiscal expenditure on environmental protection to the general fiscal expenditure

Referring to previous literature, the following control variables are selected to explain green financial policy as well, which include population (Chen, et al., 2019), GDP(Sun and Chen, 2022), Foreign trade (Tan, et al., 2023), Industrial structure (Sun and Chen, 2022), energy price (Cui and Mao, 2023) and environmental regulation cost (Tan, et al., 2023). The variables and definitions utilized in empirical analysis are outlined in Table 1.

The analysis select panel data from 30 districts in China spanning from 2013 to 2021 which aims to analysis the impact of green financial policy on renewable energy industry before and after the policy implementation. Data source are primarily selected from China Energy Statistics Yearbook, wind financial platform and the statistical yearbooks of each province and district. The empirical analysis is implemented by stata and table 2 provides descriptive statistics for main variables.

Table 2. Descriptive Statistics for Variables

Variable	N	Mean	SD	Min	Max
Rec	360	0.2870	0.2005	0.0147	1.0006
Gf	360	0.0693	0.2542	0	1
Pop	360	8.2219	0.7526	6.3474	9.4212
GDP	360	0.5592	0.1519	0.0038	0.8930
Ftrade	360	0.2745	0.2935	0.0126	1.3685
Is	360	0.4103	0.0817	0.1655	0.5576
Ep	360	2.0095	0.0339	1.9309	2.0648
Ecost	360	2.9785	0.9319	1.3188	5.7657

V. Empirical result

5.1 Comparison of real and synthetic variables

After methodological analyze, real variables and synthetic variables are compared to describe the effect of green financial policy simultaneously. Here real variables refer to the actual observed data from Shanghai, Shandong Province, Chongqing and Gansu Province. When it is expressed in figure, real variables reflect indicators before and after the green finance policy implementation and the data are typically shown with a solid line. On the other hand, synthetic variables are constructed by combining data from control units that were not affected by policy intervention, which is depicted with a dotted line in figures. The Root Mean Square Prediction Error (RMSPE) signifies the degree of fit between a real and synthetic variable, a smaller RMSPE indicate a better fit. Table 3 shows the comparison indicator between real and synthetic variables in four pilot zones.The results showed that synthetic counterparts are minimal, which suggests that control groups, established by SCM,

accurately mirrors the real treatment group variables and the analyze is feasible and operationable.

Table 3. Comparison indicator in four pilot zones

Variables	Shanghai		Shandong		Chongqing		Gansu	
	Real	synthetic	real	synthetic	real	synthetic	real	synthetic
Pop	8.482	8.467	8.406	8.380	8.367	8.356	7.739	8.058
GDP	0.642	0.6407	0.490	0.528	0.388	0.634	0.459	0.503
Ftrade	0.556	0.555	0.160	0.158	0.058	0.745	0.185	0.139
Is	0.489	0.477	0.523	0.520	0.393	0.399	0.420	0.423
Ep	2.005	2.002	2.003	2.005	2.009	2.010	2.006	1.998
Ecost	2.244	2.642	2.132	2.989	2.596	1.899	2.220	3.459
RMSPE	0.0062		0.0087		0.03497		0.0047	

5.2 Fitting result of SCM in four pilot zones

Figure 1-4 shows the synthetic control analysis result of the selected pilot zones (Shanghai, Shandong Province, Chonqing and Gansu Province) and other regions. As it is mentioned before, the solid line is the pilot zone result under green finance policy while the dotted line is the others. The vertical dotted line reflect the green finance policy time schedule for the 2019 new pilot zone.

According to the graphic expression, some illustrations can be concluded as followed. Firstly, since the new batch of four pilot cities implemented after 2019, it is clearly that the impact of the time variable on the policy is significant. Among different regions, Shanghai and Shandong had the most substantial policy impact after 2019, followed by Chongqing and Gansu. Secondly, research findings from 4 pilot cities indicate that green finance policies implemented in Shanghai, Shandong, and Chongqing have positively influenced renewable energy industry development, while the effects in Gansu Province are not significant. Compared with other pilot cities, Shanghai has experienced the greatest impact, which attributed to its geographical location, resource structure and the strength of its policies. As China's largest coastal open city, Shanghai has abundant renewable energy resources. Additionally, as the financial center of China, Shanghai has actively promoted green finance reform policies in recent years. The city has implemented a variety of timely and actionable green finance tools and measures, making its performance the best among the four cities. On the other hand, Gansu, as a major traditional energy province, has a high proportion of traditional energy sources, resulting in a relatively stable energy structure and low penetration of the new energy industry. Consequently, the impact of green finance policies is lower.

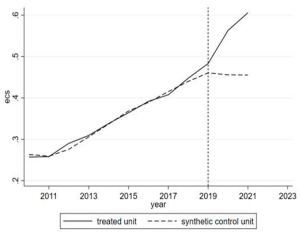

Fig. 1. ECS of real and synthetic Shanghai

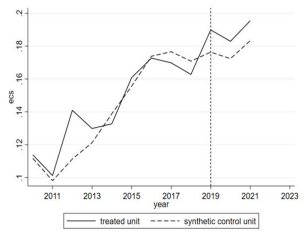

Fig. 2. ECS of real and synthetic Shandong

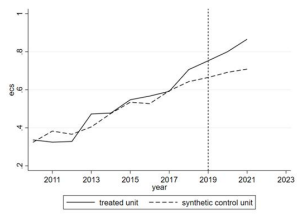

Fig. 3. ECS of real and synthetic Chongqing

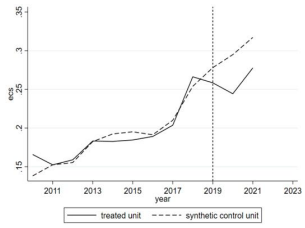

Fig. 4. ECS of real and synthetic Gansu

5.3 Robustness test

According to the original analyze of synthetic control model (Abadie et al., 2010), Placebo test and Root Mean Square Prediction Error(RMSPE) test are used to prove the causal impact of policy interventions in policy evaluation. If the observed effect in pilot zones exceed the effect in the placebo study, then green finance policy is considered to be feasible and significant.

Figure 5-8 shows the robustness test result of the impact of green finance policy, where the solid line represents the real group showing a significant change after policy and dotted lines represent placebo groups showing little or no change. The results pointed out that before 2019, the fluctuation

and gap of renewable energy development among pilot zones and other regions was not that obvious while after 2019, huge differences and gap are reflected. Furthermore, Shanghai and Chongqing performed exceptionally well in robustness analysis, suggesting that green finance policies have a significant impact on renewable energy industry while Gansu province remains the lowest. This situation can be explained that Shanghai and Chongqing enjoyed advanced economic development, robust financial infrastructure, greater capacity for innovation and better access to international expertise. On the other hand, due to the geographical resources and economic structure, the energy consumption in Gansu province is seriously influenced, as a result, the impact of green financial policy in Gansu province is not evident in short term.

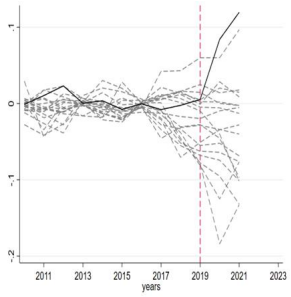

Fig. 5. RMSPE test result in Shanghai

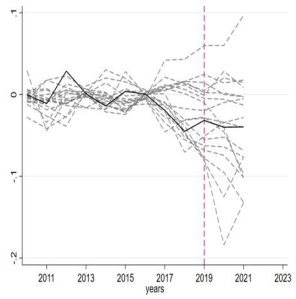

Fig. 6. RMSPE test result in Shandong

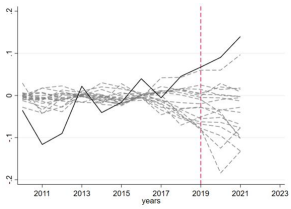

Fig. 7. RMSPE test result in Chongqing

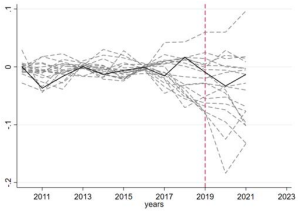

Fig. 8. RMSPE test result in Gansu

VI. Conclusion and policy suggestions

Based on 30 regional panel data from 2013 to 2021, this research facilitate 4 new pilot zones as samples and analyze the mechanism of China's green finance policy on renewable energy industry by using synthetic control method. The main research findings are as follows:

First, the implement of Green finance policy in China can significantly influence renewable energy industry and the results showed that policy effect differed after 2019. Conversely, the renewable energy industry development can promote future green finance reform as well. Second, there is a significant deviation in the effectiveness of green finance policy among different pilot zones. Overall, the financial effects in Shanghai and Chongqing pilot are more favorable than other regions, which mainly manifested that the industrial structure optimization and green financial efficiency plays an important role. On the other hand, the effectiveness of green finance policies in Gansu reflect the lower level.

According to the results, the research proposes several policy suggestions as well. First, it is important for government to conclude some successful experiences from Shanghai and Chongqing under the green financial policy implementation and promote to a larger national scale transition of low-carbon development. Second, the regional differences of green financial policy impact should also be emphasized. The green innovation level in eastern regions like Shanghai is more significantly than western regions like Gansu province because of economic development and energy structure. Therefore, the implementation of green financial policy in different region needs to be more targeted and efficient and the expansion of regional financing scales, resource endowment technological innovation should be emphasized as well.

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