Evaluation of the Effectiveness of Green Finance Pilot Policies - An Empirical Study Based on Dual Machine Learning

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Abstract. Holding the guidance of high-quality green development, vigorously developing green finance has become a consensus in policy and practice. Based on the provincial panel data of 30 provinces in China from 2011 to 2020, this paper uses the double difference and double machine learning method to explore the impact and heterogeneity of establishing green finance reform and innovation pilot zones on local green finance development. The study found that the establishment of pilot zones has improved the local comprehensive development level of green finance, and this impact has significant heterogeneity in fiscal balance, industrial coordination, and environmental regulation. The research conclusion reveals the differences in green finance development and has an enlightening effect on promoting and optimizing green finance policies.

Keywords: green finance; dual machine learning; causal forests

1 Introduction

China has always emphasised the promotion of national rejuvenation through Chinese-style modernisation, of which green development is a central part. President Xi Jinping has also stressed the need for green finance to contribute to building an ecological civilisation and a beautiful China. As a bridge connecting green organisations and green development, green finance is crucial to supply-side structural reform and green economic development.2023 The Government Work Report further emphasised the important role of green finance in expanding domestic demand, supporting the construction of industrial systems and green transformation. China's green finance development has been effective, and the international status of the green finance market has been rising, with the scale of green loans and bonds ranking among the world's top. The government has continuously introduced relevant policies, and the first batch of green financial innovation and reform pilot zones were in five provinces and eight places in 2017 to promote the development of green finance. But how effective is the promotion of relevant government policies around the world? Based on this, this paper, on the basis of the original theory, combined with big data and machine learning, establishes a set of scientific systems for green financial development, measures green finance scientifically and accurately, and analyses the policy effect of the green financial reform and innovation pilot zones on the development of green finance by using causal forests, with a view to providing references to the policy formulation for the better performance of green financial development.

2 Literature Review

In recent years, green finance has attracted much attention in national and international research as a link between finance and industry. Green finance, which focuses on eco-friendly investments and activities, has become an essential instrument for attaining carbon neutrality and sustainable green economic growth. (Bhatnagar et al., 2022) [1]. The development of green finance is indispensable for achieving the Sustainable Development Goals (SDGs) (Goel et al., 2022) [2]. In China, Li Shaozhe et al. (2023) [3] found that green finance pilot policies have a significant effect on reducing carbon emissions from heavy polluting enterprises, especially for non-state-owned enterprises and those with high external financing dependence. Wang Yao et al. (2022) [4] combined green finance with the "double carbon" target, emphasizing its crucial role in promoting social green transformation. However, current research on green finance measurement is mostly based on structured data, lacking indicators related to green innovation and risk. Zhou Chenying et al. (2022) [5] and Zhao Yu et al. (2023) [6] revealed the uneven distribution and regional differences of green finance resources in China by constructing an indicator system. This shows that there is still a need for further improvement in green finance measurement. In terms of green finance policy research, although there are many qualitative policy suggestions, quantitative research is relatively rare. Studies by Wang et al. (2020) [7] and Wen et al. (2021) [8] showed that green credit policies have a disciplinary effect on enterprises in high-energy-consuming and high-polluting industries, constraining their investment scale by reducing debt financing quotas. Qi Huaijin and Liu Siqin (2023) [9] found that green finance pilot policies can promote green innovation activities of enterprises. Wang Yao et al. (2022) [10] conducted a quantitative analysis of the policy effects by taking the incentive policy of green credit as the starting point, putting forward higher requirements for the development of green finance and optimizing the green finance policy system.

3 Indicator Design

Based on the "three major changes", quality change as the main body, power change as the basis, and efficiency change as the main line, this paper constructs an index system for green financial development in 30 Chinese provinces from 2011 to 2020 based on data availability. The dimensions include financial allocation, innovation, market maturity, activity and risk resistance, which are measured by a composite index calculated by entropy weight TOPSIS method. The core explanatory variable Did is the interaction term between the individual binary dummy variable (SYQ) and the time binary dummy variable (Post), where SYQ={0,1}, is the experimental area take 1, otherwise take 0. Post={0,1}, takes 1 in 2017, 0 thereafter, and 0 before that.

4 Evaluation of the impact of innovation pilot zones and green finance reform on policy

4.1 Basic regression findings

The fundamental regression findings are shown in Table 1. In accordance with Hypothesis 1,

columns (1) and (2) show that the estimated coefficients of Did are positive at the 10% significance level regardless of whether control variables are controlled. This suggests that the creation of innovation and green financial reform pilot zones has a significant promotion effect on the degree of green financial development in the area.

Table 1. Basic regression results

variant	(1) GF	(2) GF
Did	0.0475*	0.0373*
	(0.0249)	(0.0193)
control variable	No	Yes
individual effect	Yes	Yes
time effect	Yes	Yes
N	300	300
R²	0.863	0.905

Note: Values in parentheses are standard errors of clustering; *, **, and *** indicate 10%, 5%, and 1% significance levels, respectively; (same as in the table below).

4.2 Parallel trends and robustness test

This paper examines the validity of the DID model in Figure 1, and using regression analysis, it discovers that, prior to 2017, the development of green finance followed a similar trend for both the treatment and control groups, but that, following the creation of the financial reform and innovation pilot zone, there were notable differences. In Figure 2 this paper also adopts a placebo test by fictionalising the pseudo-treatment group and repeating the regression to verify whether the promotional effect of the pilot zone on the development of green finance is affected by random factors. The results show that the pseudo-treatment effect estimates are mostly concentrated at zero, with p-values mostly greater than 0.1, which are significantly different from the true estimates, indicating that the true results are not derived by chance.
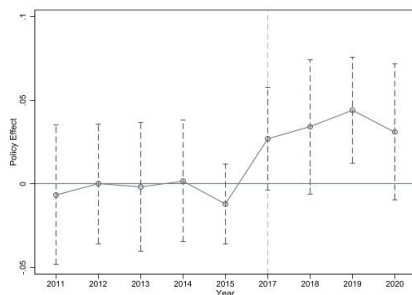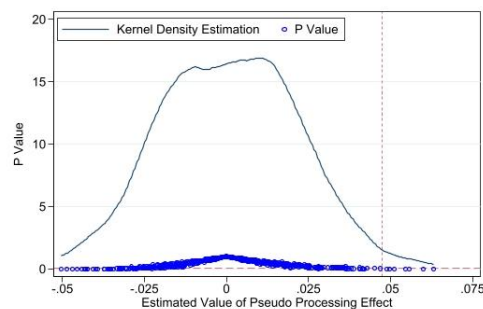

Fig1. Parallel trend test

Fig2. Placebo test

4.3 Causal forest-based heterogeneity analysis

In this paper, we further retain the control variables whose variable importance is greater than

the overall mean of the variable importance, and carry out another more effective causal forest estimation to estimate the overall average treatment effect, and the results are shown in Table 2, which shows that the establishment of the pilot area significantly promotes the level of local green financial development, and this estimation is slightly higher than the regression results of the DID model.

Table 2. Estimation results based on the causal forest approach

mould	ATE	95% confidence interval
forest of cause and effect	0.079**(0.0342)	(0.012,0.146)

Based on the significance of the variables, regressing the significant variables with CATE yields Table 3, where column (1) illustrates the heterogeneity of the policy effects in terms of the fiscal balance ratio (Fisc), the share of the secondary sector (Rsecd), and the utilisation rate of solid waste (SoWaste).

Table 3. Heterogeneity regression results

variant	(1) CATE	(2) CATE
Fisc	-0.0049***	-0.0044***
	(0.0010)	(0.0011)
Rsecd	0.0235**	0.0892***

Continued from table 3. Heterogeneity regression results

variant	(1) CATE	(2) CATE
	(0.0095)	(0.0304)
Rsecd^2		-0.0739**
		(0.0355)
SoWaste	0.0191***	0.0198***
	(0.0024)	(0.0025)
LnPat	-0.0013	
	(0.0011)	
N	300	300
R²	0.679	0.693

Figure 3 and Table 3(2) show that the establishment of pilot zones is more effective in regions with balanced fiscal revenues and expenditures, and that fiscal deficits may affect the use of funds in pilot zones and constrain the level of green finance. Meanwhile, the pilot zones have the greatest impact on regions with medium industrialization (about 60%), because industrialization is often accompanied by high pollution and requires transformation and upgrading, which provides an opportunity to improve the level of green finance. In addition, the utilization rate of solid waste is positively correlated with the level of green finance, and a high utilization rate indicates that the region has strict environmental protection regulation and pays more attention to green finance, which helps to reduce the environmental burden, improve the efficiency of resource utilization, and promote environmental protection innovation. Therefore, the establishment of pilot zones in regions with high solid waste utilization rates is more effective in promoting the level of green finance.
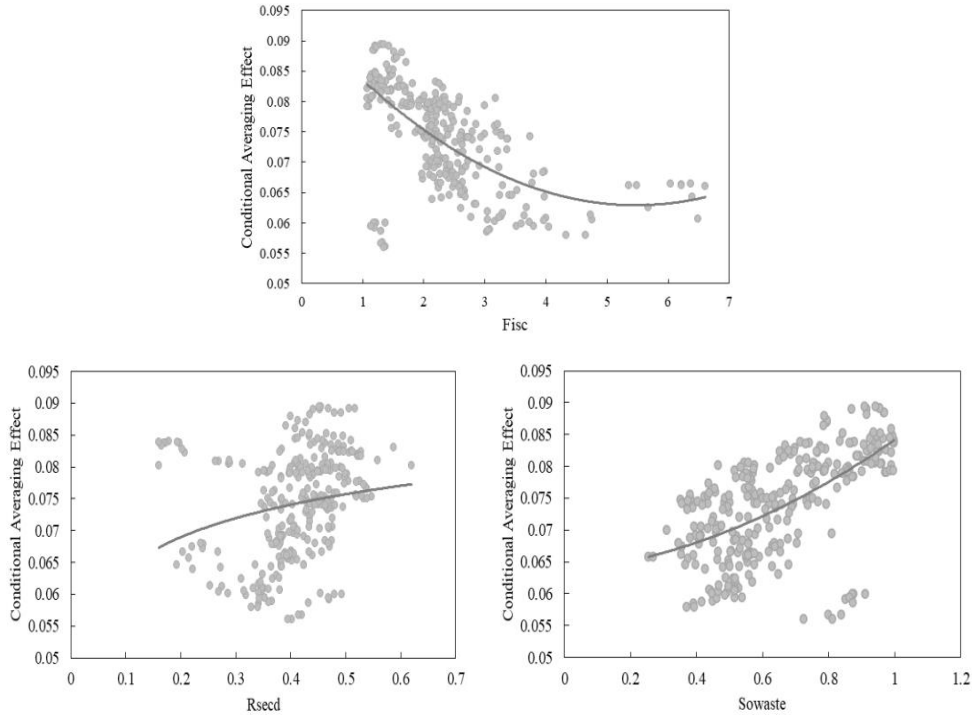
Fig 3. Conditional Average Treatment Effects with Significant Variables

5 Conclusions and recommendations

The study finds that: the level of green gold rises steadily, but declines slightly in 2018-2020, and spatially "the east is high and the west is low", with changes mainly in the order of transfer; the Gini coefficient is in the shape of "W", with a widening of the gap between regions, and polarisation in the northeast and the west; the pilot areas have a "W" shape, and the pilot areas have a polarisation phenomenon. The Gini coefficient is in a "W" shape, with widening inter-regional disparities and polarisation in the northeast and the west; the effect of the pilot areas in raising the level of local green gold is affected by fiscal revenues and expenditures, industrial structure and waste utilisation rates.

In this regard, the following suggestions are made: first, improve the green gold system and the mechanism. The government should optimise policy design, improve regulations, establish a performance assessment mechanism, foster evaluation by third-party agencies, and strengthen financial institutions' awareness of green gold. Second, strengthen coordination based on regional differences. Clearly define the development plan of each region, guide the steady growth of the central and eastern parts of the country, and promote the transformation and upgrading of the region by bringing the "first rich" to the "second rich". Encourage regional financial cooperation and establish an information-sharing platform to enhance the efficiency

of resource allocation. Lastly, pilot zones should be promoted in financially balanced, industry-led and highly environmentally regulated regions. Financial institutions should be supported in setting up green institutions, innovating green products and enhancing their service capacity, so as to promote green development and help modernisation.

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