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Can Green Finance Reform and Innovation Pilot Zones Promote the Operational Efficiency of Commercial Banks? — Empirical Research Based on 40 Commercial Banks in China

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Abstract

The Chinese government is placing significant emphasis on green development. From 2017 to 2021, the central and local governments in China established 9 green finance reform and innovation pilot zones in 6 provinces to explore the pillars of China's green finance system. Although these zones and related policies have been proven advantageous for innovative manufacturing enterprises and environmental quality, the impact on commercial banks, pivotal players in China's green finance landscape, has been understudied. This paper employs the DEA-Malmquist and DID models to investigate the impact of pilot zones on the operational efficiency of commercial banks. The results indicate that the establishment of pilot zones significantly improves banks' operational efficiency, and the mechanisms are reducing non-performing loan rates and increasing green credit balance. In addition, state-owned banks have benefited more. Further research shows that the improvement mainly comes from increased pure technical efficiency, due to better management practices and resource utilisation. These findings can be used to evaluate the impact of the government's green finance policy on the operation of commercial banks.

Keywords: green finance policy, operational efficiency, commercial bank, DEA-Malmquist model, DID model

1. Introduction

In recent years, it has become increasingly evident that the traditional extensive mode has had a significantly hindered China's high-quality economic development, therefore, implementing alternative development methods and achieving green and sustainable development has become one of the necessary pathways for China's economic progress (China's National Development and Reform Commission, 2021).

During the process of accelerating the transition towards a greener development pattern, green finance can facilitate the allocation of social resources, promote the transfer of funds from polluting and outdated industries to environmentally-friendly and emerging industries, and subsequently encourage the mobilisation of other factors of production, foster the promotion of low-carbon economic (Akomea-Frimpong et al., 2021; Bukhari et al., 2020; Liu et al., 2017; Zhang et al., 2021; Ho and Virginia, 2018), ultimately achieve the goal of "pursuing green development and promoting harmonious co-existence between humanity and nature", as outlined in the Report on the 20th National Congress of the CPC (Xi, 2022).

Therefore, the advancement of green finance serves as a major tool for facilitating both the expansion of economic quantity and quality, and a fundamental route for the forthcoming progression of China's financial institutions (Liu

& Wen, 2019).

Considering the crucial role of green finance in economic development and industrial transformation, in June 2017, the People's Bank of China and six other ministries issued the *Overall Plan for the Construction of green finance Reform and Innovation Pilot Zones*. These zones encompass Guangzhou, Guangdong, Huzhou and Quzhou, Zhejiang, Ganjiang New Area, Jiangxi, Gui'an New Area, Guizhou, Hami and Changji Prefecture and Karamay, Xinjiang Uygur Autonomous Region, a total of 5 provinces and 8 places, are set up as green finance reform and innovation pilot zones. In December 2019, Lanzhou, Gansu, was included as a new one. These pilot zones are required to conduct pilot work in combination with local characteristics and explore the five pillars of China's green finance system (People's Bank of China et al., 2017).

As one of the key roles in developing green finance in China, commercial banks have been taking the lead in implementing high-quality and well-designed green credit policies (Du & Zheng, 2020). They have also been urged by policy to actively engage in a range of green finance activities, including researching, developing and designing new green credit products, establishing specialised loans tailored to local conditions, promoting the green and innovative transformation of traditional financial instruments and providing more support for green projects such as low-carbon energy conservation and pollution control (PBOC et al., 2017). As at the end of 2020, the green loan balance in the pilot zones increased to 236.83 billion CNY, representing 15.1% of the total loan balance of local banks (Xin & Tang, 2021).

Scholars have focused on researching the association between green finance reform and innovation pilot zones with manufacturing enterprises, and it is widely accepted that the creation of these pilot zones benefits these enterprises by allowing them to undertake green technology innovations, fulfil their social responsibilities, encourage carbon reduction, and achieve ecological progress in the regional industrial structure (Sun & Meng, 2021; Shen & Liao, 2020; Fan & Zhang, 2022; Si & Yao, 2022). However, there is little research has been conducted on the effects of pilot zones on commercial banks, and the impact of green finance on the operational efficiency of commercial banks remains inconclusive (Zhou et al., 2022). As one of the main enforcers of green finance policy implementation and critical fund providers in China's financial market, the participation of commercial banks in green finance activities affects the quality of green industry growth and the rate of economic transformation (Deng et al., 2022). Moreover, the profitability of green finance undertakings would decide the willingness and capacity of commercial banks to sustain their engagement.

In order to examine the effects of establishing green finance reform and innovation pilot zones on the operational efficiency of 40 Chinese commercial banks and their transmitted channels, this paper utilises relevant data from 2013 to 2021. The operational efficiency of these banks is measured using the DEA-Malmquist model, while empirical analysis employs various models, including DID and mediation effect model.

The paper's marginal contributions are as follows: In terms of research content, this paper firstly offers an original viewpoint by concentrating on commercial banks and evaluating the impact of the setup of green finance reform and innovation pilot zones on their operational efficiency quantitatively. In terms of research methods, this paper treats the establishment of the green finance reform and innovation pilot zones as a quasi-natural experiment, which provides insight into the transmission mechanism involved and the heterogeneity of its influence on the operational efficiency of commercial banks. Moreover, this paper uses separate efficiencies of the DEA-Malmquist total factor productivity index to identify the impact of the establishment of the pilot zones on the operational efficiency of commercial banks accurately.

This paper is structured as follows: Section 2 is hypothesis proposal, and Section 3 describes research design, including model introduction and data presentation. Empirical results, analysis and robust tests are presented in section 4, while conclusion and discussion can be found in section 5.

2. Hypothesis Proposal

2.1 Green Finance and the Operational Efficiency of Commercial Banks

According to the *Guiding Opinions on Building a Green Finance System* (PBOC et al., 2016), green finance in China is defined as "financial services provided for economic activities to support environmental improvement, climate change addressing, conserving and using resources in efficient ways". Based on the *Overall Plan for Green Finance Reform and Innovation Pilot Zones* (PBOC et al., 2017), commercial banks and other financial institutions are instructed to guide financial resources towards increasing investments in areas such as energy conservation, emission reduction, circular economy, ecological protection and other related sectors, finally establishing a new allocation system that supports the development of green industries.

Based on the features of green finance and commercial banks, alongside related policies, this paper suggest that the establishment of the green finance reform and innovation pilot zones primarily affect the operational effectiveness of commercial banks in five specific areas:

Credit Risk and Asset Quality Adjustment: Considering green finance initiatives, commercial banks in China should reduce their loan exposure to polluting enterprises belonging to industries with high levels of pollution, energy consumption, or overcapacity (China Banking and Insurance Regulatory Commission, 2022). This allows banks to minimise exposure to enterprises that are vulnerable to administrative penalties and market elimination.

Social Responsibility and Innovation Assessment: Green finance concept requires commercial banks to evaluate their social responsibilities of projects and provide more favourable loan conditions to qualified green projects. This differentiated loan pricing and approval mechanism compels non-green enterprises to innovate and enhance their financial quality and survival capabilities (Zhou et al., 2022; D'Orazio & Valente, 2019; Hao et al., 2020), ultimately improving the loan quality of commercial banks.

Expansion of Investment, Service, and Management Attributes: The rapid growth and promising prospects of green industries offer commercial banks new perspectives on project valuations, financial services, and internal control. This expansion of green finance provides opportunities for commercial banks to enhance management, increase comprehensive income, and strengthen their investment and service capabilities.

Positive Externalities: The rise in green finance investment by commercial banks may have a positive impact on regional environmental quality, contributing to the indirect enhancement of commercial bank operational efficiency through generating social benefits. This, in turn, could reduce production costs for the private sector and ultimately boost overall social production efficiency (Thompson & Cowton, 2004).

Furthermore, commercial banks could diversify their business portfolios, lower their capital costs, and promote sustainable growth by utilizing green financial derivatives.

Based on the preceding discussions, the first hypothesis is as follows:

Hypothesis 1. The establishment of green finance reform and innovation pilot zones can promote the operation efficiency of commercial banks within the zones.

2.2 Mechanism Analysis

Based on the information from the green finance reform and innovation pilot zones policy and relevant studies, establishment of the pilot zones may have the potential to influence the operational efficiency of commercial banks through the following two mechanisms.

2.2.1 Improving Loan Quality and Reducing Non-Performing Loan Ratio

In line with the plan for each region, commercial banks in the trial areas are expected to "establish a green finance risk prevention and resolution mechanism" and aim to attain "a non-performing loan rate for green loans that is not higher than the average non-performing loan rate for small and micro enterprises" (PBOC et al., 2017), while increasing the supply of green credit and extend the scope of green finance services. To meet policy requirements, commercial banks in the pilot zones should actively issue green credit and ensure the quality and safety of their green loan assets. These banks could assess the social responsibilities and innovation capabilities of borrowing enterprises, whilst also enhancing their risk control and loan verification processes.

Furthermore, commercial banks could decrease industry mismatch (Cheng, 2015), and excessive concentration of loan resources by limiting loans to industries with high pollution, high energy consumption and overcapacity to mitigate policy risks associated with the elimination of outdated industries. Given the Chinese government's increasing emphasis on environmental protection, creditors such as commercial banks can avoid any spillover effects (Yi et al., 2014; Sun et al., 2017). Based on these considerations, this paper proposes the following assumption:

Hypothesis 2a. The establishment of the green finance reform and innovation pilot zones promotes the improvement of commercial banks' operational efficiency by enhancing the quality of loans.

2.2.2 Promoting Participation in Green Finance Activities and Increasing Green Credit Supply

As a developing environmentally friendly finance product, green credit offers commercial banks new opportunities and management perspectives. The *Plan* of each region proposed to expand the "green finance scale", "green credit delivery", and "proportion of green finance products" (PBOC et al., 2017), ultimately improving the quality and quantity of green finance products available in pilot zones. By diversifying the industry distribution of bank loan portfolios, green finance enables commercial banks to mitigate risk concentration, improve overall performance indicators such as yield variance and rate spreads, and comprehensively enhance their operational efficiency (Li et al., 2017; Zhang, et al., 2020). These characteristics may be particularly noticeable in regions with a well-established green economy and strong government support.

As commercial banks become more involved in green finance, the provision of green credit could assist in diminishing liquidity risk as well as fortifying internal control (Zhu, et al., 2017; Lei & Shi, 2020). Furthermore, it can also increase asset size and build social reputation. These factors may enhance the ability of commercial

banks to tolerate risks, compete within the market and generate revenue. The above discussions lead to the following hypothesis:

Hypothesis 2b. The establishment of the green finance reform and innovation pilot zones promotes the operation efficiency of commercial banks by enhancing their participation in green finance.

2.3 Heterogeneity Research

2.3.1 Heterogeneity of Scale of Commercial Banks

The plan for each region requires commercial banks in the pilot zones to establish dedicated green finance divisions or green branches to explore special loans and derivative financial products (PBOC et al. 2017). However, as an emerging financial product and concept in China, green finance needs to reach a certain scale to demonstrate its full characteristics, and larger banks oftentimes have higher probability to achieve this.

Compared with small and medium-sized banks, large banks possess advantages in liquidity management, risk diversification, and cost control, due to their stronger capabilities to raise funds from the capital market and establish branches to attract deposits (Chen & Hu, 2022). In addition, large banks always have access to a broader range of resources and experience which enable them to secure high-quality green credit projects and obtain potential returns at a higher rate (Tan, 2013; Wang & Dong, 2019; Guo & Liu, 2019). Based on afore discussions, the fourth hypothesis is as follows:

Hypothesis 3a. Larger commercial banks are more positively affected by the establishment of the green finance reform and innovation pilot zones.

2.3.2 Heterogeneity of Ownership of Commercial Banks

Non-compulsory phrases like “support”, “exploration and development”, and “giving preference” are frequently used in the plans of various pilot zones. In this circumstance, financial institutions in the pilot zones are facing uncertainties about the implementation impacts of specific innovative aspects. They would receive subsidies from governments if they undertake relevant innovations (Yang & Tang, 2017), but there is limited penalty for abstaining from such initiatives.

In general, commercial banks may be reluctant to enter the new field too soon since the green finance framework is incomplete, however, central and local state-owned banks are often easily guided by policy directives. They are incentivised to comply with policy requirements and can receive compensation for project-related losses through government subsidies (Sun & Li, 2016).

In addition, green finance encompasses significant social responsibility considerations. As banking leaders and state-owned enterprises, state-owned commercial banks always bear greater responsibility in China (Deng et al., 2022). Therefore, comparing with general public banks, state-owned banks demonstrate more active involvement in green finance innovation, they can avail themselves of policy support and be granted priority in selecting high-quality green projects, thereby demonstrating a more significant impact of green finance. As mentioned earlier, this paper proposes the following assumption:

Hypothesis 3b. State-owned commercial banks are more positively affected by the establishment of the green finance reform and innovation pilot zones.

2.3.3 Heterogeneity of Public Listing of Commercial Banks

Green credit has positive externalities, and it can demonstrate the social and environmental responsibilities taking of commercial banks. As emphasised in *the Overall Plan* (PBOC et al., 2017), local governments should strengthen social guidance and public awareness, and promote the participation and enthusiasm of stakeholders in green finance. With the growing importance of green investment concepts and the availability of green financing instruments, listed commercial banks would have advantages than non-listed commercial banks due to their stricter information disclosure obligations and higher popularity (Wang & Sun, 2019; Zhang & Zhang, 2019). As the volume of green loans increases and relevant information disclosure deepens, they may accumulate better environmental and social reputations, thus promoting long-term performance over time. Based on these considerations, this paper proposes the following assumption:

Hypothesis 3c. Listed commercial banks are more positively affected by the establishment of the green finance reform and innovation pilot zones.

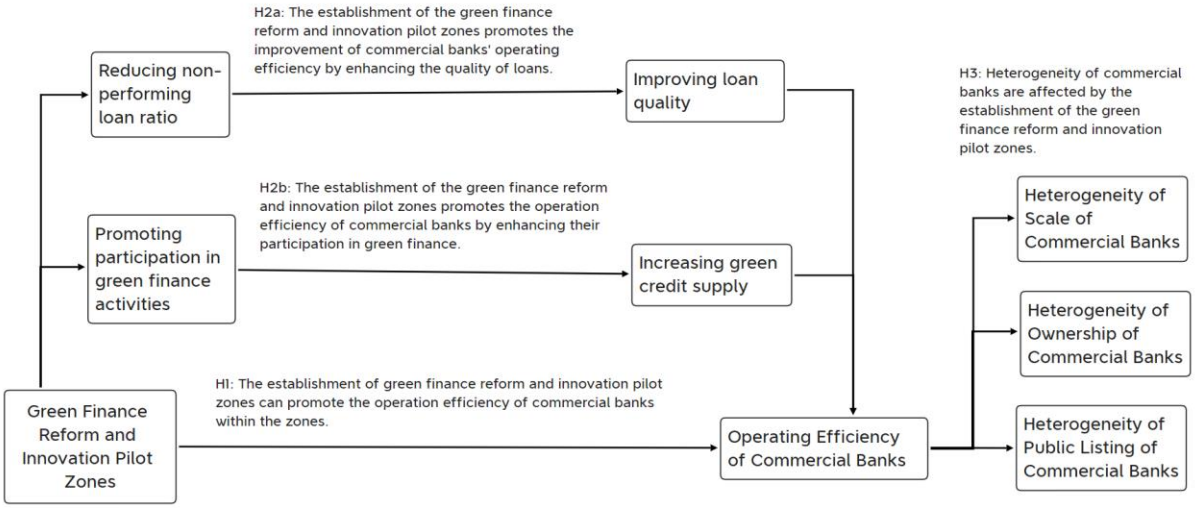

Figure 1. The Impact of the Establishment of Green Finance Reform and Innovation Pilot Zones on the Operational Efficiency of Commercial Banks

3. Research Design

3.1 DEA-Malmquist Model

DEA-Malmquist is a nonparametric estimation method originally proposed by Färe et al. (1994), which combines the characteristics of the DEA model and the Malmquist model to assess the relative changes in efficiency among decision making units (DMUs) in a multi-input and multi-output framework and is widely used to assess the production and operational efficiency of various entities.

As financial institutions, commercial banks primarily generate loans and profits by investing capital and human resources, therefore, this paper is based on the relevant research by Wang (2022) and Liu (2019), applies the production method, set net assets, total assets and total human cost as input variables, while net profit and performing loan balance are selected as output variables. The following model (1) is set up to calculate the operational efficiency of commercial banks:

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{S_0^{t+1}(x_{t+1}, y_{t+1})}{S_0^t(x_t, y_t)} \times \frac{D_0^{t+1}(x_{t+1}, y_{t+1}|V,S)}{D_0^t(x_t, y_t|V,S)} \times \left[\frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D_0^t(x_t, y_t)}{D_0^{t+1}(x_t, y_t)}\right]^{\frac{1}{2}} \quad (1)$$

3.2 Difference-in-Differences Model

The Difference-in-Differences (DID) Method utilises a double difference statistic to capture the policy effect by comparing the differences between the control and treatment groups before and after the policy implementation, the statistic is integrated into a regression model, and the coefficients of the interaction terms represent the net effect of the policy. This paper sets up the following model to investigate the impact of the establishment of the green finance reform and innovation pilot zones on the performance of commercial banks:

$$tfpch_{it} = a_0 + a_1 post_{it} \times treat_{ii} + \emptyset \tilde{X}_{it} + u_{it} + \varepsilon_{it} \quad (2)$$

In model (2), the dependent variable is the total factor productivity of commercial banks ($tfpch_{it}$), calculated by the DEA-Malmquist method.

The core independent variable is the interaction term $treat_{it} \times post_{it}$, which is the interaction term of the commercial banks' registered ($treat_{it}$) and the time of establishment of the green finance reform and innovation pilot zones ($post_{it}$). The time dummy variable ($post_{it}$), is set to 0 for years prior to the establishment of the green finance reform and innovation pilot zones, and 1 thereafter. Similarly, the policy dummy variable ($treat_{it}$) is assigned a value of 1 if the registered place of a commercial bank is located in a province with at least one of the green finance reform and innovation pilot zones, and 0 otherwise.

If the coefficient a_3 of $treat_{it} \times post_{it}$ is significantly positive, the establishment of pilot zones would have significantly promoted the operational efficiency of commercial banks. In addition, bases on the relevant studies conducted by Yan (2022), Zhao (2022) and Deng (2022), this paper introduces cost-income ratio, net interest margin, financial leverage ratio, total assets per human recourse, and other indicators that affect bank performance as control variables in the model; $\tilde{X}_{it}$ in the model are the control variables mentioned above, u_{it} are the two-way fixed effects of individual and time, and ε_{it} are the random error terms.

3.3 Data Sources and Descriptive Statistics

The sample consists of 40 commercial banks from 18 provinces, autonomous regions and municipalities in China over the period 2013-2021. The financial data are obtained from the Win.d database, and the green finance data are manually collected from the annual reports and social responsibility reports of each commercial bank, all using annual data. In addition, this paper uses the median method to supplement individual unreported data in the green credit balance of some specific commercial banks in previous years.

The descriptive statistics of the aforementioned variables, as well as other variables necessary for the overall effect, mesomeric effect analysis, robustness test and further discussion, are all presented as follows.

Table 1. Descriptive Statistics of Variables

Variables	Symbol	N	Average	Std. Dev	Min.	Max.
Total Asset	TA	360	3156.804	5626.095	70	35171.4
Net Asset	NA	360	41867.25	68156.311	841	351713.83
Total Human Cost	THC	360	187.902	310.459	3.98	1371.15
Net Income	NI	360	391.352	698.257	1.34	3520.16
Performing Loan Ratio	PLR	360	21869.765	37965.335	338.58	203738.16
Total Factor Productivity	tfpch	320	0.998	0.096	0.641	1.507
Dummy Variable of Policy	treat	320	0.3	0.459	0	1
Dummy Variable of Time	post	320	0.625	0.485	0	1
Interaction Term of Dummy Variables	treat×post	320	0.188	0.391	0	1
Net Interest Margin	nim	320	2.216	0.651	0.81	5.591
Cost Income Ratio	cir	320	30.179	6.116	18.01	66.47
Total Asset per unit of Human Cost	taphr	320	242.65	71.646	74.388	516.278
Financial Leverage Ratio	flr	320	14.307	2.879	9.359	33.518
Core Tier One Capital Adequacy Ratio	cor1	320	10.016	1.547	7.75	15.49
Non-Performing Loan Ratio	nplr	320	1.415	0.424	0.302	2.97
Incremental Loan Balance	ilb	320	2408.337	4387.786	-18235.9	41233.8
Green Credit Balance	gr	320	2.237	1.009	-0.201	4.394
Return On Equity	roe	320	11.926	3.809	1.557	27.377
Capital Preservation and Appreciation Rate	capr	320	17.519	13.209	-24.522	87.280
NPL Provision Coverage	nplpcr	320	238.284	92.597	132.44	639.21
Net Asset Liability Ratio	nalr	320	13.307	2.879	8.359	32.518
Technical Progress Index	techch	320	0.996	0.07	0.787	1.204
Pure Technical Efficiency Change Index	pech	320	1.002	0.078	0.709	1.477
Scale Efficiency Change Index	sech	320	1.002	0.058	0.822	1.349

4. Empirical Results and Analysis

4.1 Operational Efficiency of Commercial Banks

The detailed results of the DEA-Malmquist total factor productivity of 40 commercial banks, calculated using DEAP 2.1 software, are presented in Table 2. Figure 2 is derived from the data in Table 2, which reports that the total factor productivity of the sample commercial banks has been greater than 1 on average since 2016, indicating a relatively stable upward trajectory in recent years, except for a notable decline in 2020, seems like to be due to the impact of the Covid-19 pandemic.

Table 2. DEA Malmquist Total Factor Productivity (2014-2021)

	2014	2015	2016	2017	2018	2019	2020	2021

Industrial and Commercial Bank of China	0.967	0.947	1.101	0.909	0.995	0.984	0.978	1.048
China Construction Bank	0.991	1.011	0.899	0.988	1	0.996	0.995	1.043
Agricultural Bank of China	0.935	0.948	0.985	1.02	0.998	1.005	1.017	1.051
Bank of China	0.974	0.966	1.095	0.939	1.023	1.022	1.028	0.911
Bank of Communications	1	0.95	1.046	1.012	1.032	1.004	1.032	1.018
China Merchants Bank	0.956	0.963	1.019	0.953	1.003	1.046	0.953	1.044
Postal Savings Bank of China	0.982	0.907	0.952	0.986	1.062	1.011	0.912	0.987
Industrial Bank	0.919	0.898	0.98	0.943	0.992	1.007	0.957	1.095
Shanghai Pudong Development Bank	1.079	0.913	0.994	0.972	1.025	0.977	1.016	1.042
CITIC Bank	0.96	1.019	0.899	1.116	1.072	1.006	0.961	1.017
China Minsheng Bank	0.894	0.902	1	1.01	0.991	0.981	0.987	1.025
China Everbright Bank	0.949	0.97	1.244	0.888	1.11	1.026	0.914	1.053
Ping An Bank	1.051	0.982	1.017	1.015	1.1	0.997	1.012	1.05
Huaxia Bank	0.976	0.977	0.894	1.038	1.027	1.022	1.008	0.989
Bank of Beijing	1.058	0.817	1.061	1.008	1.088	0.993	1.055	0.951
China Guangfa Bank	0.945	0.979	1.032	1.052	1.014	1.033	1.011	1.028
Bank of Shanghai	0.893	0.958	0.942	1.005	1.087	1.013	0.995	0.944
Bank of Jiangsu	0.993	0.956	0.951	0.893	1.041	1.04	0.922	1.102
China Zheshang Bank	0.955	0.878	1.001	1.065	1.136	1.014	1.043	0.971
Bank of Ningbo	0.9	0.908	1.042	1.029	0.931	0.98	0.917	1.276
Chongqing Rural Commercial Bank	0.932	0.937	0.995	1.016	0.971	1.059	0.881	1.011
China Bohai Bank	1.101	1.032	1.07	1.051	1.106	0.914	1.049	1.068
Shanghai Rural Commercial Bank	0.923	0.996	0.96	1.03	0.957	1.096	0.954	0.984
Bank of Hangzhou	0.895	0.882	0.961	0.902	1.094	1.052	0.907	1.141
Xiamen International Bank	0.973	0.924	1.103	1.279	1.005	0.878	0.997	1.047
Bank of Tianjin	0.893	0.886	0.719	1.132	1.068	0.932	1.019	0.978
Harbin Bank	0.902	0.985	1.002	0.971	1.032	0.811	1.029	1.014
Guiyang Bank	0.865	1.001	0.779	1.052	0.978	1.018	0.968	0.907
Bank of Changsha	0.807	0.861	1.042	1.033	1.003	0.971	1.037	0.981
Bank of Zhengzhou	1.08	0.885	0.985	0.856	0.641	1.023	1.062	1.151
Bank of Chongqing	0.978	0.899	1.192	0.928	0.946	1.032	1.016	0.959
Bank of Kunlun	0.96	0.898	0.917	1.037	0.971	1.004	0.867	0.896
Jiangxi Bank	1.11	0.936	0.95	1.23	0.877	1.033	1.048	1.507
Bank of Dongguan	0.86	1.015	0.917	1.028	1.06	1.401	0.806	1.048
Hangzhou United Bank	1.116	0.702	1.124	1.039	1.061	1.111	1.005	1.088
Bank of Qingdao	0.998	0.922	0.893	1.014	0.955	1.105	1.036	1.378
Bank of Lanzhou	1.073	0.948	1.014	0.993	1.001	0.93	1.08	0.957
HanKou Bank	0.711	1.268	1.047	1.052	1.077	1.107	1.063	0.876
Taizhou Bank	0.924	0.989	0.914	1.106	1.075	0.874	0.807	0.968
Guangxi Beibu Gulf Bank	1.101	0.846	1.309	0.938	1.184	1.032	1.091	1.036

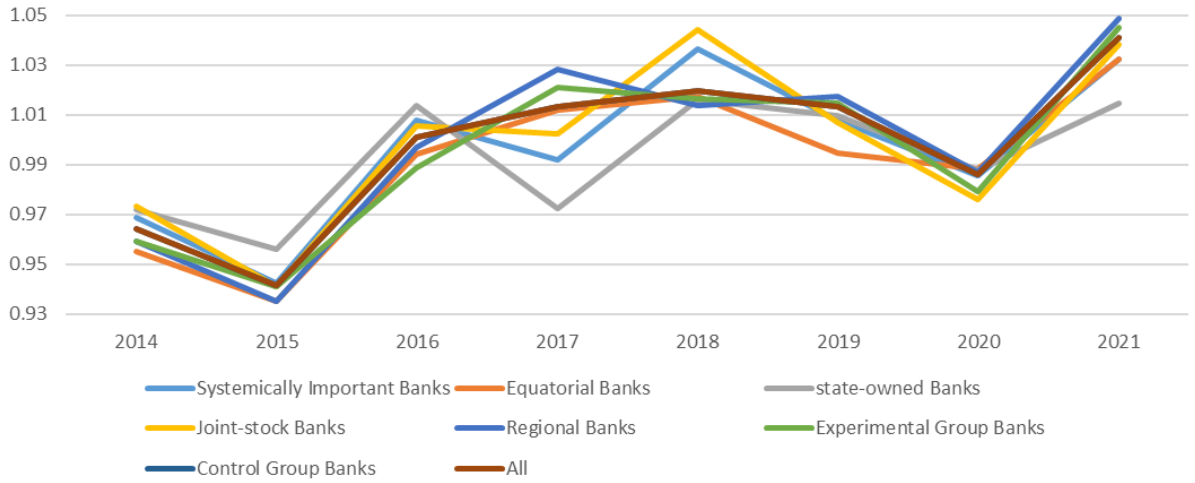

Figure 2. DEA-Malmquist Total Factor Productivity

4.2 Benchmark Regression Results

The data used in this paper are panel data. Considering the results of the Hausman test indicate a significant rejection of the random effects model at the 1% level of significance, and in order to mitigate the impact of unobservable or difficult-to-quantify factors on the regression results, such as the national and international macroeconomic climate, this paper employs the two-way fixed effects model to control time and individual factors.

Table 3 reports the regression results of model (2). To ensure the robustness of the conclusions, this paper progressively includes control variables based on the core explanatory variables, and the results show that the positive effects of core explanatory variables $treat_{it} \times post_{it}$ are statistically significant at the 5% level. Furthermore, the results in column (6) demonstrate a high level of goodness-of-fit.

Following the establishment of green finance reform and innovation pilot zones in the same regions as the registered places of commercial banks, the DEA-Malmquist total factor productivity of the experimental group was found to be approximately 4.57% higher than that of the control group. *Hypothesis 1* is approved, the establishment of the pilot zones improves the operational efficiency of commercial banks in the designated area.

Table 3. Benchmark Regression Results

Variables	Regression (1)	Regression (2)	Regression (3)	Regression (4)	Regression (5)	Regression (6)
$treat_{it} \times post_{it}$	0.03761**	0.03853**	0.04050**	0.05332***	0.04528**	0.04571**
	(2.37)	(2.35)	(2.41)	(2.98)	(2.36)	(2.37)
nim		0.00973	0.00786	0.03248**	0.04441**	0.04392**
		(0.95)	(0.80)	(2.29)	(2.11)	(2.07)
cir			-0.00107	0.00322	0.00370**	0.00367**
			(-0.59)	(1.67)	(2.17)	(2.14)
taphr				0.00099***	0.00095***	0.00096***
				(6.01)	(5.80)	(5.87)
flr					0.00979**	0.01011**
					(2.35)	(2.34)
cor1						0.00174
						(0.25)
Constant	0.99027***	0.9685***	1.00450***	0.57871***	0.40714***	0.38689**
	(321.78)	(42.65)	(17.31)	(5.75)	(2.85)	(2.49)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	320	320	320	320	320	320
Within R^2	0.0102	0.0120	0.0130	0.1547	0.1897	0.1899

Note: the value in brackets is t-statistics; *, **, and *** indicate the statistical significance at 10%, 5%, and 1% levels, respectively. Stata MP software estimated the regressions. The latter is the same as this.

4.3 Robustness Test

4.3.1 Parallel Trend Test

An essential requirement for the use of the DID model is to satisfy the parallel trend assumption. This paper takes the year prior to the establishment of each pilot zone as the base period and uses individual fixed effects model.

Results are presented in Figure 3, which shows that there is no significant difference between the control and treatment groups before the establishment of the green finance reform and innovation pilot zones, however, after the establishment of the pilot zones, except for the period after-3 (which corresponds to 2020 for most of these banks) which may be due to the impact of COVID-19, all subsequent years show statistically significant positive effects at a 5% significance level. Based on these findings, it can be concluded that there is no significant difference between the two groups before the establishment of the pilot zones, which is consistent with the parallel trend assumption.

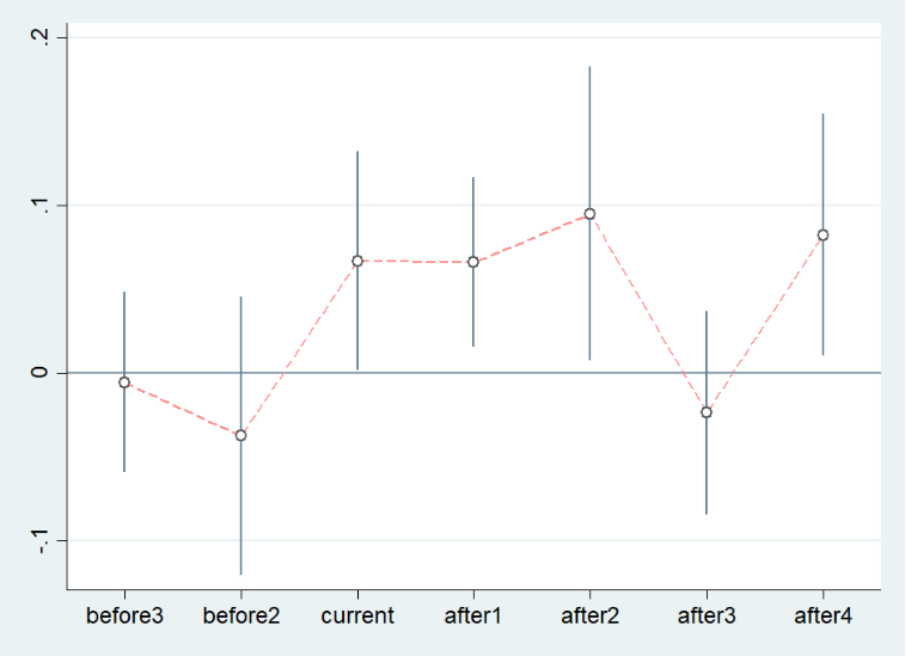

Figure 3. Parallel Trend Test

4.3.2 PSM-DID Test

In order to address the potential endogeneity issues arising from sample selection errors, referring to Wang and Lu (2019), this paper adopts the propensity score matching (PSM) method to conduct a robustness test and minimise the differences in individual characteristics between the experimental and control group samples.

The test is obtained by 1:3 neighbour matching PSM-DID and radius matching PSM-DID, and the results are presented in columns (1) and (2) of Table 4. The regression coefficients of the core explanatory variables continue to show significant positive effects at the 10% and 5% significance levels.

4.3.3 Winsorization and Truncation Test

In order to address the influence of extreme values on the regression results, this paper employs winsorization and truncation tests at the 1% and 99% levels, the results of which are presented in columns (3) and (4) of Table 4. The regression coefficients of the core explanatory variables still have significant positive effects at the 5% and 10%

significance levels, consistent with the previous regression results.

Table 4. PSM-DID Tests and Winsorization and Truncation Test

	(1)	(2)	(3)	(4)
Processing method	PSM Nearest Neighbour Matching	PSM Radius Matching	Winsorization	Truncation
$treated_i \times post_{it}$	0.0473*	0.0511**	0.04369**	0.03931*
	(1.81)	(2.43)	(2.34)	(2.02)
Control Variables	Yes	Yes	Yes	Yes
Constant	0.5981***	0.4031***	0.41944***	0.60785***
	(3.69)	(2.75)	(2.84)	(4.03)
Individual fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
N	217	313	320	288
Within R^2	0.1454	0.1580	0.1663	0.0853

4.3.4 Placebo Test

Given the limited time span of the short panel data used in previous regressions, this paper follows the approach of Zhou et al. (2018) and Lu et al. (2021) to conduct a placebo test by randomising the experimental group 1000 times.

The P-value coefficient scatter plot (Figure 4) indicates that 97% of the estimated coefficient kernel density estimation values of the core explanatory variables deviate from their true values after randomization. In addition, it is observed that 89.5% of the coefficients remain insignificant at the 10% significant level, which further enhances the robustness of the positive impact of the establishment of the pilot zones on the performance of commercial banks.

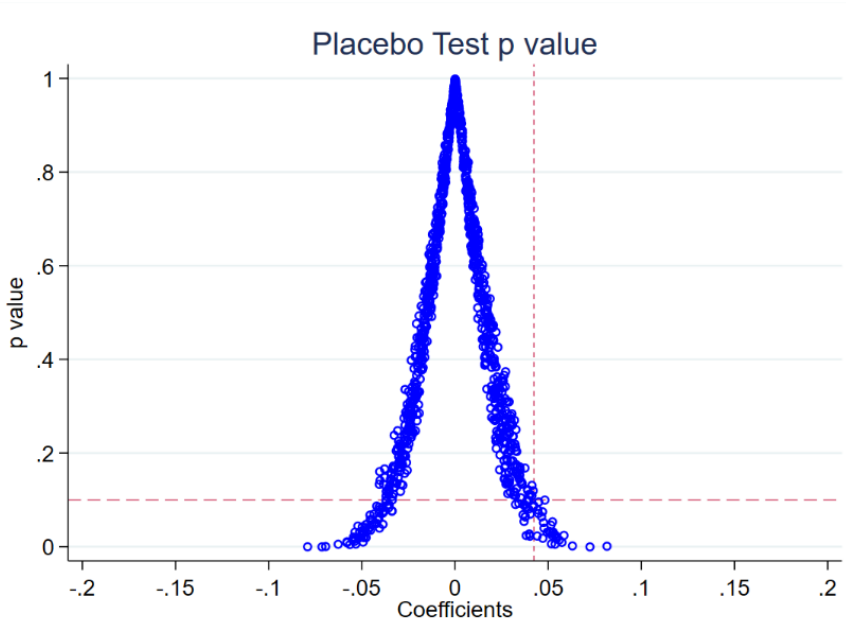

Figure 4. Placebo Test

4.3.5 Replacing the Dependent Variables

Although the DEA-Malmquist model provides a comprehensive measure of the commercial banks' operational efficiency, it cannot directly reflect their financial indicators. To address this limitation, this paper refers to the Measures for Performance Evaluation of Financial Enterprises (China's Ministry of Finance, 2011) and replaces the original explained variable $tfpch$ with the following, respectively: roe (return on equity, which reflects profitability), $capr$ (capital preservation and appreciation rate, which represents business growth), $nplpcr$ (non-performing loan provision coverage ratio, which reflects asset quality), and $nalr$ (net asset-liability ratio, which indicates solvency). The results are presented in columns (1) to (4) of Table 5, and their interaction terms are all significantly positive at the 10% significance level, align with the results in Table 3.

4.3.6 Excluding Large Banks

In this study, the experimental and control groups are determined based on whether the registration place of commercial banks is located in a province with at least one of the pilot zones. However, given the prominent positions of BOC, ABC, CCB, ICBC, BOC and PSBC in China, as well as some other large joint-stock commercial banks, this paper conducts additional regressions by sequentially excluding these two types of banks. The results are presented in columns (5) and (6) of Table 5, indicating statistically significant positive correlations at a 10% level of significance for the main dependent variables. This observed positive effect is also suitable for local banks.

Table 5. Replace the Evaluation Label

	(1)	(2)	(3)	(4)	(5)	(6)
Explained Variables	roe	cpar	nplpcr	nalr	tfpch	tfpch
$treat_{it} \times post_{it}$	1.27439**	6.53963*	55.38371*	0.96903*	0.03872*	0.05200*
	(2.07)	(1.69)	(1.93)	(1.71)	(1.97)	(1.74)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	23.90542***	139.4204***	343.4423***	35.14997***	0.29520*	0.24087
	(6.46)	(4.81)	(3.56)	(7.32)	(1.77)	(1.16)
Individual fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
N	320	320	320	320	272	184
Within R^2	0.1790	0.1921	0.1282	0.4304	0.2123	0.2262

4.4 Mechanism Analysis

To investigate the mechanisms through which the establishment of the green finance reform and innovation pilot zones influences and magnifies the advantages of banks within the zones, this paper extends the analysis to examine the mediation effect. Following the approach introduced by Jiang (2022), a two-stage mediation effect model is constructed as follows:

$$M_{it} = \beta_0 + \beta_1 treat_{it} \times post_{it} + \delta \tilde{X}_{it} + u_{it} + \varepsilon_{it} \quad (3)$$

$$tfpch_{it} = \rho M_{it} + \gamma_0 + \gamma_1 treat_{it} \times post_{it} + \sigma \tilde{X}_{it} + u_{it} + \varepsilon_{it} \quad (4)$$

In model (3), the intermediate variable M_{it} is introduced as a dependent variable, while in model (4) the bank's operational efficiency serves as the dependent variable. The coefficient p represents the effect of the intermediate variable M_{it}, and the construction of the other variables follows the same approach as in model (2).

This paper uses the non-performing loan ratio ($nplr$) and the logarithm of green credit balance (gr) as intermediate variables to examine the mediation effect of the establishment of the green finance reform and innovation pilot zones on the operational efficiency of commercial banks. The results are presented in Table 6:

Table 6. Regression Results of the Mediation Effect

	(1)	(2)	(3)	(4)
Explained Variables	nplr	tfpch	gr	tfpch
$treat_{it} \times post_{it}$	-0.41011***	0.03713**	0.32961**	0.03965*
	(-3.43)	(2.08)	(2.16)	(1.91)
nplr		-0.03949*		

		(-1.90)		
gr				0.04347*
				(1.98)
Control Variables	Yes	Yes	Yes	Yes
Constant	1.79621***	0.64964***	2.39440***	0.00408
	(4.60)	(6.90)	(4.75)	(0.02)
Fixed effects	Yes	Yes	Yes	Yes
N	320	320	320	320
Within R^2	0.1408	0.1670	0.1200	0.2336

In column (1) and (2) of Table 6, the coefficients of $treat_{it} \times post_{it}$ and $nplr$ are significantly negative, indicating that the establishment of the green finance reform and innovation pilot zones contributes to a reduction in the non-performing loan rate of commercial banks, and the reduction in the non-performing loan rate leads to the improvement of commercial banks' operational efficiency. The results support *hypothesis H2a*, the establishment of the green finance reform and innovation pilot zones promotes the improvement of commercial banks' operational efficiency by improving their loan quality. Specifically, the negative impact of non-performing loan ratio on operational efficiency is mitigated by the influence of the pilot zones, therefore improving operational efficiency.

In column (3) and (4) of Table 6, the coefficients of $treat_{it} \times post_{it}$ and gr are significantly positive, which support *hypothesis H2b*, indicating that the establishment of the green finance reform and innovation pilot zones promotes the improvement of commercial banks' operational efficiency by encouraging them to engage in green finance. In precise, the establishment of pilot zones stimulate commercial banks to increase their lending to green industries and expand their green credit business, the transfer of lending direction has a positive impact on commercial banks' operational efficiency.

The above findings suggest that the establishment of the green finance reform and innovation pilot zones enhances operational efficiency of commercial banks by strengthening risk management practices for both existing and new loans, as well as increasing their engagement in the green credit sector.

4.5 Heterogeneity Analysis

To further examine the heterogeneity of the impact of the establishment of the green finance reform and innovation pilot zones on operational efficiency of commercial banks, this paper incorporates additional variables into the analysis.

At first, the dummy variable $size_{it}$ is introduced to represent the size of commercial banks. According to the classification method of large banking deposit financial institutions in the *Financial Industry Enterprise Classification Standard Regulations* (PBOC et al., 2015), commercial banks with total assets exceeding 4 trillion CNY at year-end are assigned a value of 1, while those below this threshold are assigned a value of 0. Secondly, the dummy variable $hold_i$ indicates the ownership of commercial banks, a value of 1 is assigned to central or local state-owned banks, whereas a value of 0 is assigned to public and private banks. Thirdly, the dummy variable ipo_{it} is constructed to demonstrate the listing status of commercial banks. If a commercial bank has already been listed in Shanghai, Shenzhen or Hong Kong Stock Exchanges by the end of the year, a value of 1 is assigned; otherwise, a value of 0 is assigned. Establishing triple-interaction items with three dummy variables as $treat_{it} \times post_{it} \times size_{it}$, $treat_{it} \times post_{it} \times hold_i$ and $treat_{it} \times post_{it} \times ipo_{it}$ and making regression, the results are displayed in Table 7:

Table 7. Heterogeneity Analysis

	(1)	(2)	(2)
$treat_{it} \times post_{it} \times size_{it}$	-0.02100		
	(-1.55)		
$treat_{it} \times post_{it} \times hold_i$		0.06130***	
		(3.14)	
$treat_{it} \times post_{it} \times ipo_{it}$			0.02207

			(1.02)
Control Variables	Yes	Yes	Yes
Constant	0.38344**	0.34734**	0.39167**
	(2.36)	(2.26)	(2.51)
Fixed effects	Yes	Yes	Yes
N	320	320	320
Within R^2	0.1762	0.1919	0.1779

The results of the regression analysis presented in Table 7 highlight the differences among commercial banks, with only column (2) showing a statistically significant positive effect at the 1% level. This provides support for *hypothesis H3b*, while H3a and H3c are rejected. Thus, it could be concluded that the green finance reform and innovation pilot zones have a more positive impact on state-owned commercial banks when compared to banks owned by the public or private sector.

4.6 Further Discussion

In model (1), the DEA-Malmquist index can be decomposed into three components: technical progress index ($techch$), pure technical efficiency change index ($pech$) and scale efficiency change index ($sech$) (Färe et al., 1994)). To better understand the impact pathway of the establishment of the green finance innovation pilot zones, this paper investigates the effects on each decomposition term of total factor productivity. The results of this analysis are presented in Table 8:

Table 8. Analysis of DEA-Malmquist Index Decomposition

	(1)	(2)	(3)
Explained Variables	techch	pech	sech
$treat_{it} \times post_{it}$	0.00500	0.03629*	0.00345
	(0.50)	(1.97)	(0.23)
Control Variables	Yes	Yes	Yes
Constant	0.77155***	0.63723***	1.04201***
	(13.58)	(4.67)	(12.21)
Fixed effects	Yes	Yes	Yes
N	320	320	320
Within R^2	0.0439	0.0907	0.0507

Table 8 illustrates that only the coefficient of the core dependent variable $pech$ in column (2) exhibits significant positivity at the 10% level. These findings suggest that the establishment of the green finance reform and innovation pilot zones mainly affects the operational effectiveness of commercial banks by improving their pure technical efficiency.

Compared with other commercial banks, the ones located in the pilot zones have showcased a greater efficiency in utilising production factors and internal management practices. Through the implementation and promotion of green finance initiatives in the pilot zones, commercial banks could enhance their ability to allocate resources effectively and attain better operational outcomes. These might be achieved by enhancing internal controls, strengthening loan verification and risk management procedures, fulfilling social responsibility and taking other measures.

5. Conclusion and Discussion

Commercial banks have had a notable impact on the development of green finance in China. This research analysis the establishment of green finance reform and innovation pilot zones as a quasi-natural experiment to determine its effect on commercial banks' operational efficiency.

The sample for this study is drawn from panel data covering 40 commercial banks in China during the years 2013-

2021. Total factor productivity of these banks is assessed using the DEA-Malmquist model, while the impact of the establishment of the pilot zones on operational efficiency is analysed with the DID model. The findings illustrate that the establishment of the green finance reform and innovation pilot zones has enhanced the operational efficiency of commercial banks in the treatment groups. The improvement in efficiency is due to a decrease in the non-performing loan rate and a rise in the supply of green credit. Significantly, the state-owned banks have witnessed better outcomes from the pilot zones. And the further discussion reveals that the positive effect primarily manifests in enhancing the pure technical productivity of commercial banks. This improvement can be attributed to advancements in management practices and the banks' ability to utilise their existing resources effectively.

Apart from the positive effects of the pilot zones, the findings also indicate that green credit, when supported by appropriate policies, could enhance the operational efficiency of commercial banks. However, this positive impact is more pronounced in state-owned banks, this could be the revenue for them as trailblazers or their better understanding of how to comply with regulations and satisfy the government, which is the major shareholder, but private banks may lack. Therefore, it is crucial to establish a clear and effective regulatory and guidance framework. Moreover, it appears that there is limited promotion of scale efficiency and technological progress, these banks might benefit from adopting financial technology (Fin-Tech) as an innovative approach to enhance their efficiency.

Although this paper includes many models and robust tests to verify the regression results regarding the impact of pilot zones on the operational efficiency of commercial banks, the lack of data availability on green credit balances and other financial indicators at the provincial and city levels is a limitation. Therefore, using more detailed data could improve the precision of the results. Researching similar perspectives with objective companies that have different models can further develop the relationship theory regarding the impact of establishing green finance reform and innovation pilot zones on financial companies.

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