Hindawi
Mathematical Problems in Engineering
Volume 2022, Article ID 7503917, 12 pages
https://doi.org/10.1155/2022/7503917

Research Article

Does Green Finance Reform Promote Corporate Green Innovation? Evidence from a Quasi-Natural Experiment

Weicheng Wang and Qiaoyun Zhang

School of Finance, Southwestern University of Finance and Economics, Chengdu 611130, Sichuan, China

Correspondence should be addressed to Weicheng Wang; wangweicheng@smail.swufe.edu.cn

Received 4 August 2022; Revised 22 September 2022; Accepted 26 September 2022; Published 11 November 2022

Academic Editor: Fatih Ecer

Green innovation is an important tool in environmental management, and green finance can provide financial support for green innovation. The greening of the financial system has attracted attention. In order to promote the development of green finance, the Chinese government has implemented policy intervention in the financial market. Green finance reform differs from green credit policy, as it is a comprehensive green finance policy aimed at the financial system. In order to study the policy effects of green finance reform on corporate green innovation, this paper applies the green finance reform that the Chinese government introduced in 2017 as a quasi-natural experiment and implements the difference-in-difference (DID) method to investigate the impact of green finance reform on corporate green innovation. We found that green finance reform promotes corporate green innovation. The result remained valid after a series of robustness tests and is more prominent for state-owned enterprises (SOEs) and large enterprises. Furthermore, we examined the impact of green finance reform on different types of innovation, finding that it had a positive effect on green invention innovation and green utility model innovation. Mechanism tests showed that green finance reform promotes corporate green innovation by alleviating financial constraints.

1. Introduction

Since reform and opening-up policies were first implemented in China in the 1970s, China's economy has achieved an annual growth rate of 9.5%. It has become the world's second-largest economy, ranking second only to the US. However, due to its extensive mode of economic growth, the Chinese economy has been driven by scale, which has led to high-intensity energy consumption and a disregard for environmental protection, thus causing severe issues with environmental pollution [1]. In 2020, 4.97 billion tons of standard coal was consumed in China, which was 3.82 times as much as in 1990. According to the Second National Survey of Pollution Sources, which the Chinese government released in 2020, China's generated amount of industrial solid waste and sulfur dioxide emissions reached 3.868 billion tons and 5.298 million tons, respectively, in 2017. The total emission of carbon dioxide reached 9.34 billion tons. To maintain economic growth and employment for residents, local governments have failed to strictly implement the central government's environmental supervision policies. High-pollution and high energy-consuming enterprises have rapidly developed in China, which has increased its resource consumption and pollutant discharge.

Green innovation is an important influencing tool in environmental management [2], as it can enhance the efficiency of resource utilization [3, 4], reducing environmental pollution [5, 6], and reducing energy consumption [7, 8]. However, the high cost of research and development (R&D) [9] leads to the lack of funding for green innovation, so it needs financial support from the financial system. Sustainable finance emphasizes that finance provides services for transforming the economy to a low-carbon, high-resource utilization, a circular economy, and other sustainable development modes. Green finance refers to all financial products and services aimed at achieving broader environmental goals [10]. In developing countries such as China, green finance mainly focuses on the goal of

controlling industrial environmental pollution [11]. Insufficient incentives and a low supply of green finance restrict enterprises from investing in corporate green innovation [12]. However, the development of green finance faces many obstacles, policy guidance is needed [10], and the importance of green financial policies is gradually increasing.

Recent studies have shown that green finance policies enhance regional green development by promoting industrial and technological upgrading [13] and reduce environment pollution [14]; Huang and Zhang,2021). At the corporate level, green financial policies strengthen the quality of corporate environmental information disclosures [16] and reduce debt financing costs [17]. However, there are few studies on the policy effects of green finance policies on green innovation, which are mainly limited to the impact of green credit policies on green innovation [12, 18–20]. It was necessary to study the effects of comprehensive green financial policies aimed at the financial system on corporate green innovation. Therefore, this paper studied the impact of green financial reform on corporate green innovation.

Green finance reform in China provides a chance to examine its impact on corporate green innovation. In 2017, the Executive Meeting of the State Council chose eight regions as locations for green finance reform pilot programs. This reform was an exogenous shock to corporate green innovation and allowed us to use the difference-in-difference method (DID) to alleviate the concern of the relationship between green finance and corporate green innovation. Following Chen et al. [21], we used green patents to measure corporate green innovation. Using a large sample of Chinese listed firms for the period between 2012 and 2019, we documented a significantly positive relationship between green finance and corporate green innovation. The findings remained valid after we used green innovation indicators based on patent citations, parallel trend tests, and propensity scores to match samples.

We also examined the impact of enterprise characteristics on the relationship between green finance reform and corporate green innovation. Compared to non-state-owned enterprises, state-owned enterprises (SOEs) can obtain more financial resources from banks [22] and are prioritized to obtain government subsidies [23]. Meanwhile, SOEs are the main entities for the implementation of the government's innovation strategy [24]. We expect that the impact of green finance reform on corporate green innovation is more prominent for SOEs. In addition, large enterprises have more advantages and better innovative performance than small enterprises [25], and information asymmetry causes equity financing to become the main external capital for small enterprises [26], which causes green finance reform that affects enterprises' sustainable development based on bank credit to have less of an effect on green innovation in small enterprises. The empirical results supported our conjecture that the impact of green finance reform is more prominent for SOEs and larger enterprises.

Finally, we investigated the impact of green finance reform on different types of green innovation. The China National Intellectual Property Administration classifies patents into three types, namely, invention patents, utility model patents, and design patents. Invention patents cover new technological advancements. Utility model patents cover new applications of existing technologies. Design patents focus on limited and advanced technologies, which cause scholars to exclude design patents when studying innovation in China [27, 28]. We found that green finance reform has a significantly positive effect on green invention innovation as well as green utility model innovation.

This research may contribute to the literature based on the following aspects: First, prior research on green finance policies regarding enterprises was mainly limited to short-term influences, such as impacts on corporate debt financing [17] and efforts to strengthen the quality of corporate environmental information disclosures [16]. This study empirically examined the impact of green finance reform on corporate green innovation. It found that green finance reform has a positive effect on corporate green innovation, which can deepen our understanding of the long-term effect of green finance policies.

Second, various studies have focused on the connection between environmental regulations and green innovation [29–31]. Due to the potential influence of corporate innovation on environmental policies and regulations [32], the proxy variables of relevant policies may be endogenous. As an environmental policy introduced from the perspective of corporate financing, the implementation of green finance reform can be regarded as a quasi-natural experiment [13, 32]. It examined the influence of green finance reform on corporate green innovation, which can enrich documents about environmental policies on the impact of corporate green innovation.

The remainder of the paper is organized as follows: Section 2 introduced the background of green finance reform and proposed research hypotheses. Section 3 depicted the data and introduced the model specifications and variable selections in the article. Section 4 reported the empirical results. Section 5 was the discussion and policy implications. Section 6 was the conclusion.

2. Background and Hypotheses

2.1. Background. In June 2017, the Executive Meeting of the State Council declared eight regions in five provinces as zones for green reform pilot programs, including Huzhou and Quzhou in Zhejiang; Guangzhou in Guangdong; Changji, Hami, and Karamay in Xinjiang; Guiyang in Guizhou; and the Ganjiang New Area in Jiangxi. The purpose was to establish an experimental zone for green finance reform, but each specific policy in various provinces had its own emphasis. In Guangdong, the policy emphasis was on forging the green finance market for environmental rights and interests, including the right of pollution discharge, as well as providing support for green finance to transform and upgrade traditional industries. In Zhejiang, the policy emphasis was on promoting the construction of green cities and towns. In Jiangxi, the policy emphasis was on assisting green finance during clean energy projects, agricultural production, and sewage discharge. In Guizhou, the key emphasis of policies was the assistance of green finance in emerging

industries, such as modern agriculture and big data. In Xinjiang, the policy emphasized the assistance of green finance in high-end clean energy manufacturing industries.

The green finance reform pilot programs will undertake the following key tasks. First, lending assistance from the Central Bank should be enhanced, as should financial discounts and tax preferences from the local and central governments to reduce the cost of green finance. Second, innovation for green finance products and services should be upgraded. Third, the transparency of the green finance market should be increased to resolve the issue of information asymmetry in the market's investment and financing process. The ultimate objective of this policy is to establish a green finance system and accomplish the green transformation of China's economy.

2.2. Hypotheses. Research has shown that the innovation level of enterprises is highly associated with their financing ability. Gorodnichenko and Schnitzer [33] found that the innovation ability of enterprises is subject to the influence of financial market friction because of information asymmetry. More severe financial friction reduces the ability of enterprises to innovate. Falcone [34] found that when there is information asymmetry, financial institutions adopt stricter loan policies for green investment, and decreased information closeness between banks and enterprises hinders enterprises from investing in environmental innovation. García-Quevedo et al. [35] discover that the huge financing constraints that enterprises confront increase the probability of giving up innovative projects and reducing their innovative achievements. Ghisetti et al. [36] state that enterprises' perception of financing constraints hinders them from investing in environmental innovation due to technology lock-in, uncertain investments, a lack of subsidies, and the influence of noncompetitive markets. Therefore, green innovation faces major financing constraints due to information asymmetry between enterprises and financial institutions. The development of green finance can help enterprises meet their financial needs for green innovation. External pressure from national institutions is very important for greening the financial system. If these institutions lack formal channels to exert pressure to promote this greening, it will not help these enterprises to attain financing for green innovation [37]. As a green finance policy led by national institutions and targeted at the financial system, green finance reform can promote the greening of the financial system, encourage financial institutions to provide financing to develop green innovation, and alleviate financial constraints.

Green assets are more attractive to investors since they are safe and highly profitable [38]. In the green finance market, commercial banks and other financial institutions possess more information, while private investors lack information and have limited investment abilities. The asset price, interest rate, and duration can be regarded as indicators of company quality [39]. Based on signal transmission theory, financial institutions with an information advantage transmit these indicators to private investors who have an information disadvantage, thereby lessening information asymmetry in the green finance market [40]. The guidance of green finance reform enables commercial banks and other financial institutions to provide financing for enterprises. This will give enterprises more cash flow to invest in green innovation. This increased financing and the decreased financing interest rate will be reflected in enterprises' financial reports, which will indicate to private investors who guide these enterprises that they should continue to make green investments.

Green investment of enterprises is closely related to green innovation and needs technical support. When enterprises make green investments, they develop green innovation. Green finance is important for promoting enterprises' efforts to invest in green projects [41]. When analyzing the problems and challenges of green finance in Italy, Falcone and Sica [10] found that enterprises' green investment faced key problems such as uncertain government policies and financial institutions with an insufficient credit supply, while short-term financial instruments and effective policy intervention are needed to solve these problems. Green finance reform aimed at the financial system can help to solve the problems that green investment faces, such as financial institutions with an insufficient credit supply and highly uncertain government policies. In addition, offering short-term financial instruments and encouraging enterprises to invest in green projects can enhance efforts to promote green innovation of enterprises:

> Hypothesis H1: The promulgation of green finance reform promotes the green innovation of enterprises.
>
> In many developing countries, the government controls the channels that enterprises use to obtain financing [42]. Chinese state-owned banks possess the most credit resources, as SOEs are the most important customer groups for state-owned banks [22]. State equity allows SOEs to borrow more funds at interest rates lower than the average level [43]. They are also prioritized to obtain government subsidies [23], enabling them to invest more funds in innovation. Additionally, the Chinese government regards innovation as a crucial guarantee for the country's future and has issued many policies to encourage enterprises to innovate [22]. Meanwhile, SOEs are the main entities intended for implementing the government's innovation strategy [24]. Hence, as the Chinese government has introduced green finance reform, SOEs are obligated and motivated to implement it. This will further reduce their financing constraints, and they will proactively invest in green innovation.
>
> Hypothesis H2a: Compared with private enterprises, green finance reform has a more significant positive impact on the green innovation of SOEs.
>
> Innovation has a scale effect because of innovation-related financing discrimination, the scattered ownership of small companies, and the substantial

requirements of innovation for capital investment, while larger companies will have a greater impact on innovation [25]. Compared with large-scale enterprises, small enterprises confront more challenges when financing innovative projects [44]. After the promulgation of green finance reform, financial institutions that implement this policy are more willing to grant preferential treatment to large companies while considering their advantages and innovative performance. Meanwhile, small enterprises tend to raise funds from their own shareholders as a result of information disadvantages rather than relying on external financing channels such as financing from external equity and debt [26]. However, the focus of green finance reform is to encourage financial institutions to provide green finance products. In this regard, it provides enterprises with external financing. Therefore, the following assumptions were proposed based on the above analysis.

Hypothesis H2b: Compared with small-scale enterprises, green finance reform has a more significant positive impact on the green innovation of large-scale enterprises.

3. Research Design

3.1. Sample Selection and Data Sources. In this paper, we only investigated green reform in Guangzhou city in Guangdong province for the following reasons: First, green finance reform has different objectives in each region. Guangdong focuses on supporting green transformation and upgrading of traditional manufacturing enterprises, while other provinces emphasize supporting environmentally friendly infrastructure construction of small towns as well as the development of photovoltaic industries and other new energy industries. Moreover, Guangdong's huge economic volume and vast amount of listed companies make it an ideal setting for this empirical study. In 2020, Guangdong's GDP was US$1.6 trillion, ranking first among all China provinces. The traditional manufacturing industry in Guangdong Province is developed, and Guangdong has a large number of energy-consuming enterprises and labor-intensive enterprises. More importantly, it has 675 A-share listed companies, accounting for 14.98% of China's total number of A-share listed companies. However, other pilot programs only include prefecture-level cities or districts with 0 or several listed companies, which made it impossible to acquire relevant data. Finally, focusing on enterprises within a province helped us to exclude the impact of regional policies on corporate green innovation.

To construct our sample, we started with all A-share listed companies in Guangdong during the period from 2012 to 2019. The financial data was collected from the China Securities Market and Accounting Research (CSMAR) database, and the green patent data was collected from the Chinese Research Data Services (CNRDS). Then, we excluded financial services firms and firm-year observations with missing information. Our final sample included 3,218 firm-year observations representing 590 individual firms. To mitigate the effect of outliers, we also winsorized all continuous variables at the 1% and 99% levels.

3.2. The Measurement of Corporate Green Innovation. Patents stipulated in China's Patent Law are divided into three categories: invention patents, utility model patents, and design patents. Since the increase in design patents cannot represent actual technological progress, to accurately measure the ability of enterprises, we used the number of green invention and utility model patents to measure corporate green innovation. As the time required to file patent applications can more accurately capture the actual time when enterprises produce innovation results, we used the number of green patent applications to capture corporate green innovation. In addition, when considering the right skewness of the patent counts and referencing Tan et al. [45]; we used the natural logarithm of one plus the number of green invention and green utility model patent applications to measure corporate green innovation (Patent).

3.3. Empirical Methodology. The model used in this paper was based on the DID method, which regards institutional change and economic policies as a "natural experiment" exogenous to the economy [46]. If the selection and grouping of experimental samples are considered as carried out, it is a "quasi-natural experiment." When a public policy is implemented, some enterprises are affected in a certain way, while others may be unaffected or slightly affected. If a public policy can be regarded as a quasi-natural experiment, those affected by the policy are put into the treatment group and those unaffected are put into the control group. The effect of the policy was tested by comparing the differences between the treatment and control groups after the policy was implemented. To study the impact of green finance reform on green innovation after green finance reform was established in 2017, we constructed the following DID model:

$$\text{Patent}_{i,t+1} = \beta_0 + \beta_1 \text{Treat} \times \text{Post}_t + \gamma' \text{Control}_{i,t} + \mu_i + \upsilon_t + \epsilon_{i,t}. \tag{1}$$

Here, i denotes individual firms and t denote years, respectively. Patent is corporate green innovation output measured by the natural logarithm of one plus the number of green invention and green utility model patent applications to measure corporate green innovation. Treat is a dummy variable that equals 1 when a firm is located in Guangzhou and otherwise equals 0. A Treat of 1 indicates that the sample of this group is affected by the policy shock of green finance reform, and a value of 0 indicates that it is not affected by this shock. Post is a dummy variable that equals 1 after 2016 and otherwise equals 0. A Post of 1 indicates that the policy shock has occurred, and a Post of 0 indicates that this shock has not occurred. Treat × Post is the DID estimator. If the coefficient of Treat × Post is positive and significant at the significance level above 10%, it indicates that after the implementation of the green finance reform pilot program policy, the listed companies

in Guangzhou, which is one of the locations of the green finance reform pilot zones, have developed more green innovations than other listed companies in Guangdong. Green finance reform has a positive impact on enterprise green innovation.

Based on Hall and Ziedonis [47]; Aghion et al. [48]; and Hirshleifer et al. [49], this paper chose leverage, firm size, tangible assets ratio, R&D investment, cash holdings, firm age, and ownership as control variables for enterprise characteristics. Due to the inverted U-shaped relationship between product market competition and innovation, this paper selected the Herfindahl index and its square as the control variables to measure market competition. We also included firm fixed effects (μ_i) to control unobservable time-invariant firm-specific characteristics and year fixed effects (υ_t) to control common time trends. All variable definitions are shown in Table 1.

4. Empirical Research Results

4.1. Descriptive Statistics of Variables. The descriptive statistics of the variables are presented in Table 2. The total sample size is 3,218, in which the maximum value of green innovation (Patent) is 4.625, the minimum value is 0, and the standard deviation is 1.149, indicating that there is a major difference in the level of green innovation among the listed companies. The median of green innovation (Patent) is 0, and the average value is 0.873, indicating that most listed companies have not developed green patents. Thus, the level of green innovation is low. The average values of Treat and Post were 0.163 and 0.493, respectively. The ratio of the experimental group to the total sample was 16.3%. The ratio of samples to total samples after the promulgation of the policy in 2017 was 49.3%.

4.2. Main Results. Table 3 reports the regression results of the impact of green finance reform on green innovation. In column 1, we only regressed corporate green innovation on green finance reform. We found that the coefficient of Treat × Post was significantly positive, suggesting that green finance reform promotes corporate green innovation. In column 2, we controlled firm size, leverage, tangible assets ratio, R&D investment, and cash holdings. The coefficient of Treat × Post is positive and significant at the 1% statistical level. In column (3), we concluded that all control variables and the coefficient of Treat × Post was significantly positive. The above results indicated that after the implementation of green finance reform, the listed companies in the treatment group developed more green invention and green patents than the other listed companies in the control group, while the implementation of green finance reform promoted corporate green innovation. Our results supported Hypothesis 1.

In terms of the control variables, enterprises conduct more green innovation in cases when there is a larger enterprise size, lower debt level, higher tangible assets ratio, and longer enterprise survival time. The regression results of the control variables were consistent with the findings of previous literature studies.

4.3. Heterogeneity Research. According to the ownership nature of the sample enterprises, this paper divided them into a SOEs group (SOEs) and non-state-owned enterprise group (No-SOEs) and used the two subsamples to test the impact of ownership on the relationship between green finance reform and corporate green innovation. As shown in Table 4, the coefficient of Treat × Post is positive and significant at the 5% statistical level in the SOEs group and is insignificant in the No-SOEs group. This indicates that after the implementation of green finance reform, SOEs developed more green invention and green utility model patents, while the number of No-SOE green patents did not increase. Our results supported Hypothesis 2a as the relationship between green finance reform and corporate green innovation was more prominent for SOEs.

Furthermore, we divided the sample into two groups according to the mean value of enterprise size, namely, a large enterprise group (Large) and a small enterprise group (Small). Then, we used a model (1) to examine the impact of enterprise size on the association between green finance reform and corporate green innovation. As shown in Table 4, the coefficient of Treat × Post is positive and significant at the 1% statistical level in large enterprises and insignificant in small enterprises. This indicates that after the implementation of green finance reform, large enterprises have developed more green invention and green utility model patents, while the number of green patents of small enterprises has not increased. Our results supported Hypothesis 2b that the relationship between green finance reform and corporate green innovation is more prominent for small enterprises.

4.4. Robustness Test

4.4.1. Parallel Trend Test. The parallel trend hypothesis is the key hypothesis of the DID model. This hypothesis requires that the time trends of green innovation in the treatment and control groups are consistent, especially before the introduction of green finance reform in 2017. To test this hypothesis, we developed the interaction terms between the dummy variable Treat and four year indicators (Year2013, Year2014, Year2015, and Year2016), namely, Treat × Year2013, Treat × Year2014, Treat × Year2015, and Treat × Year2016. (We regarded Year2012 as the benchmark. When the year was 2013, year 2013 was 1; otherwise, it was 0, and the settings of dummy variables for the other years were the same) Then, we added these interactions into model (1). If none of the above interaction items were significant, then there was a parallel trend between the treatment and control groups. The regression results are shown in Table 5. Although the coefficient of Treat × Year2016 was significant, the coefficients of Treat × Year2013, Treat × Year2014, and Treat × Year2015 were not significant. This indicated that before the implementation of green finance reform in 2017, there was no significant difference between the estimated coefficients of the treatment and control groups, and their samples were comparable with the same time trend. The regression results indicated that the parallel trend assumption was satisfied.

Table 1: Variable definitions.

Variable	Definition
Patent	The natural logarithm of one plus the number of green invention and green utility model patent applications
Treat	Dummy variable, the sample value of listed companies in Guangzhou is 1, and the sample value of other listed companies is 0
Post	Dummy variable. The value is 1 in years from 2017 to 2019 and 0 in other years
Size	The natural logarithm of the company's total assets
Lev	The ratio of a company's total liabilities to total assets
Tangi	The ratio of a company's net fixed assets to total assets
RD	The ratio of a company's R&D expenses to total assets
Cash	The ratio of net cash flow from a company's operating activities to total assets
HHI	The Herfindahl index, which measures competition in an industry
HHS	The square of the Herfindahl index
Age	The logarithm of the company's age plus 1
SOE	Dummy variables, the value of state-owned enterprises is 1 and that of non-state-owned enterprises is 0

Table 2: Descriptive statistics.

Variable	N	Mean	SD	Min	p50	Max
Patent	3218	0.873	1.149	0	0	4.625
Treat	3218	0.163	0.369	0	0	1
Post	3218	0.493	0.500	0	0	1
Size	3218	21.88	1.178	19.80	21.74	25.79
Lev	3218	0.391	0.192	0.0460	0.383	0.866
Tangi	3218	0.180	0.133	0.00300	0.157	0.604
RD	3218	0.0270	0.0210	0	0.0230	0.111
Cash	3218	0.0470	0.0690	−0.152	0.0460	0.247
HHI	3218	0.106	0.130	0.0360	0.0580	0.888
HHS	3218	0.0280	0.101	0.00100	0.00300	0.789
Age	3218	2.934	0.318	2.197	2.944	3.638
SOE	3218	0.175	0.380	0	0	1

4.4.2. Green Innovation Indicators Based on Patent Citation. In the benchmark regression, we measured green innovation by using the number of green invention and green utility model patents that listed companies applied for every year. Patents are one of the important means for enterprises to establish technical barriers and protect their intellectual property rights. Green patent applications are an important measurement of green innovation enterprise output. However, due to large differences in the economic and technical significance of patents [49], the increase in green patent applications by companies does not mean that they have improved their green innovation performance. Therefore, following Hall et al. [50], we used patent citations to measure the quality of green innovation. In the robustness test, we used the natural logarithm of one plus the total number of green invention application citations and green utility model application citations (Cite). Then, we replaced Patent in model (1) with Cite. As shown in Table 6, the coefficient of Treat × Post is positive and significant at the significance level of 10%, indicating that after the implementation of green finance reform, the number of green patent citations of enterprises in the treatment group was significantly higher than in the control group and green finance reform effectively promoted green innovation of enterprises. After constructing alternative indicators of enterprise green innovation for regression, the regression results were consistent with the benchmark regression, indicating that our regression results were robust.

Table 3: Baseline regression results.

	(1) Patent	(2) Patent	(3) Patent
Treat × Post	0.200***	0.187***	0.183***
	(2.773)	(2.633)	(2.578)
Size		0.409***	0.410***
		(10.105)	(10.144)
Lev		−0.326**	−0.380**
		(−2.189)	(−2.532)
Tangi		0.561***	0.551***
		(2.670)	(2.619)
RD		1.884	1.946
		(1.308)	(1.352)
Cash		−0.349	−0.342
		(−1.450)	(−1.421)
HHI			−1.055
			(−1.097)
HHS			1.312
			(1.312)
Age			0.871**
			(2.307)
SOE			0.118
			(0.869)
Constant	0.421***	−8.283***	−10.589***
	(10.086)	(−9.585)	(−7.939)
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
N	3218	3218	3218
R^2	0.149	0.182	0.184

This table examines the impact of green finance reform on corporate green innovation. The standard errors are included in parentheses. The symbols ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

4.4.3. PSM-DID Model. To alleviate the impact of the heterogeneity of firm's characteristics on our findings and make the treatment and control groups comparable, drawing on the research of Rosenbaum and Rubin [51], we used the propensity score match (PSM) method to select the treatment and control firms. Our matching procedure relied on a one-to-one nearest neighboring matching of property score without replacement, which was estimated by a logit model regression of the binary treatment variable on a set of firm characteristics that included leverage (Lev), firm size (Size), tangible asset ratio (Tangi), R&D investment (RD), corporate profitability (Roa), age of enterprise (Age), and ratio of

Table 4: Heterogeneity tests.

	SOE Patent	No-SOE Patent	Large Patent	Small Patent
Treat × Post	0.354**	0.0610	0.300***	0.116
	(2.462)	(0.722)	(2.851)	(1.069)
Size	0.363**	0.407***	0.434***	0.413***
	(2.497)	(9.529)	(5.167)	(5.904)
Lev	0.815	−0.406**	−0.0760	−0.257
	(1.548)	(−2.539)	(−0.269)	(−1.382)
Tangi	−0.152	0.806***	0.662	0.908***
	(−0.262)	(3.525)	(1.544)	(3.604)
RD	2.213	1.597	2.277	−0.626
	(0.576)	(1.026)	(0.839)	(−0.373)
Cash	−0.481	−0.388	−0.592	−0.480*
	(−0.705)	(−1.507)	(−1.486)	(−1.654)
HHI	1.213	−1.065	−2.299	−0.726
	(0.444)	(−1.026)	(−1.480)	(−0.576)
HHS	−0.845	1.225	1.907	1.028
	(−0.332)	(1.083)	(1.208)	(0.796)
Age	1.088	1.126***	0.615	0.620
	(0.917)	(2.629)	(0.898)	(1.123)
Cons	−11.134**	−11.103***	−10.548***	−9.874***
	(−2.233)	(−7.543)	(−4.093)	(−5.010)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
N	563	2655	1609	1609
R^2	0.229	0.176	0.212	0.103

The table reports the impact of ownership on the relationship between green finance reform and corporate green innovation in columns 1 and 2. This table also reported the impact of enterprise size on the association between green finance reform and corporate green innovation in columns 3 and 4. The standard errors are included in parentheses. The symbols ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

net cash flow (Cash). Table 7 reports the balanced tests results. After matching, the t-test results of the control variables showed that they were not significant, showing that there was no statistically significant difference across total firm characteristics after PSM. The influence of omitted variables that may affect green innovation is reduced.

Then, samples with highly similar data features after matching were used in model (1). As shown in Table 8, the coefficients of Treat ∗ Post in columns (1), (2), and (3) were all positive and significant at the significance level of 10%, indicating that after the implementation of green finance reform, the number of green invention and green utility model patents increased for firms in the treatment group. The regression results were consistent with the benchmark regression, which indicates that our regression results were robust.

4.5. Mechanism. Financing constraints refer to a series of constraints that companies face when seeking external financing support due to factors such as information asymmetry and agency costs, thus leading to differences between external and internal financing costs. Financing constraints are closely related to corporate innovation. When enterprises face large financing constraints, their R&D investment is insufficient, and their innovation ability decreases [33]. Green finance reform is intended to guide financial institutions to conduct green finance

Table 5: Parallel trend test.

	(1) Patent	(2) Patent	(3) Patent
Treat × Post	0.370**	0.342**	0.341**
	(2.567)	(2.410)	(2.408)
Treat × Year2013	0.166	0.160	0.161
	(1.042)	(1.020)	(1.032)
Treat × Year2014	0.150	0.144	0.150
	(0.945)	(0.923)	(0.962)
Treat × Year2015	0.0510	0.0360	0.0390
	(0.332)	(0.239)	(0.256)
Treat × Year2016	0.299**	0.281*	0.282*
	(2.007)	(1.919)	(1.924)
Size		0.408***	0.409***
		(10.079)	(10.117)
Lev		−0.321**	−0.375**
		(−2.150)	(−2.494)
Tangi		0.560***	0.550***
		(2.665)	(2.614)
RD		1.884	1.949
		(1.309)	(1.353)
Cash		−0.346	−0.339
		(−1.436)	(−1.407)
HHI			−1.060
			(−1.101)
HHS			1.297
			(1.296)
Age			0.874**
			(2.314)
SOE			0.118
			(0.875)
Constant	0.419***	−8.268***	−10.581***
	(10.034)	(−9.564)	(−7.932)
Year firm fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
N	3218	3218	3218
R^2	0.151	0.183	0.186

The table represents the results of the parallel trend tests. The standard errors are included in parentheses. The symbols ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

business as well as provide financing support to enterprises that can develop green and low-carbon economic growth. To examine whether green finance reform can promote corporate green innovation by alleviating the financing constraints of enterprises, we used the intermediary effect model to assess the mechanism of green finance reform that promotes green innovation of enterprises. Based on Hadlock and Pierce [52] we used firm size and company age to construct an index to measure financing constraints (SA). A greater SA index indicates greater financing constraints that an enterprise must face. The model that was tested was set as follows:

$$\begin{aligned} \mathrm{SA}_{i,t} &= \alpha_0 + \alpha_1 \mathrm{Treat}_i \times \mathrm{Post} + \gamma' \mathrm{Control}_{i,t} \\ &\quad + \mu_i + \upsilon_t + \varepsilon_{i,t}, \\ \mathrm{Patent}_{i,t} &= \chi_0 + \chi_1 Treat_i \times Post_t + \chi_2 \mathrm{SA}_{i,t} \\ &\quad + \gamma' \mathrm{Control}_{i,t} + \mu_i + \upsilon_t + \varepsilon_{i,t}. \end{aligned} \tag{2}$$

Here, i denoted an individual firm and t denoted a year, respectively. SA measured financial constraints. Other

Table 6: Green innovation indicators based on patent citation.

	(1) Cite	(2) Cite	(2) Cite
Treat × Post	0.171*	0.167*	0.147*
	(1.785)	(1.809)	(1.744)
Size		0.177**	0.181**
		(2.024)	(2.064)
Lev		−0.703**	−0.753**
		(−2.129)	(−2.248)
Tangi		−0.143	−0.0740
		(−0.303)	(−0.157)
RD		3.216	3.020
		(1.024)	(0.958)
Cash		0.381	0.364
		(0.755)	(0.721)
HHI			−2.890
			(−1.296)
HHS			2.052
			(1.008)
Age			0.970
			(1.181)
SOE			−0.311
			(−1.121)
Constant	1.252***	-2.389*	−4.809*
	(14.551)	(−1.677)	(−1.647)
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
N	1547	1547	1547
R^2	0.270	0.275	0.278

variables had the same definition as model (1). If green finance reform affects corporate green innovation by alleviating corporate financial constraints, the regression result of α_1 should be significantly negative and the coefficient of χ^2 should be significantly negative. Meanwhile, the regression result of χ^1 should be significantly positive and the value of χ^1 is smaller than in column (3) of Table 3.

The results of mechanism tests are shown in Table 9. As shown in columns (1) and (3) of Table 9, the coefficients of Treat × Post were significantly negative, indicating that after the implementation of green finance reform, the financial constraints of companies in the treatment group were weakened. It suggests that green finance reform has a negative impact on corporate financial constraints. Moreover, in columns (2) and (4) of Table 9, the coefficients of SA were significantly negative and the coefficients of Treat × Post were significantly positive. More importantly, in columns (2) and (4) of Table 9, the value of the coefficient of Treat × Post was smaller than that in column (3) of Table 3. This indicates that after the implementation of green finance reform, these measures alleviated the financial constraints of enterprises, thus promoting their green innovation. Overall, alleviating financial constraints is the mechanism for green finance reform to promote corporate green innovation. After the implementation of green finance reform, the financing ability of enterprises is improved and they can invest more funding in corporate green innovation.

4.6. Further Research. In this section, we examined the effect of green finance reform on different types of green innovations, namely, green invention innovation and green utility model innovation. Compared with invention patents, utility model patents have a lower technical level and innovation but have a practical value. We constructed green invention innovation and green utility model innovation indicators, which were the natural logarithm of 1 plus the invention patents and the natural logarithm of 1 plus the utility model patents. In addition, we used green invention innovation indicators and green utility model innovation indicators as dependent variables to perform regression on model (1), and the regression results are shown in Table 10. The coefficient of Treat × Post in column (1) was positive and significant at 1%, while the coefficient of Treat × Post in column (2) was positive but only significant at 10%. The regression results show that green finance reform prompted enterprises to apply for more green invention and green utility model patents, but the promotion of green invention patents was increasingly significant. Our results showed that green finance reform can effectively promote a higher level of corporate green innovation.

5. Discussion and Policy Implications

The construction of China's green finance system is characterized by a top-down structure, with its central government leading the construction of the green finance system and implementing extensive policy interventions. Pressure from institutional actors at the national level helps to make the financial system more environmentally friendly, and policy interventions in the financial system are necessary to promote corporate green innovation [37]. The results of this paper showed that the government's green finance reform can promote corporate green innovation. This means that the government's comprehensive policy intervention in the green finance system is effective, enabling it to better promote corporate green innovation. In this paper, the results showed that the positive effect of the green financial reform policy mainly reflected the green innovation of SOEs and large enterprises. This shows that the government's dominant green financial reform has deficiencies since it did not provide financing support to private enterprises, and its most typical weakness is its domination by government policy interventions. Based on the above discussion, we propose the following suggestions.

First, more provinces should be included in green finance reform, especially those with backward industrial structures as well as mainly high-polluting and energy-intensive industries. Second, it is necessary to establish a diverse green financial market system. Third, the government should encourage commercial banks, investment banks, and insurance companies to establish green finance divisions by using direct and indirect financing based on the premise of preventing and controlling financial risks and should also encourage financial institutions to implement innovations of green financial products. Fourth, policy support for private enterprises should be strengthened when promoting green finance reform.

Table 7: Balance tests after PSM.

Variable	Unmatched and matched	Mean treated	Mean control	% bias	% redact bias	t	$p > t$
Size	U	22.028	21.857	14.1		3.04	0.002
	M	22.028	22.038	−0.8	94.1	−0.13	0.898
Lev	U	0.382	0.393	−5.8		−1.19	0.235
	M	0.382	0.384	−1.0	82.1	−0.17	0.865
Cash	U	0.058	0.045	17.8		3.73	0.000
	M	0.058	0.058	−0.4	97.5	−0.07	0.944
RD	U	0.028	0.027	4.6		0.92	0.358
	M	0.028	0.031	−13.2	−188.2	−1.97	0.049
Roa	U	0.047	0.031	11.9		2.12	0.034
	M	0.047	0.042	3.6	69.5	0.84	0.404
Tangi	U	0.187	0.178	6.0		1.26	0.206
	M	0.187	0.176	8.0	−33.8	1.31	0.190
Age	U	2.927	2.935	−2.4		−0.51	0.611
	M	2.927	2.934	−2.1	11.5	−0.34	0.730

Table 8: PSM-DID method results.

	(1) Patent	(2) Patent	(3) Patent
Treat × Post	0.210*	0.242*	0.223*
	(1.651)	(1.929)	(1.772)
Size		0.509***	0.499***
		(4.944)	(4.837)
Lev		−1.043***	−1.065***
		(−2.896)	(−2.950)
Tangi		0.817	0.792
		(1.494)	(1.441)
RD		2.780	2.565
		(0.792)	(0.727)
Cash		−0.442	−0.546
		(−0.740)	(−0.909)
HHI			−3.218
			(−1.365)
HHS			2.512
			(0.938)
Age			0.783
			(0.928)
SOE			0.207
			(0.474)
Constant	0.360***	−10.319***	−11.952***
	(3.927)	(−4.712)	(−3.780)
Year fixed effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
N	921	921	921
R^2	0.196	0.235	0.240

The table reports the results of the PSM-DID method. The standard errors are included in parentheses. The symbols ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

Table 9: Mechanism tests.

	(1) SA	(2) Patent	(3) SA	(4) Patent
Treat × Post	−0.015*	0.182**	−0.015*	0.178**
	(−1.883)	(2.564)	(−1.889)	(2.505)
SA		−0.313*		−0.326*
		(−1.738)		(−1.807)
Size	1.134***	0.765***	1.134***	0.780***
	(258.192)	(3.672)	(257.997)	(3.747)
Lev	−0.046***	−0.342**	−0.049***	−0.397***
	(−2.869)	(−2.291)	(−3.005)	(−2.640)
Tangi	−0.0150	0.558***	−0.0160	0.547***
	(−0.677)	(2.658)	(−0.695)	(2.606)
RD	0.198	1.948	0.199	2.014
	(1.266)	(1.354)	(1.275)	(1.400)
Cash	0.00700	−0.350	0.00800	−0.343
	(0.272)	(−1.459)	(0.309)	(−1.430)
HHI			−0.00300	−1.072
			(−0.025)	(−1.115)
HHS			0.0170	1.328
			(0.154)	(1.330)
Age			0.0600	0.880**
			(1.462)	(2.335)
SOE			−0.00200	0.116
			(−0.124)	(0.860)
Constant	−20.491***	−14.714***	−20.652***	−17.295***
	(−218.510)	(−3.880)	(−142.627)	(−4.377)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
N	3218	3218	3218	3218
R^2	0.981	0.183	0.981	0.185

The table reports the results of the mechanism tests. The standard errors are included in parentheses. The symbols ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

Table 10: Further analysis.

	(1) Invent	(2) Utility
Treat × Post	0.200***	0.114*
	(3.332)	(1.860)
Size	0.308***	0.293***
	(9.002)	(8.391)
Lev	−0.247*	−0.240*
	(−1.942)	(−1.853)
Tangi	0.495***	0.387**
	(2.782)	(2.135)
RD	1.449	2.433*
	(1.190)	(1.961)
Cash	−0.204	−0.239
	(−1.005)	(−1.151)
HHI	−1.026	−0.240
	(−1.261)	(−0.290)
HHS	1.359	0.105
	(1.606)	(0.122)
Age	0.224	0.896***
	(0.701)	(2.755)
SOE	0.123	0.108
	(1.074)	(0.931)
Constant	−6.891***	−8.374***
	(−6.111)	(−7.283)
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
N	3218	3218
R^2	0.149	0.161

This table reports the impact of green finance reform on different types of green innovation. The standard errors are included in parentheses. The symbols ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

6. Conclusion

Based on the green finance reform that the Chinese government introduced in 2017, this paper used the unbalanced panel data of Guangdong's A-share listed companies from 2012 to 2019 as well as the DID method to study the impact of green finance reform on corporate green innovation. The research results showed that (1) green finance reform had a significantly positive effect on the quantity and quality of green patents, and the promoting effect of green finance reform on green innovation was mainly reflected in SOEs and large-scale enterprises; (2) green finance reform encouraged enterprises to apply for more green invention and green utility model patents; however, these policies have a greater and more significant effect on green invention patents; (3) green finance reform can promote corporate green innovation by alleviating financing constraints.

The literature on the policy effect of green finance policy on corporate green innovation mainly emphasized on the effect of green credit policy on corporate green innovation [12, 18–20]. We studied the impact of green financial reform targeting the financial system on corporate green innovation. The limitation of this study is that we did not consider the specific impact of different types of financial institutions during green finance reform, nor did we extensively study the impact of green credit, green bonds, and other green financial products during this reform. In the future, the impact of different financial intermediaries and financial products introduced during green financial reform should be extensively studied. At the same time, other mechanisms through which green financial reform affects corporate green innovation should be studied, such as corporate governance and corporate information environments.

Data Availability

The datasets used to support the finding of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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