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Impact of capital market openness on corporate green technology innovation: evidence from the Shanghai-Hong Kong Stock Connect program

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ABSTRACT

This paper explores the impact of capital market openness on corporate green technology innovation using the Difference in Differences model (DID) and a quasi-natural experiment with the Shanghai-Hong Kong Stock Exchange using A-share listed corporations data from 2011 to 2020. The findings indicate that capital market openness has a significant promotion effect on corporate green technology innovation. This effect is consistent using Propensity Score Matching-Difference in Differences model (PSM-DID), counterfactual and placebo tests. Moreover, capital market openness can indirectly stimulate corporate green technology innovation by increasing corporate R&D investment and improving corporate management. Notably, the promotion effect of capital market openness on green technology innovation of SOEs and small-scale corporations is stronger.

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1. Introduction

Nowadays, the global economic market is severely challenged by the rising tide of anti-globalization ideology and trade protectionism against economic openness (Wang et al., 2023; Ciftci & Durusu-Ciftci, 2022). Although economic globalization is hampered, global integration and openness is still unavoidable world development trend (Ciravegna & Michailova, 2022). As an overriding component of national participation in the global price-setting mechanism, capital market openness is an instrumental part of financial openness and a crucial part of participation in international financial governance (Meng et al., 2023). Meanwhile, capital market openness is also an essential factor in each nation's layout of openness abroad, which is one of the means to promote financial system reform and economic development (Zhang et al., 2021; Levine, 1997). As a major representative of emerging economies, China has been adhering to the basic state policy of opening its markets worldwide (Dong, 2014). Since China acceded to the

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WTO in 2001, it has accelerated the internationalization of its capital market (Witt et al., 2023). The Chinese government enacted the Qualified Foreign Institutional Investor (QFII) system, which provides the first attempt to integrate the capital market into globalization in 2002 (Wang & Xiao,2023)[1]. The QFII for the capital market is launched in 2007, and the RMB Qualified Foreign Institutional Investor (RQFII) system is introduced in 2011 (Wu & Ohk, 2023).

The Shanghai-Hong Kong Stock Connect program (SHKSCP) is formally introduced in November 2014 (Jiang et al., 2023). By eliminating the barriers to entry for foreign investors, the SHKSCP assists the local capital market become more integrated with the world market (Jiang et al., 2023). SHKSCP has served an invaluable role in China's capital market development (Li & Chen, 2021). The SHKSCP is, to a certain extent, not only an interconnection between two exchanges but also between China and the world (Bai & Chow, 2017). It is the first time in the world that a capital market with Chinese characteristics is connected to a fully open, near-international-level capital market (Cuestas & Tang, 2021). Establishing the SHKSCP trading system will provide valuable experience for linking similar markets worldwide, and presents a successful example of gradual capital markets openness under the condition of local currency non-convertibility (Huo & Ahmed, 2017). Meanwhile, owing to the worldwide recession and the European debt crisis that followed it (Marangos, 2023), the economic development of emerging market economies has accelerated and investable markets capacity has expanded (Khurshid et al., 2023), becoming the major direction for global asset diversification and allocation, with China being a typical representative (Attig et al., 2023).

The pace of economic globalization has quickened with the proliferation of global industry and commerce (Zhang et al., 2023). Simultaneously, Due to increased population and the use of less-than-ideal production techniques, the world's ecosystems are in peril, energy consumption is through the roof, and pollution levels are over the roof (Yang et al., 2022a). Realizing green and innovation is the key to solving resource and environmental problems and is also a key part of global economic development (Gao et al., 2022). As an essential driving force for sustainable development, green technology innovation has served as an inevitable choice for national sustainable development (Razzaq et al., 2021; Sun & Razzaq, 2022). For example, the European Union (EU) has vigorously implemented a green innovation action plan, requiring member states, regions, and localities to formulate relevant policies to protect green innovation R&D activities (Gu et al., 2019; Dong et al., 2021). An increasing number of EU enterprises have started to actively carry out innovation in green technology, make the most of limited resources while prioritizing ecological preservation to improve market competitiveness (Tosun et al., 2023).

The Chinese government is also actively promoting green technology innovation in corporations and has formulated relevant policies (Jiakui et al., 2023; Sun et al., 2022; Irfan et al., 2022). The 18th National Congress report proposes to adhere to resource conservation, vigorously promote green, circular, and low-carbon development, and an overall reversal of the environmental degradation that has occurred in recent decades (Pan et al., 2023)[2]. Compared with the environmental pollution caused by traditional innovation, green innovation underlines new processes, products, and

technologies to reduce pollution and improve energy utilization (Cheng & Yu, 2023; Gao et al., 2022; Xu et al., 2023). Capital market openness generates substantial offshore capital for corporations willing to pursue green innovation, increasing liquidity of its stock in the capital market, stabilizing stock and increasing investment returns (Feng et al., 2022). Furthermore, capital market openness broadens social scrutiny of non-clean listed corporations, forcing corporations to enhance their reputation through green innovation to cater to corporate social responsibility (Sha et al., 2022). Since the capital market openness is accelerating, then what impact it has on green technology innovation? What is the impact mechanism of capital market openness on green technology innovation? This issue warrants concern and deliberation. To investigate this issue, we study the nexus between SHKSCP and corporate green technology innovation level, aiming to to furnish confirmation that the Chinese economy can undergo a green revolution and boost its openness level.

The contributions made by this study may primarily be broken down into three categories. First, the economic behavior of capital market openness is examined in light of green technology innovation, which broadens the related research and bridges the gap of existing research. Secondly, the net effect of SHKSCP affecting green technology innovation is assessed using the DID model, which well-avoids the endogeneity problem in previous researchers and enriches the empirical research. Finally, the heterogeneous effects and role mechanisms of capital market openness affecting green technology innovation are revealed from the perspectives of heterogeneity, property rights attributes, and corporate scale, which give fresh experiences and insights into capital market openness in emerging economies.

The remainder of this paper is organized as follows. Section 2 reviews and summarizes the literature related to capital market openness and green technology innovation. Section 3 provides the economics strategy, variable selection, and data sources. Section 4 contains sufficient analysis and discussion of the empirical results. Finally, conclusions and policy implications are given.

2. Literature review

2.1. Research green technology innovation

The 1960s are the starting point for the history of green technology (Zhao et al., 2022; Bodin & Björklund, 2022). Western countries have adopted a two-pronged strategy to tackle the sudden environmental pollution concerns (Lis & Szymanowski, 2022). Corresponding pollution control standards and environmental management systems are formulated (Gómez-Sanabria et al., 2022; Shammi et al., 2022). Next, construction of green R&D institutions is being aggressively stimulated in order to generate the technological assistance necessary for successfully discussing problems relating to environmental pollution (Ren et al., 2022; Irfan et al., 2022). Along with the emergence of green technologies, green technology innovation has also received academic attention (Gao et al., 2022; Behera & Sethi, 2022). Braun and Wield (1994) define the purpose of green technology like any innovation, procedure, or service that contributes togreen growth. James (1997) describe green innovation from a microscopic perspective as new products or processes that simultaneously reduce corporate

environmental pollution, boost corporate profits, and increase corporate vitality. Wang et al. (2022) consider green innovation as a process in which individuals within a corporation innovate to reduce environmental pollution and boost corporate performance by improving technology.

From the perspective of production's whole process, OECD (2009) includes a methodical summary of both the process of green technology innovation, defining it as the creative act of inventing or enhancing products, processes, and marketing tactics for pollution prevention. Regarding the factors that are influential in green technologies, scholars have undertaken a considerable amount of study in terms of concepts, institutions, and markets (Sahoo et al., 2022; Liu et al., 2022a; Begum et al., 2022). Wagner (2007), for example, argues that managers' environmental protection awareness can positively influence corporate green patent output. Schaefer's (2007) find that institutional pressure is an essential driver of green behavior change in corporations, which can effectively facilitate green technology innovation. Horbach (2008) indicates that government regulatory actions can significantly reduce corporate emissions and promote corporate product recycling rates. According to Eiadat et al. (2008), free markets have the potential to stimulate green technologies as well as encourage businesses to develop and enhance environmental incentives. Besides, According to Lee (2008), the most significant drivers for organizations to apply green innovation are buyer influence, government participation, and the maturity of the green supply chain. Chang (2011) argues that the environmental ethics of firms can promote green product innovation and gain long-term competitive advantage, using the Taiwanese manufacturing industry as an example. Dubey et al. (2015) discover that pressure from the government, consumers, and suppliers significantly drives firms' demand for green innovation. Yuan and Cao (2022) find that firms' innovation risk is mainly determined by both external and market aspects.

2.2. Research on capital market openness

From the existing literature, the economic consequences of capital market openness mainly exist at two parts of research, namely the macroscopic and microscopic levels (Cavalli et al., 2022). From the macroscopic level, the impact of capital market liberalization on macroeconomics is not unanimous, with two opposed views (Abbass et al., 2022; Bhandari et al., 2022). Some scholars have affirmed the positive impact of capital market openness on economic effects (Boubaker et al., 2022; Tiwari et al., 2022). As an essential factor driving economic growth, Edison et al. (2002) argue that capital market openness can be a positive influence on the economic growth by increasing investment. Azimi (2022) and Bekaert et al. (2005) verify that capital market openness can reduce the cost of capital and mitigate market volatility, thus bringing positive effects on economic development. Conversely, some scholars argue that capital market openness is detrimental to economic development (Liu et al., 2022b). Bae et al. (2004) investigate market risk view. They argue that capital market openness can increase market risk and is detrimental to the stability of the domestic economy, thus increasing the possibility of economic crises. In addition, Dang (2014), by studying different phases of capital market openness in eight emerging economies, find that

during the expansion phase after capital market openness, the economy grows faster compared to the expansion before openness. Economic growth declines more significantly in the post-openness capital market recession than in the pre-openness recession.

From the microscopic level, scholars have discussed various aspects of capital market openness for corporate governance, investment efficiency, information disclosure, and stock price volatility (Peng et al., 2021). In terms of corporate governance, Stulz (1995) finds that firms face the possibility of mergers and acquisitions after capital market openness, thus forcing managers to improve themselves to cope with this risk and driving optimization of corporate governance. Ghosh et al. (2008) argues that capital market openness can introduce advanced management experience, giving evidence for capital market openness to improve corporate governance. Aggarwal et al. (2011) reveals that corporations with such a larger share of foreign shareholdings are far less likely to fire managers with inadequate management abilities. Similarly, Ferreira and Matos (2008) find that corporations with fewer connections between foreign investors and their internal operations have higher governance efficiency and profitability, a phenomenon that arises as a disincentive for managers to overinvest. From the perspective of information disclosure, Capital market openness can attract many foreign investors (Ho et al., 2022). Due to the differences in geographic culture and political system, foreign investors are in an information-disadvantaged situation and prefer to invest in firms with good information disclosure (Shou et al., 2022; Matthews et al., 2022).

To attract foreign investors, enterprises will improve information disclosure scope, as confirmed by the studies of Yoon (2017) and Tsang et al. (2019). Iwata and Wu (2009) and Umutlu et al. (2010) may have argued that such a rise in the number of investors and a more equitable distribution of risk may result from capital markets openness, which positively impacts reducing stock market volatility and stabilizing stock prices. Gul et al. (2010) point out that capital market openness alleviates information asymmetry and promotes information disclosure, which is also beneficial for stabilizing stock prices. Chang (2010), however, hold the opposite view, arguing that there is short-term investment and herding behavior of foreign investors, which is detrimental to the stock market stability.

The SHKSCP in China is a vital symbol of China's capital market openness and can be regarded as a milestone event on the road to openness (Zhang et al., 2022a; Sha et al., 2022; Chen et al., 2022). Since the implementation of SHKSCP, scholars' interest has been piqued. In terms of financing, Tan and Shao (2021) focus on capital market openness and corporate equity financing and find that the SHKSCP promotes equity financing of State-owned enterprises (SOEs) by expanding financing channels, expanding capital supply, and increasing investor equity demand, which ultimately reduces the financing constraints of the underlying enterprises. Song and Guo (2021) argues capital market openness makes commercial credit financing decline by reducing commercial credit, and only reduces commercial credit financing for non-target and non-SOEs. From the market side, Pan and Han (2022) examine the effect and influence mechanism of the SHKSCP on market stability from the perspective of tail systemic risk, and find that the implementation of this system is prone to left-tail systemic risk, which is detrimental to market stability in the short term. From the

perspective of corporate tax avoidance, Qi et al. (2021) argue that the SHKSCP inhibit the occurrence of corporate tax avoidance by alleviating financing constraints, enhancing supervision, and improving information disclosure. Wang et al. (2022) also holds the same view. Luo and Chen (2020) and Zhu and Yi (2020) argue that the SHKSCP has a positive impact on corporate innovation, optimizing corporate governance, and reducing risk and improving the governance capacity of managers. In addition, Zhang et al. (2022a) find that SHKSCP increases the underlying firms' substantive innovation investment and promotes strategic innovation behavior.

From the existing studies, scholars have conducted many discussions on the influencing factors of green technology innovation and the economic consequences of capital market openness, which provides a reliable reference implication. Specifically, scholars have extensively discussed the background of green technology innovation's emergence and its influencing factors. Moreover, scholars have also conducted detailed investigations on the impact of capital market openness at the macroscopic level (positive and negative effects of capital market openness on the economy) and at the microscopic level (capital market openness on corporate behavior, valuation, and information disclosure), as well as on SHKSCP in terms of financing, markets, and tax avoidance. However, scare scholars have linked Capital market openness with green technology innovation, ignoring the change of Capital market openness on firms' green innovation behavior. We emnploy the exogenous policy shocks provided by the implementation of the SHKSCP, and examines more comprehensively the impact mechanism of capital market openness on green technology innovation, trying to reveal the principle of capital market openness affecting corporate green technology innovation and gives novel empirical lessons and enlightenment for capital market opening of emerging economies.

3. Study design

3.1. Economics strategies

The SHKSCP is an interoperability mechanism for stock market trading between the Shanghai Stock Exchange and the Hong Kong Stock Exchange, allowing investors on either exchange to purchase and sell equities listed on the other exchange within a certain price range via local securities organizations (Sha et al., 2022). Stock trading under the Shanghai-Hong Kong Stock Connect begins on November 17, 2014. SHKSCP provides a quasi-natural experiment (Wang et al., 2022). The Chinese government has repeatedly stated that they will focus on promoting a fresh round of high-level openness, of which the expansion of the service industry, including capital market openness, is essential (Chen et al., 2022). The government additionally indicates that thereafter it intends to proactively seek to impose requirements for establishing an interoperable mechanism for trading in the Shanghai and Hong Kong stock markets to stimulate further the bidirectional openness of the capital markets of mainland China and Hong Kong as well as its healthy development. Simultaneously, deeper convergence with the global market will continuously elevate the openness level (Cui & Chen, 2022). The Difference in Differences (DID) is a commonly used measurement identification strategy (Yang et al., 2022b; Zhao et al., 2022; Chai et al., 2022). For

specific studies, it divides the sample into experimental and control groups. It explores whether there is a policy impact by analyzing the changes in both before and after the event or policy (Bertrand et al., 2004). To assess the characteristics of the relationship between the two, following Zhao et al. (2021), a DID model are constructed.

$$GI_{i,t} = \beta_0 + \beta_1 SHK_{i,t} + \beta_n control_{i,t} + \gamma_t + \mu_i + \varepsilon_{i,t} \quad (1)$$

Among them, $GI_{i,t}$ denotes the green technology innovation level of corporation i in year t. $SHK_{i,t}$ indicates whether corporate i buys the underlying in year t. It is recorded as 1, otherwise it is recorded as 0. $control_{i,t}$ denotes the added control variables, mainly including shareholding concentration (Sc), number of corporate employees (Nce), executive compensation (Ec), Return on assets (Roa), gearing ratio (Gr), and asset turnover ratio (Atr) θ_t, μ_i and $\varepsilon_{i,t}$ denote the year fixed effects, individual fixed effects, and residual terms. β_0 is estimation factor.

To test whether corporate research and development investment (Crd) and corporate management level (Cm) play a mediating role between capital market openness and corporate green technology innovation, the mediating effect is tested by a three-step procedure, specifically, according to Eqs. (2) and (3):

$$M_{i,t} = \alpha_0 + \alpha_1 SHK_{i,t} + \alpha_2 control_{i.t} + \theta_t + \mu_i + \varepsilon_{i,t} \quad (2)$$

$$GI_{i,t} = \gamma_0 + \gamma_1 SHK_{i,t} + \gamma_2 M_{i,t} + \gamma_2 control_{i.t} + \theta_t + \mu_i + \varepsilon_{i,t} \quad (3)$$

Among them, $M_{i,t}$ is the mediating variable, which is specifically denoted as corporate research and development investment (Crd) and corporate management level (Cm) in this paper. The rest of the variables are consistent with Eq. (1).

3.2. Variable selection

3.2.1. Explained variables

Green technology innovation (GI) follows ecological principles to control pollution and save resources and energy (Razzaq et al., 2021; Sun et al., 2022). The number of patents is generally used to characterize the level of green technology innovation. Green technology patents are mainly categorized into the number of green utility models and green invention patents. Since the degree of creativity of green invention patents is higher than that of utility model patents, applying for them is more difficult. Therefore, this paper uses the number of green inventions independently obtained in the current year to characterize corporate green technology innovation.

3.2.2. Core explanatory variables

We mainly considers the shock of capital market openness on corporate green technology innovation under the SHKSCP mechanism. Therefore, it is measured according to whether the corporate buys the underlying of SHKSCP in that year, and is recorded as 1, which indicates a high degree of capital openness, otherwise it is recorded as 0, which corresponds to a low degree of capital openness.

3.2.3. Mechanism variables

Corporate research and development investment (Crd), characterized by taking the natural logarithm of the total R&D expenditures of listed companies (plus one panned by one unit). and corporate management level (Cm), following Xu et al. (2022) which is captured using corporate overhead expenditures.

3.2.4. Control variables

Referring to Sha et al. (2022), Chen et al. (2022), and Zhang et al. (2022b), the following six control variables, which include shareholding concentration (Sc), number of corporate employees (Nce), executive compensation (Ec), Return on assets (Roa), gearing ratio (Gr), and asset turnover ratio (Atr), are selected to control the interference of potential factors on the dependent variable. Shareholding concentration (Sc). Shareholding concentration (Sc) is quantified by the total shareholding of the top ten shareholders. Several corporate employees (Nce). The number of corporate employees (Nce) is characterized by taking the natural logarithm of the number of corporate employees plus one. Executive compensation (Ec). Executive compensation (Ec) is expressed as the natural logarithm of the total number of the top three executives' compensation plus one. Return on assets (Roa). Return on assets (Roa) is characterized as follows.

$$Roa=\frac{\text{Earnings before interest and taxes}*2}{(\text{Total assets at the beginning of the period} + \text{Total assets at the end of the period})*100\%} \tag{4}$$

Gearing ratio (Gr). The gearing ratio (Gr) is expressed as a percentage of total liabilities divided by total assets. Asset turnover ratio (Atr). Asset turnover ratio (Atr) is characterized as follows.

$$Atr=\frac{\text{Operating income (TTM)}*2}{(\text{Total assets at the end of the period} + \text{Total assets at the beginning of the period})} \tag{5}$$

3.3. Data

We take A-share listed corporations from 2011 to 2020 as the research sample. As the stock trading under the SHKSCP start on November 17, 2014, some enterprises in 2014 already belonged to the subject of SHKSCP buy. To determine the trend test before implementing the interoperability mechanism, this paper determines the start of the research sample as 2011. Limited by corporate green patents' data, the sample's end is determined as 2020 in this paper. In addition, the following processing has been done for the research sample. (1) exclude ST enterprises; (2) to accurately assess the impact of the SHKSCP mechanism, this paper excludes enterprises listed after 2011; (3) to avoid some enterprises identified to be part of the SHKSCP buy-in bid and then exit, this paper strictly identifies the experimental group as the enterprises identified to be the SHKSCP buy-in bid in 2014 and no exit until 2020; (4) to render the panel data to be a balanced panel, the null data are supplemented with 0. 1749 research subjects are screened, and 17490 observation samples are obtained. Data on

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std.dev.	Min	Max
GI	17490	0.57	5.22	0.00	249.00
SHK	17490	0.10	0.30	0.00	1.00
Sc	17490	56.47	15.86	0.00	98.59
Nce	17490	7.77	1.40	0.69	13.22
Ec	17490	5.17	0.82	−0.17	9.08
Roa	17490	7.40	28.36	−1157.70	2078.76
Gr	17490	47.04	141.68	−19.47	17834.60
Atr	17490	0.65	0.63	−0.01	22.08

Source: produced by the authors.

whether subject to SHKSCP buy, shareholding concentration, number of corporate employees, executive compensation, return on assets, gearing ratio, and total asset turnover ratio are from the wind database, and patent data from CNRDS. Table 1 reports descriptive statistics.

4. Results and discussion

4.1. Parallel trend test results and discussion

The use of DID analysis technique is subject to a strict prerequisite that the control group and the experimental group should meet the parallel trend test (Sun et al., 2022; and Fang et al., 2022). Regardless of whether the enterprises are SHKSCP buy-in targets, the corporate green technology innovation level trend is consistent before the implementation of SHKSCP. Referring to Tanaka (2015) and Yan et al. (2021), this paper plots parallel trends to test whether the study satisfies the beforehand test of the DID technique. Figure 1 reveals that before the implementation of SHKSCP in 2014, the trend is identical for both the experimental and the control group, and only after policy implementation began to experience a change in trend, indicating that a parallel trend test is passed and the DID technique is applicable.

4.2. Variable correlation test results and discussion

Table 2 implies that the correlations among the variables are all less than 0.5, which lays a good data foundation for the regression analysis later (Jagannathan et al., 2017; Yang et al., 2022a). From the correlation coefficient, the correlation technology between capital market openness and corporate green technology innovation is 0.0514, which is significant at the 10% level, and also indicates to some extent that capital market openness has a beneficial effect on corporate green technology innovation.

4.3. Baseline regression results and discussion

Table 3 contains the results of capital market openness and corporate green technology innovation. Columns (1)-(3) of Table 3 indicate the results of OLS, two-way fixed effects model without control variables, and two-way fixed effects model with control variables, respectively. Table 3 reveals that the coefficient of *SHK* lies between 0.451 and 0.895 (p-value < 0.01), implying that capital market openness can significantly

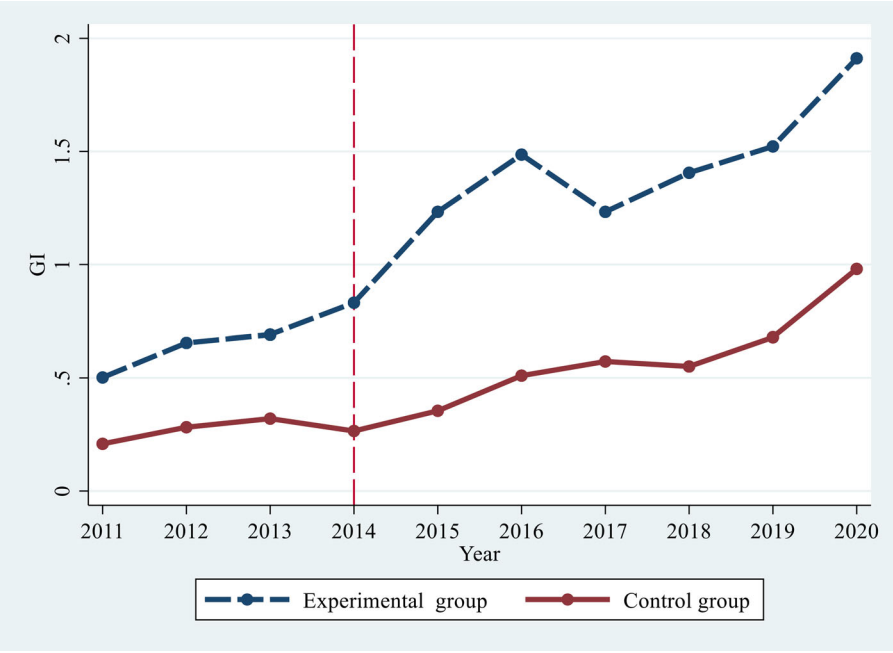

Figure 1. Parallel trend graph.
Source: produced by the authors.

Table 2. Variable correlation test results.

	GI	SHK	Sc	Nce	Ec	Roa	Gr	Atr
GI	1							
SHK	0.0514*	1						
Sc	0.0488*	0.1525*	1					
Nce	0.1782*	0.3605*	0.2476*	1				
Ec	0.1243*	0.2620*	0.0933*	0.4024*	1			
Roa	0.0072	0.0532*	0.0593*	0.0377*	0.0688*	1		
Gr	0.0054	0.0193	−0.0123	0.0104	0.0004	−0.0159	1	
Atr	0.0084	−0.0125	0.0149	0.1400*	0.0320*	0.0619*	0.005	1

Note: ***, **, * indicate that parameter estimates are significant at the 1%, 5%, and 10% statistical levels, respectively.
Source: produced by the authors.

contribute to corporate green technological innovation. The results are supported by Sha et al. (2022), Zhang et al. (2021) and Feng et al. (2022), suggesting that capital stock market openness reforms that generate capital and market uptake will reinforce the incentives for corporations to innovate green technologies. Foreign investors from developed countries tend to be more aware of the importance of environmental protection and sustainable development than investors from developing countries (Sha et al., 2022). In addition, with capital market openness, increasing number of corporations can effectively improve the market information environment and improve corporate governance (Chen et al., 2022). Not only has this helped lower the cost of capital and reduce financing limitations for corporations, but it has also stimulated additional capital to be put into establishing novel green technology (Zhang et al., 2022a). A study has been conducted to demonstrate that the advantages of stock markets in resource allocation and financing can provide important support for corporate

Table 3. Baseline regression results.

Variables	(1) OLS	(2) FE	(3) FE
SHK	0.895***	0.470***	0.451***
	(0.132)	(0.154)	(0.155)
Sc			−8.04e − 05
			(0.00312)
Nce			0.0983*
			(0.0530)
Ec			−0.101
			(0.0639)
Roa			0.000349
			(0.000933)
Gr			−1.28e − 05
			(0.000190)
Atr			−0.142*
			(0.0793)
Constant	0.479***	0.250***	0.110
	(0.0415)	(0.0780)	(0.476)
Year-FE	No	Yes	Yes
Individual-FE	No	Yes	Yes
Observations	17,490	17,490	17,490
R-squared	0.003	0.007	0.008
Number of id		1,749	1,749

Note: ***, **, * indicate that parameter estimates are significant at the 1%, 5%, and 10% statistical levels, respectively.
Source: produced by the authors.

innovation activities (Wang et al., 2022). Therefore, corporations are much more inclined to innovate with green technology to boost their fundamental competitiveness (Qi et al., 2021).

4.4. Robustness test results and discussion

The test for robustness evaluates at whether the evaluation methods and indicators can justify the findings. Determine whether the assessment techniques and indicators still provide a more consistent and stable explanation of the evaluation findings when specific factors are altered. The Propensity Score Matching-Differences-in-Differences (PSM-DID) method, the counterfactual test, and the placebo test are chosen to assess the robustness of the DID model used in this paper to investigate the nature of the link between capital market openness and corporate green technology innovation. First, PSM and DID are both included into the model. The PSM's task is to identify suitable controls for the treated individuals, whereas the DID's is to detect the impacts of policy shocks. In order to re-estimate the effect of capital market openness on corporate green innovation (See column (1) of Table 4), we use the radius matching approach for PSM.

Consistent with the baseline findings, and offering early indication of the robustness of underlying regression results, column (1) of Table 4 demonstrates a substantially positive regression coefficient of 0.451 between capital market openness and corporate green technology innovation. Second, the counterfactual test involves initially making a prediction about the current performance and then conducting validation investigation (See columns (2)-(3) of Table 4). Columns (2)-(3) of Table 4 reveal that when the year of policy implementation is advanced by two years, the

Table 4. Robustness test results.

Variables	(1) PSM-DID	(2) Counterfactual test	(3) Counterfactual test
SHK	0.451***		
	(0.155)		
L2.SHK		0.226	
		(0.166)	
L3.SHK			−0.000446
			(0.175)
Sc	−8.04e − 05	0.000668	−0.00156
	(0.00312)	(0.00415)	(0.00494)
Nce	0.0983*	0.108	0.109
	(0.0530)	(0.0706)	(0.0827)
Ec	−0.101	−0.0972	−0.120
	(0.0639)	(0.0814)	(0.0939)
Roa	0.000349	0.000208	7.03e − 06
	(0.000933)	(0.00119)	(0.00135)
Gr	−1.28e − 05	−2.97e − 05	−3.22e − 05
	(0.000190)	(0.000200)	(0.000204)
Atr	−0.142*	−0.208*	−0.206
	(0.0793)	(0.112)	(0.126)
Constant	0.110	0.132	0.330
	(0.476)	(0.637)	(0.745)
Year-FE	Yes	Yes	Yes
Individual-FE	Yes	Yes	Yes
Observations	17,490	13,992	12,243
R-squared	0.008	0.006	0.006
Number of id	1,749	1,749	1,749

Source: produced by the authors.

coefficient of capital market openness is 0.226, which is not significant. When the policy implementation year is advanced by three years, the regression coefficient of capital market openness is −0.000446, which is insignificant. Again, results robustness is illustrated. Finally, the general practice of placebo testing is to fudge the policy time for regression. If the regression results are insignificant, the robustness of the underlying effect is indicated (see Figure 2). Figure 2 depicts the regression by fictitious policy, and the regression coefficients are all around zero. At the same time, the p-values are all greater than 0.1. The t-values are mostly distributed around zero values, indicating that the effect of capital market openness is insignificant under the dummy policy, again demonstrating underlying results robustness.

4.5. Role mechanism results and discussion

In order to test whether *Crd* and *Cm* plays a mediating role between capital market openness and corporate green technology innovation, a three-step method is adopted in this paper to conduct a stepwise test (see Table 5). Column (1) of Table 5 reveals the regression results between capital market openness and corporate green technology innovation, demonstrating the regression coefficient of SHK is 0.451 ($p < 0.01$). Column (2) of Table 5 reveals the regression results of Capital market openness and corporate R&D investment, demonstrating a coefficient of R&D is 0.992 ($p < 0.01$). Column (3) in Table 5 reveals that the regression coefficient of SHK changes from 0.451 in column (1) to 0.395 ($p < 0.05$), demonstrating the regression coefficient of R&D is 0.0560 ($p < 0.01$). Column (4) in Table 5 reveals the results of capital market openness on corporate management level with a regression coefficient of 0.770

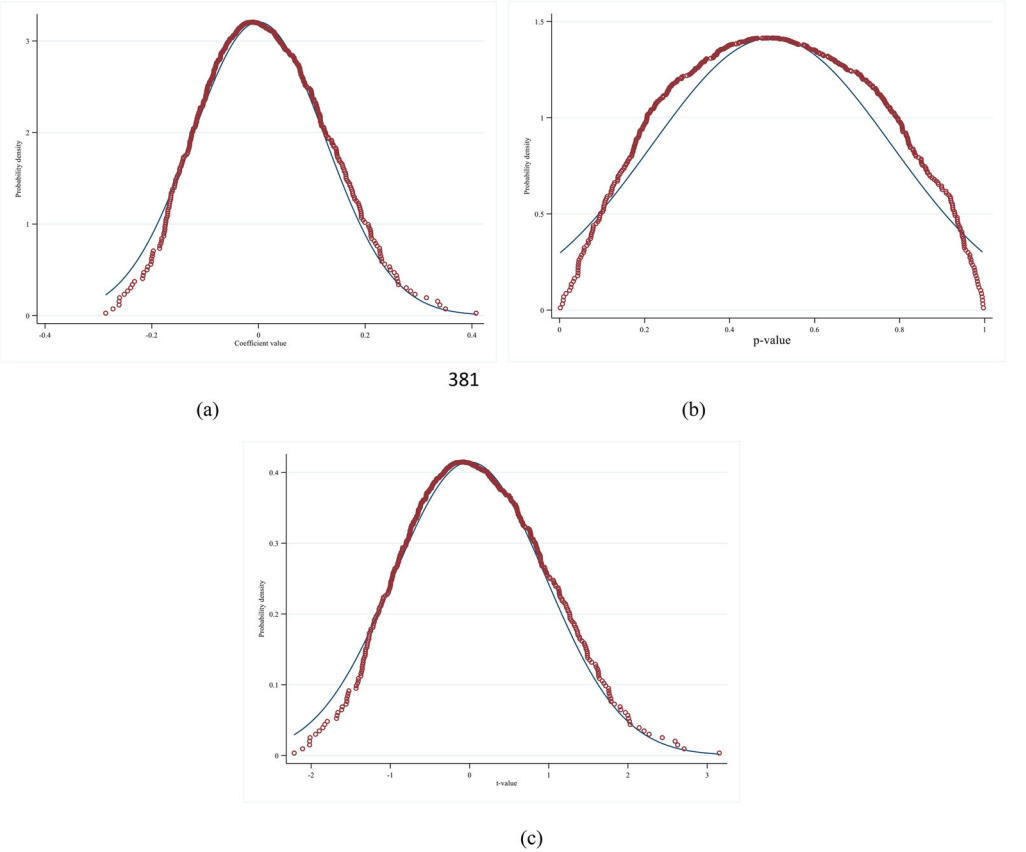

Figure 2. placebo test graph.
Source: produced by the authors.

($p - value < 0.01$) for SHK. Column (5) of Table 5 reveals the results after adding corporate management to the base regression results, confirming that the coefficient of *SHK* changes from 0.451 to 0.390 ($p - value < 0.05$) and the regression coefficient of the level of corporate management is 0.0789 ($p - value < 0.05$). First, capital market openness reinforces cooperation among corporations so that management experiences will be elevated (Sha et al., 2022). Improving the corporate management level is beneficial to the efficient operation of corporations and entrance into favorable operation conditions before attaching more emphasis to the R&D of green technology and strengthening corporate competitiveness (Feng et al., 2022). Mediation mechanism test reveal that capital market openness affects corporate technology green technology innovation, mainly through improving the corporate R&D investment and enhancing the corporate management level to act on the corporate green technology innovation (Cao & Wang, 2017). Further, by measuring the mediation effect, implying that the mediating effect of R&D investment is 0.056 and the mediation effect of management level is 0.061; therefore, it can be judged that the mediation effect of management level is greater than the mediating effect of R&D investment. Thus, corporate R&D investment and management are essential mechanisms for capital market openness to act on corporate green technology innovation.

Table 5. Role mechanism results.

Variables	(1) Gl	(2) Crd	(3) Gl	(4) Cm	(5) Gl
SHK	0.451***	0.992***	0.395**	0.770***	0.390**
	(0.155)	(0.158)	(0.155)	(0.0488)	(0.156)
Sc	−8.04e − 05	0.0401***	−0.00232	0.00607***	−0.000559
	(0.00312)	(0.00318)	(0.00313)	(0.000980)	(0.00312)
Nce	0.0983*	1.200***	0.0311	0.206***	0.0821
	(0.0530)	(0.0542)	(0.0537)	(0.0167)	(0.0532)
Ec	−0.101	0.106	−0.107*	−0.109***	−0.0929
	(0.0639)	(0.0653)	(0.0638)	(0.0201)	(0.0639)
Roa	0.000349	−0.000357	0.000369	0.000210	0.000333
	(0.000933)	(0.000954)	(0.000932)	(0.000294)	(0.000933)
Gr	−1.28e − 05	−0.000371*	7.95e − 06	5.23e − 05	−1.70e − 05
	(0.000190)	(0.000194)	(0.000190)	(5.97e − 05)	(0.000190)
Atr	−0.142*	−0.0359	−0.140*	0.0705***	−0.148*
	(0.0793)	(0.0810)	(0.0791)	(0.0249)	(0.0793)
Crd			0.0560***		
			(0.00779)		
Cm					0.0789***
					(0.0253)
Constant	0.110	−0.0965	0.115	−1.133***	0.199
	(0.476)	(0.487)	(0.476)	(0.150)	(0.477)
Year-FE	Yes	Yes	Yes	Yes	Yes
Individual-FE	Yes	Yes	Yes	Yes	Yes
Observations	17,490	17,490	17,490	17,490	17,490
R-squared	0.008	0.164	0.011	0.051	0.008
Number of id	1,749	1,749	1,749	1,749	1,749

Source: produced by the authors.

4.6. Heterogeneity test results and discussion

Table 4 reveals that capital market openness has a significant promotional effect on corporate green technology innovation. Compared with non-SOEs, SOEs are more susceptible to government policy shocks and more responsive to government initiatives in their production and operation activities (Zhao et al., 2022). The SHKSCP reflects the government's determination to support capital market liberalization strongly; thus, SOEs are more sensitive to this decision. Meanwhile, SOEs have government backing and are stronger in refinancing and reputation, therefore, SHKSCP may be significantly different for green technology innovation under different property forms (Sahoo et al., 2022). In addition, large-scale corporations possess a relatively larger capital base and are better financed. Small-scale corporations are faced with constraints in terms of market size, innovation resources, financing costs, and other resources, which may prevent them from successfully launching green innovation activities. Thus, does the above effect differs for corporations of different properties and scales? The following groups are explored to further investigate the impact of capital market openness on corporate green technology innovation under different corporate properties and corporate scales. On the one hand, this paper classifies the sample into SOEs and non- SOEs according to enterprise properties (See columns (1) and (2) of Table 6). Columns (1) and (2) in Table 6 reveal that among SOEs, the coefficient of capital market openness is 0.514 ($p - value < 0.01$), while the regression coefficient of capital market openness to the outside world is 0.384 but insignificant among non-SOEs, implying that the effect of capital market openness in promoting green technology innovation among SOEs is stronger. SOEs can better

Table 6. Heterogeneity test results.

Variables	SOES (1)	Non-SOES (2)	Large-scale corporations (3)	small-scale corporations (4)
SHK	0.514***	0.384	−0.183	0.204*
	(0.138)	(0.312)	(0.311)	(0.121)
Sc	−0.0108***	0.00649	0.00462	−0.000356
	(0.00394)	(0.00458)	(0.00926)	(0.00123)
Nce	0.135**	0.0782	0.232	0.0255
	(0.0617)	(0.0791)	(0.183)	(0.0210)
Ec	−0.0307	−0.175*	−0.0922	−0.0270
	(0.0700)	(0.0992)	(0.153)	(0.0278)
Roa	−0.000644	0.00227	6.15e − 05	−7.65e − 05
	(0.000830)	(0.00180)	(0.00268)	(0.000350)
Gr	0.000170	−3.20e − 05	−0.00386	4.79e − 06
	(0.00187)	(0.000224)	(0.00765)	(5.36e − 05)
Atr	−0.0253	−0.263**	−0.598**	−0.0173
	(0.0781)	(0.133)	(0.272)	(0.0314)
	(0.135)	(0.210)	(0.348)	(0.0518)
Constant	0.0137	0.267	−1.031	0.0818
	(0.578)	(0.692)	(1.760)	(0.190)
Year-FE	Yes	Yes	Yes	Yes
Individual-FE	Yes	Yes	Yes	Yes
Observations	7,460	10,030	7,449	10,041
R-squared	0.014	0.007	0.015	0.004
Number of id	746	1,003	1,090	1,341

Source: produced by the authors.

progress resource allocation in the policy context and alleviate the corporate financing constraints to facilitate corporate green technology innovation than non-SOEs, which have a strong social responsibility and leveraging effect.

In addition, the implementation of SHKSCP has the similarly different impact on corporations under different sizes. This paper also groups the sample with large-scale corporations and small-scale corporations. This paper uses total assets to characterize corporate scale. The average value of the natural logarithm of the corporate scale in the sample is calculated to distinguish between large scale and small-scale corporations. The mean value of corporate scale is 22.36, therefore, the corporations with scale greater than or equal to 22.36 are large-scale corporations and vice versa are small-scale corporations (See columns (3) and (4) of Table 6). Columns (3-(4) of Table 6 reveal that among large-scale corporations, the regression coefficient of the capital market openness is −0.183 but insignificant, while among small-scale corporations, the regression coefficient of the capital market openness is 0.204 $(p - value < 0.1)$, revealing that the capital market openness has a stronger effect on the promotion of green technology innovation among small-scale corporations. Large-scale corporations have stronger capital strength compared to small-scale corporations. SHKSCP is more helpful in alleviating the financing constraints of small-scale corporations. Therefore, capital market openness has a greater effect on the green technology innovation of small-scale corporations.

5. Conclusions and policy implications

Using A-share listed corporations from 2011 to 2020 as the research sample, this paper explores the impact of capital market openness on corporate green technology innovation by using DID model and quasi-natural experiment with SHKSCP. The

main findings indicate that capital market openness has a significant promotion effect on corporate green technology innovation, and the findings still valid following PSM-DID, counterfactual test, and placebo test. Role mechanism tests suggest that capital market openness can indirectly stimulate corporate green technology innovation through increasing corporate R&D investment and improving corporate management level, with the mechanism effect of management level being greater than the mechanism effect of R&D investment. The impact of capital market openness on corporate green technology innovation differs by corporate attributes and corporate scale. Specifically, the promotion effect of capital market openness on green technology innovation of SOEs and small-scale corporations is more substantial. The following implications are proposed.

1. Policymakers should increasingly step up efforts in capital market diversification. the SHKSCP is a major part of the capital market openness towards outsiders, enabling not only the realization of two-way capital circulation but also facilitating green technology innovation by corporations through increasing R&D investment and raising management levels. Presently, the participation of listed corporations in SHKSCP is comparatively confined, demonstrating that the capital market's openness level remains to be further developed. Given the dual carbon and innovation objective, corporate green technology innovation can generate momentum for sustainable development. Therefore, the capital market openness must be smoothly, orderly, advanced, and strengthened to play its key role in corporate green technology innovation.
2. Policymakers shall stimulate green technology innovation of non-SOEs. SOEs can better optimize resource allocation in the context of capital opening given its special nature, and interact positively with policies with stronger corporate responsibility effects. Meanwhile, SOEs should grasp the opportunity of capital market opening and play the leading role of enterprises. In contrast, non-SOEs may have stronger profit-oriented motives during their development, therefore green technology innovation does not significantly influence under the influence of capital market opening. Therefore, it is necessary to continuously guide SOEs to carry out green technology innovation, enabling them to boost green technology innovation at the whole enterprise level.
3. Keeping capital market openness positively influencing green technology innovation in small-scale corporations is imperative. Large-scale corporations are subject to stronger financing constraints than small-scale corporations, and capital market openness is beneficial to mitigate the financing constraints of small-scale corporations, thus better stimulating their green technology development. Therefore, small-scale corporations shall capture the opportunities of market liberalization to continuously elevate their green technology innovation, optimize their competitive edge, and continuously expand its scale.
4. Optimizing the financial market system to fuel capital market openness is productive. Corporate advancements can still not be achieved without the platform supplied by the financial markets and regulatory system constraints. Maximum advantages of capital market opening to private enterprises should be ensured.

For example, policymakers should mitigate corporate financing constraints by improving market access restrictions and trading allowance restrictions for foreign investors, and so on. Stimulating a higher corporate green technology innovation level will benefit dual carbon goals positively.

Notes

1. See more detail: https://www.investopedia.com/terms/q/qualified-foreign-institutional-investor-qfii.asp
2. See more detail: http://www.moa.gov.cn/ztzl/sbdhd/zyjs/201211/t20121127_3074189.htm

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