The impact of independent director interlocks on corporate green innovation: evidence from Chinese listed companies

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Abstract: Green innovation plays a critical role in mitigating environmental issues and balancing the interaction between economic growth and the natural environment. Drawing on social network and resource-dependence theory, this article scrutinises the relationship between independent director interlocks and corporate green innovation. Using the data from listed Chinese companies from 2010 to 2022, this study finds that independent director interlocks can significantly promote corporate green processes and product innovation. This research further finds that internal corporate contexts can also influence the relationship between independent director interlocks and green innovation. Moreover, the results indicate that corporate environmental commitment positively moderates the relationships between independent director interlocks and corporate green innovation. This study also provides significant implications for firms seeking green innovation performance and for policymakers seeking ways to fulfill the mission of carbon dioxide abatement.

Keywords: interlocks, environmental commitment, resource dependence theory, independent directors, green innovation.

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1 Introduction

In the 21st century, greenhouse gas emissions have become a limiting factor for human development, due to their environmental impact. The world's nations need to take immediate action to solve the critical issue of balancing the interaction between the natural environment and economic growth. China, the greatest growing nation in the world, has long sustained strong economic development while causing issues including resource scarcity, pollution, and ecological destruction. British petroleum (BP) estimates that China consumed 26.1% of disposable energy and produced 30.7% of carbon emissions in 2020, significantly more than any other geographical region. At the 75th UN General Assembly, China promised to achieve peak carbon by 2030 and carbon neutrality by 2060 in response to this terrible scenario. The Chinese government has emphasised encouraging green innovation and gradually improving environmental quality through cutting-edge technological innovation.

Green innovation refers to the process of streamlining and refining manufacturing procedures, production technologies, intermediate and finish goods, or the entire industrial production system, intending to minimise or eliminate environmental harm (Dai et al., 2015). Green innovation holds the key to resolving environmental issues (Xie et al., 2022) and promoting high-quality, sustainable economic growth in the country as a whole. Meanwhile, 'double externality' is a hallmark of green innovation (Rennings, 2000). The seeming discrepancy between the advantages and hazards of green innovation might make businesses reluctant to engage in green innovation initiatives. In light of these circumstances, enhancing Chinese firms' green innovation is crucial for enterprises seeking to gain a competitive edge as well as for achieving the green transition that will drive global economic growth.

There are three primary areas of research for green innovation drivers. First, there is the environmental policy of the government, which includes green financial instruments, carbon trading rights, voluntary emission reduction programs, and environmental subsidies (Wang et al., 2022; Khoruzhy et al., 2022; Tian et al., 2022). Second, the stakeholder pressure factors encompass competition, customer and supplier demands, as well as environmental claims raised by community stakeholders (Cai and Li, 2018; Demirel and Kesidou, 2019). Lastly, the company's internal elements include corporate

resources, managerial traits, and governance capacity (Lu and Wang, 2018; Kassinis et al., 2016). However, little study has been done on the process underlying external connection's contribution to green innovation. This article aims to investigate how independent director interlocks (IDI) influence corporate green innovation, specifically focusing on two categories: green process innovation and green product innovation.

Interlock connections, in accordance with social network theory, make it easier to get more beneficial information that is difficult to obtain through other channels. One important aspect of corporate governance is an independent director's corporate interlock (IDCI) is more likely to develop if they simultaneously hold concurrent responsibilities in many organisations. Interlocking independent directors possess unique advantages in terms of accessing a wide range of knowledge, information sources, and resource networks, positioning them to offer decision-makers vital and diverse information (Granovetter, 1973). Such a wide range of information resources improves corporate GI. Furthermore, independent directors of companies have directorships in financial institutions, establishing independent directors' financial interlock (IDFI). The strong relationship between the bank and the company eases financial hardship, lowers the cost of financial distress, lessens bankruptcy, and gives capital market knowledge (Markarian et al., 2006), all of which are beneficial to GI (Amore and Bennedsen, 2016). Chinese culture places a high value on interpersonal relationships. Owing to the interconnectedness of Chinese culture, informal social systems greatly impact both individual and organisational behaviour (Xie and Chen, 2012). As a result, independent directors have the highest potential to tap into resources within their interlock connections. Regrettably, is the level of GI getting better as independent directors become interlocking? Specifically, which actions are they take? Does a corporation's interlock relationships and its internal resources corporate environmental commitment (CEC) together matter to corporate GI? These questions have not received a clear answer. As a result, a study on Chinese listed companies is done to find out how IDI and GI are related. This study also investigates how CEC moderates the effects of the above relationship.

This article makes notable contributions to various aspects of the existing literature. First, to the best of our knowledge, this study is the first to explore the impact of independent directors' interlocks on corporate green innovation, drawing from resource dependency and social network theories. This study offers factual support for the idea that IDI might encourage green process and product innovation in Chinese businesses. More specifically, this study also explores the possible interlocks of independent directors in the financial (banking) sector of China (IDFI) and its possible effects on sustainable advancements which have never been investigated before. Secondly, the research on the consequences of IDI is expanded in this essay. The existing literature mainly concentrates on the effects of independent directors on different elements of corporate governance, including corporate value, information disclosure, and innovation within firms (Hermalin and Weisbach, 1998; Chen and Jaggi, 2000; Wu and Dong, 2021; Shafeeq Nimr Al-Maliki et al., 2023). This paper examines how IDI affect green innovation, in the context of resource management in addition to their monitoring and advisory responsibilities. Third, this study is the first to assess the CEC as a possible moderator in the relationship between IDI and GI. Drawing conclusions from our data suggests that shared positions held by independent directors can lead to enhanced GI facilitated by CEC. Lastly, this research studied ID interlocks and GI in China, an emerging economy focused on sustainable industrial growth (Gao et al., 2022). Recent

findings show companies globally recognise the importance of board member sharing for low-carbon targets (Zona et al., 2018), suggesting broader applicability beyond China as well.

The article's remaining section is organised as follows. Section 2 reviews the literature on independent directors' interlocks with other key variables. Section 3 outlines the theoretical framework with several significant research hypotheses. Section 4 outlines the measurements, data, and techniques. Our key findings are illustrated in Section 5. The results are addressed in Section 6. This article's conclusion is found in Section 7.

2 Literature review

2.1 Independent director interlocks

Independent directors have an indirect but valuable association, providing objective insights and promoting transparent governance (Khan et al., 2024). The appointment of independent directors is a fundamental aspect of the board of directors' 'independence' structure, serving as a means of oversight and guidance (Adams et al., 2010). Conventional research primarily concentrates on the role of independent directors in functioning within a governance capacity, effectively identifying and rectifying CEO failures (Fogel et al., 2021), and monitoring the influence on the organisation's value and performance (Fareed et al., 2022). Recent studies have redirected their attention from monitoring and advisory roles to exploring the resource-management function of directors and the significance of board social capital (IDI) in effectively managing information and knowledge resources (Howard et al., 2017; Lu et al., 2021a). Interlocking relationships are the fundamental and latest channel for knowledge sharing between companies (Lin and Chen, 2017).

A director may serve as a director for many companies. A director of this kind serves as an outlet between the companies. Firms that are connected in this manner are interlocked. In instances where two companies share a director, this individual is commonly acknowledged as an interlocking director, and the resulting affiliation or connection is commonly labeled as an IDCI (Mizruchi, 1996). Additionally, when an independent director of an organisation is also a director in a financial institution (i.e., banks) at the same time, it is known to be an IDFI. According to the resource dependency hypothesis, part-time directors gain from their connections within the organisation (Pfeffer and Salancik, 2015). Through this connection, the firm may perform better by absorbing outside knowledge, information, and resources (Fang et al., 2021). The fundamental interlocking links of independent directors also favourably influence how technologically innovative businesses behave by functioning as a conduit for government assistance, financial restrictions relief, and technology knowledge (Wu and Dong, 2021).

In China's current business environment, firms are facing both environmental and economic challenges. Green innovation has surfaced as a strategic approach for businesses to effectively navigate environmental regulations, resulting in enhanced credibility, recognition, and financial gains (Li et al., 2021). Nevertheless, firms in developing nations like China frequently lack the information, expertise, and funding necessary to implement green practices (Yin and Yu, 2022; Shu et al., 2016). In this regard, two types of interlocks have been examined: IDCI and IDFI. IDCI helps firms acquire external resources such as pertinent knowledge, information, and other resources,

while IDFI provides easier and cheaper access to finance, increases monitoring, and removes financial distress. These interlocking activities help to access external scarce resources, manage environmental uncertainties (Jiang and Yuan, 2018), and establish a robust basis for adopting GI.

2.2 Green innovation

Green innovation pertains to an organisation's capacity to apply creative ideas to develop novel, practical products, and services while enhancing current ones with an emphasis on environmental sustainability (Castellano et al., 2022). Research to date demonstrates that leading companies in green innovation may gain a competitive edge by improving low-cost manufacturing (e.g., increasing resource efficiency and minimising costly pollution control) and product differentiation (e.g., green image and reputation) (Ftiti et al., 2024).

Green innovation can be divided into two main types: green process innovation and green product innovation (Huang and Li, 2017). The term 'green process innovation' refers to performance in process innovation that focuses on energy efficiency, pollution reduction, waste recycling, or non-toxicity (Chen et al., 2006). It indicates that businesses employ creative strategies to minimise the detrimental effects of their industrial processes on nature (Chen et al., 2006). Green product innovation involves developing environmentally-conscious goods that prioritise energy efficiency, waste recycling, pollution reduction, eco-friendly designs, and non-toxic materials (Chen et al., 2006). Green product innovation allows businesses to create safe, high-quality, and environmentally responsible goods. Green innovation compels organisations to fundamentally transform their business processes, product designs, and management systems, drawing on innovative capabilities, cutting-edge knowledge, and abundant complementary resources (Huang and Li, 2017). However, due to its risky, ambiguous, and resource-demanding characteristics (Peters and Buijs, 2022), successful green innovation necessitates integrating inside and outside environmental knowledge, acquiring varied information, and accumulating substantial resources.

2.3 Corporate environmental commitment

CEC pertains to the behaviour of organisations aimed at improving their environmental performance through various policies, strategies, and practices that demonstrate a dedication to sustainability (Naveed et al., 2023). It includes a variety of environmental initiatives, including implementing eco-friendly practices, the BODs' dedication to 'going greener,' and cultivating an eco-friendly workplace culture (Burki and Dahlstrom, 2017). It takes a careful equilibrium of assets, capabilities, and communication pathways to satisfy the expectations of many stakeholders, making it difficult to achieve and sustain CEC (Vargas et al., 2019). Businesses with lower CEC levels are typically characterised by inadequate and reactive environmental procedures that are unable to handle a greater variety of environmental problems. Conversely, companies with higher CEC levels actively and willingly work to safeguard the environment, maintaining it as a key component of their business strategy for value generation and competitive advantage (Murillo-Luna et al., 2008). Because of their lengthy investment cycle and low return, environmental protection projects would ordinarily be considered unrealistic. CEC helps

to create these initiatives proactively (Zeng et al., 2023). Moreover, it protects enterprises from the detrimental externalities that the regulatory agencies impose (Song et al., 2020).

3 Theoretical framework and hypotheses

3.1 Independent director's interlock and corporate green innovation

Corporate green innovation refers to the process of reducing environmental impact through innovative practices in manufacturing. It encompasses a range of activities and outcomes that leverage knowledge in product design, production techniques, emissions management, and energy efficiency. It also involves the creation and adoption of innovative solutions that reduce resource consumption, mitigate pollution, and encourage the shift towards a more sustainable and greener future (Razzaq et al., 2021). Because it depends on diverse information sources and multi-level R&D investments, it increased demand on their knowledge base and reserves of resources (Saunila et al., 2018). It calls on firms to combine internal and external green expertise, gather a variety of knowledge, and amass abundant resources. Through the interlocking connections created by multiple appointments in various corporations (corporate interlock), independent directors are capable of completing the organisation's resource endowments and information gathering, removing technological obstacles, and helping businesses better implement green innovation.

According to social network theory, independent directors who have more external connections offer the firm access to a wider range of information sources (Helmers et al., 2017). These information sources provide vital data on green technology, information on government regulations and policies, as well as market trends and outlooks (Larcker et al., 2013). Such information assists enterprises in raising their degree of green innovation (Zhang et al., 2023). Conversely, green innovation encompasses several domains of expertise, necessitating that organisations possess an extensive array of green knowledge and robust knowledge integration capacities. A corporate interlock with independent directors is a valuable source of information. Independent directors' connections with other directors and businesses through a web of interlocking directorships are a crucial component of their social capital (Horton et al., 2012). These interlocking connections significantly facilitate the information transfer route between organisations. By sharing green knowledge, independent directors strengthen the environmental dynamics within companies, thereby promoting corporate green innovation (Lin and Chen, 2017).

According to the resource dependency theory, organisations are inherently interdependent and cannot independently cultivate crucial resources; rather, they depend on external parties to supply these necessities for existence and to support their sustained financial commitment endeavours (Frooman, 1999). Implementing green innovations often demands more resources due to their innovative and radical nature, which can lead to higher technological risks and increased financing requirements (Amore and Bennedsen, 2016). In 2012, the Chinese government also issued the green credit policy (GCP) for the environmental and economic stability of the firms. However, recent studies proved that GCP fails to achieve cross-firm credit allocation within industries, eco-friendly, and firms are still facing financing problems, i.e., politically connected firms utilising GCP as a shield, banks are restrained from approving credit for a firm

located in low GDP provinces, banks give credit to their preferred low-risk businesses and widely ignoring pollution-intensive firms (Huang et al., 2021). Additionally, GCP has set strict environmental standards (Articles 17, 18, 20, 22, and 23), and banks charge high interest rates to firms with more exposure to climate risk (Lu et al., 2023). Lack of funding can hinder companies from pursuing green innovation and may even undermine their core values (Biondi et al., 2000). In light of these financial limitations, this study examines the financial interlock relationships of independent directors. When an independent director of a firm is also serving in a bank at the same time, it creates closer ties between the firm and banks and helps to provide easier and cheaper finance (Markarian, 2006), which helps organisations enhance their green practices (GI). Thus, we conjecture that:

H1 The IDCI positively affects the corporate green process innovation.

H2 The independent director's financial interlock positively affects the corporate green process innovation.

H3 The IDCI positively affects the corporate green product innovation.

H4 The independent director's financial interlock positively affects the corporate green product innovation.

3.2 Corporate environmental commitment as a moderator

CEC' refers to an organisation's propensity or readiness to take part in environmental protection to minimise the detrimental impacts that its operations have on the environment (Xing et al., 2019). Firm environmental commitment is influenced by the growing emphasis on environmental friendliness of manufacturing due to social and economic growth (Albitar et al., 2023). Vanek (2000) discovered that one of the major factors influencing a company's green innovation is the degree to which it prioritises environmental protection. For instance, the way that technical innovation is carried out is directly influenced by the attitudes and environmental awareness of executives, as well as by their views of environmental pressures (Fontana, 2019). Simultaneously, businesses that demonstrate a strong dedication to environmental values are eager to foster customer relationships by gaining a deep understanding of their preferences regarding environmental protection. These businesses then make an effort to create and provide goods and services that meet the market's need for environmentally friendly options. Therefore, a company's commitment to environmental sustainability strengthens its actions in areas such as green product design, green processes, and more. This commitment plays a key role in improving green innovation performance.

Furthermore, the advancement of environmentally friendly innovation is shaped by external interconnected resources and the environmental commitment of companies as well, along with the amalgamation of internal and external influences. According to recent research, an organisation's willingness to assume environmental responsibilities, such as actively improving GPCI and GPDI, to lessen the adverse effects of its operations on the environment, increases with its level of environmental commitment (Haddoud et al., 2021). Robust environmental dedication shows an organisation's increased attention to environmental concerns and willingness to shift resources, including financial and human capital, in favour of environmentally friendly behaviour. That is why businesses that care deeply about the environment are typically more open to using green

innovation as their primary means of reducing outside pressure. The impact of external interlock connections on green innovation is strengthened by CEC because it is assumed that if an organisation got external rare resources with the help of its interlock relationships but it did not have robust CEC, the resources proved to be useless. That is why, firms with IDI (IDCI and IDFI) are more likely to invest in green innovation if they have a deeper environmental commitment (see Figure 1). Therefore, we put forth the following hypothesis:

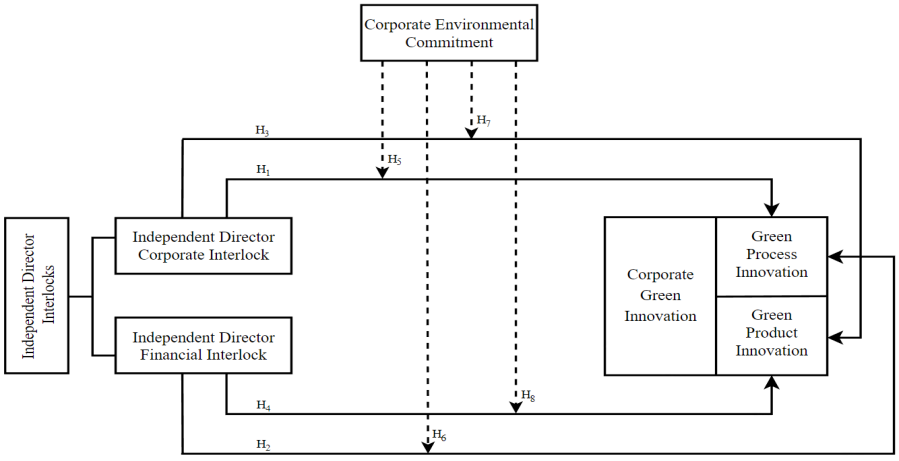
H5 CEC positively moderates the relationship between independent directors' corporate interlock and green process innovation.

H6 CEC positively moderates the relationship between IDFI and green process innovation.

H7 CEC positively moderates the relationship between independent directors' corporate interlock and green product innovation.

H8 CEC positively moderates the relationship between IDFI and green product innovation.

Figure 1 Conceptual framework



4 Methodology

4.1 Sample and data

A-share-listed Chinese firms from 2010 to 2022 make up the sample of our research. It is excluded from our analysis of firm-year observations that are designated as special treatment '(ST)' since these observations may signal a firm's imminent delisting from China's stock market. The financial firms are also excluded based on previous research (Lu et al., 2021b), indicating that financing firms are often less likely to invent green technologies directly. The final research sample consists of 39,255 firm-year

observations, including 4,902 listed firms. For independent director financial interlock, our sample includes 42 Chinese-listed financial (banking) firms.

Information about independent directors of firms and banks is collected from China stock market and accounting research database (CSMAR). We collect data about GI from CNRDS and the rest from CSMAR, such as CEC and financial information.

4.2 Measurement

4.2.1 Independent variables

An independent director's interlock is comprised of firms that share the same board of directors (Mizruchi, 1996). In order to construct an interlock, we followed these three steps. First, we arrange independent directors' data by company code in rows based on a yearly basis. Then, we adopt MS Excel to find the unique names of independent directors, manually scrutinise these names and related information of independent directors of each listed firm in each fiscal year. In this way, we determined whether any two firms have independent directors who serve on both boards in the same year. In this case, we define the pair of firms as interlocked. Second, using the method followed by Mazzola et al. (2016), we generate an annual matrix of independent director interlocks, for IDCI and IDFI separately. Third, we measure the IDCI and IDFI using a dummy variable, 1 for firms that have the IDCI or IDFI and 0 for others.

4.2.2 Dependent variable

Based on the research literature's split (Huang and Li, 2017), our study categorises green innovation into two distinct types: green process innovation and green product innovation. Following (He and Jiang, 2019), we employ ISO14001 certification for measuring GPCI. For GPDI, we adopt the approach proposed by Ji et al. (2023) and He and Jiang (2019), which considers the number of low-carbon patents granted plus green utility models.

4.2.3 Moderator variable

In the study, CEC serves as the moderating variable. CEC describes how firms behave in order to improve their ecological performance (Calza et al., 2016). The degree of connectivity of a company with environmental issues suggests the degree of CEC. This study adopts Naveed et al. (2023), build an index to represent a firm's environmental commitment. Thus, we measure the CEC by developing an index of fifteen items, giving a score from 0 to 15, as explained in Table 1.

4.2.4 Control Variables

Numerous variables that might affect company GI are controlled in this study. First, we control firm's age, which is calculated by taking the natural logarithm of the total number of years the firm has been in existence (Ji et al., 2023). We also consider the size of the firm, which is calculated by taking the natural logarithm of total assets (He and Jiang, 2019). We look at the firm's leverage, which is calculated by dividing its total debts by its total assets (Xia et al., 2024). We also account for the effect of board size by incorporating the total number of directors serving in a firm as a control variable (Qiu

and Yu, 2023). We also consider CEO duality (dual), giving a value of one when the CEO holds two distinct positions otherwise zero, within an enterprise. This variable captures the situation where CEO has significant control over the corporate agenda, including whether to develop GI. For this purpose, we also control the corporate growth. Return on equity (ROE) is calculated by providing net profit by the average balance of shareholder's equity. Additionally, we include a control for state-owned enterprises by utilising a binary variable that assumes the value of 1 when the firm is under government-controlled otherwise, 0. In summary, we offer an overview of each variable along with its description in Table 2.

Table 1 Corporate environmental commitment index

No.	*Item*	*Definition*	
1	Environmental protection concept	If a company adopts environmental philosophy, policies, organisational structure for environmental management, and applies concepts like circular economy and sustainability	Scoring criteria 0, 1
2	Environmental targets	If a company has accomplished or established ecological targets for the future	
3	CSR report	If a company has issued a CSR report which includes environmental information	
4	Environmental education	If a company has engaged in ecological education and conducted training programs	
5	Environmental involvement	If a company has engaged in specific eco-friendly or social welfare initiatives	
6	Environmental emergency response	If a company has established an ecological emergency protocol, including containment and treatment measures	
7	Green incentives	If a company has been awarded any environmental incentives within the year	
8	Three-simultaneous system	If a company implements a 'three-simultaneous system,' which entails designing, implementing, and utilising pollution prevention and control measures across all business operations concurrently	
9	Pollution surveillance unit	If a company has established a pivotal pollution control division	
10	Pollution emission criteria	If the company's pollution emissions comply with the prescribed standards	
11	Environmental accidents	If the company has remained accident-free in terms of environmental incidents throughout the year	
12	Environmental violations	No environmental violations were reported by the company during the year	
13	Environmental petition case	No environmental petition case was recorded by the company during the year	
14	Environmental report	If the company issued a separate environmental report	
15	ISO9001 certification	If a company has passed ISO 9001 certification	

Table 2 Information summary of variables used in this study

Variables	*Description*
IDCI	Organisations have interlock give 1, otherwise 0
IDFI	Organisations have interlock give 1, otherwise 0
CEC	Develop an index for CEC based on score from 0 to 15
GPCI	Organisations that have ISO 14001 certifications give 1, otherwise 0
GPDI	Number of green patents granted + utility models (log transformed)
FirmLev	Total debts to total assets
FirmSize	Total assets of firms (log transformed)
FirmAge	The time period since the firm was established (log transformed)
BoardSize	Number of board of directors
Dual	A dummy variable that equals one if CEO plays a dual role in firm, otherwise zero
Growth	Current income growth rate
ROE	Net profit divided by the average balance of shareholder's equity
SOE	If a firm is state-owned give 1, otherwise 0

4.3 Econometric model

To test the relationship between interlocking independent directors on firm green innovation, we established 2 econometric equations with reference to Nam and An (2018). In these equations, we show how different variables and their combinations affect the corporate GI. First, we tested the impact of IDCI or IDFI on corporate green processes and product innovation. Second, we added CEC as a moderator to our baseline model and investigated respectively. Additionally, we also put all the control variables, i.e., firm age, size, leverage, board size, CEO duality, growth, ROE and SOE, which have some effect on the corporate GI with all previous combinations of interlocks.

$$\text{GPCI or GPDI}_{it} = \alpha_1 + \beta_1 \text{IDCI}_{i,t-1} \text{ or } \text{IDFI}_{i,t-1} + \beta_2 \sum \text{Control Variables}_{i,t-1} + \text{Fe} + \varepsilon_{i,t} \quad (1)$$

$$\text{GPCI or GPDI}_{i,t} = \alpha_1 + \beta_1 \text{IDCI}_{i,t-1} \text{ or } \text{IDFI}_{i,t-1} \times \text{CEC}_{i,t-1} + \beta_2 \sum \text{Control Variable}_{t-1} + \text{Fe} + \varepsilon_{i,t} \quad (2)$$

In these equations, t stands for the observed time point, and i represents the firm. IDCI or IDFI denoted the independent director's corporate and financial interlock, respectively. GPCI denotes green process innovation while GPDI denotes green product innovation. CEC denotes corporate environmental commitment; Fe represents industry fixed effect and yearly fixed effect; ε is the random error term; denotes the sum. Independent and control variables lagged for a year in light of potential endogenous problems brought on by reverse causality. Our report, which addresses panel heteroskedasticity, is based on robust standard error clustered at the company level.

Table 3 Descriptive statistics and correlations

Variable		*Mean*	*Std. dev.*	*1*	*2*	*3*	*4*	*5*	*6*
1	GPCI	0.238	0.426	1					
2	GPDI	0.544	1.095	0.093***	1				
3	IDCI	0.735	0.441	0.037***	0.088***	1			
4	DFI	0.179	0.384	0.035***	0.177***	0.114*	1		
5	CEC	0.801	0.711	0.402***	0.249***	0.084***	0.115***	1	
6	FirmAge	2.578	0.869	–0.025***	0.089***	0.003***	0.033***	0.104***	1
7	FirSize	22.132	1.354	0.023***	0.399***	0.125***	0.155***	0.437***	0.263***
8	FirmLev	0.389	0.231	–0.045***	0.169***	–0.07***	0.042***	0.092***	0.401***
9	BoardSize	2.274	0.256	–0.011***	0.082***	0.054***	0.094***	0.124***	0.124***
10	Dual	0.297	0.457	0.009*	–0.024***	–0.011*	–0.050***	–0.104***	–0.093***
11	Growth	0.169	0.747	–0.010	0.005*	0.032***	–0.019***	–0.053***	0.075***
12	ROE	0.046	0.276	0.024***	0.025***	0.292***	0.014***	0.052***	–0.051***
13	SOE	0.239	0.426	–0.065***	0.078***	0.030***	0.068***	0.156***	0.189***

		7	*8*	*9*	*10*	*11*	*12*	*13*
7	FirmSize	1						
8	FirmLev	0.372***	1					
9	BoardSize	0.238***	0.173***	1				
10	Dual	–0.146***	–0.102***	–0.149***	1			
11	Growth	0.011	0.061***	–0.048***	0.067***	1		
12	ROE	0.052***	–0.179***	–0.049***	0.004	0.166***	1	
13	SOE	0.331***	0.253***	0.234***	–0.245***	–0.139***	–0.004	1

Notes: *** 1%, ** 5%, and * 10% significance. GPCI denotes green process innovation. GPDI represents green product innovation. IDCI denotes independent director corporate interlock. IDFI denotes independent director financial interlock. CEC represents corporate environmental commitment.

5 Results

Descriptive data and correlations between independent, moderating, dependent, and control variables are presented in Table 3. The data indicates that there is no significant problem with multicollinearity, because all correlation coefficients are less than 0.8 and the greatest variance inflation factor (VIF) value is 1.22 (Xia et al., 2024). Preliminary evidence in favour of H1, H2, H3 and H4 comes from the appearance of positive and very significant correlations observed between dependent variables (GPCI & GPDI) and the variables of interest, IDCI and IDFI.

In order to corroborate our conjectures, we present comprehensive regression outcomes for H1 and H2, as indicated in Table 4. Models (1) and (2) investigate the direct impact of IDCI and IDFI on GPCI. In particular, H1 is supported by the positive and very significant IDCI coefficients ($\beta = 0.009$ $p < 0.01$) that predict GPCI. However, as the IDFI coefficient ($\beta = 0.012$, $p < 0.05$) is also positive and very significant in Model (2) of Table 4 offers empirical support for H2.

Furthermore, the model (3) and (4) of Table 4 show the impact of IDCI and IDFI on corporate green product innovation, where the coefficients are ($\beta = 0.036$, $\beta = 0.106$, $p < 0.01$) positive and highly significant. Hence, H3 and H4 are also supported. All these interactions in Table 4 indicate the positive correlations between independent directors' corporate and financial interlock, and GPCI and GPDI. Therefore, these findings indicate that the connections and resources obtained through independent directors' external board positions can directly contribute to the firm's green innovation (Wu and Dong, 2021).

The moderating function of corporate environmental commitment in the link between IDCI, IDFI, and corporate green process and green product innovation is tested using Table 5. It is conceivable that CEC motivates independent directors to explore their interlocks strategically for green innovation and spot chances for it, maximizing CEC's potential.

To amplify the effectiveness of the coefficient in the regression equation, Table 5 computes the moderating role.

According to Table 5's regression results, model (1) (2) (3) and (4), CEC has a positive relationship with GPCI and GPDI where the coefficients are ($\beta = 0.897$, $\beta = 0.873$, $\beta = 0.073$, $\beta = 0.071$). These positive relationships support to our literature basis created in the literature review section. In models (1) and (2) of Table 5, Interactions (CEC x IDCI and CEC x IDFI) are significantly positively correlated with GPCI ($\beta = 0.780$, $\beta = 0.740$, $p < 0.01$). This indicates that CEC strengthens the positive connection between independent directors' corporate and financial interlocks and green process innovation. Hence, H5 and H6 are supported.

Furthermore, model (3) and (4) of Table 5 show the interactions between CEC x IDCI and CEC x IDFI with GPDI, which are positive and highly significant, their coefficients are ($\beta = 0.052$, $\beta = 0.053$, $p < 0.01$). This indicates that CEC reinforces the positive relationship between independent directors' corporate and financial interlocks and green product innovation. Therefore, the results provide support for H7, and H8. These findings demonstrate that CEC enhances the positive link between independent directors' corporate and financial interlock and corporate green innovation (Zhang et al., 2024).

Table 4 Effects of independent director interlocks (corporate and financial) on corporate green innovation

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
IDCI	0.009***			
	(1.52)			
IDFI		0.012**		
		(1.76)		
IDCI			0.036***	
			(2.9)	
IDFI				0.106***
				(7.28)
FirmAge	0.072***	0.074***	0.323***	0.316***
	(8.43)	(9.08)	(17.99)	(17.62)
FirmSize	0.018***	0.014***	0.320***	0.318***
	(4.18)	(4.21)	(36.52)	(36.31)
FirmLev	–0.022	–0.018	–0.113***	–0.119***
	(–1.03)	(–0.94)	(–2.64)	(–2.78)
BoardSize	0.015	0.013	–0.010	–0.017
	(1.32)	(1.25)	(–0.41)	(–0.73)
Dual	0.008	0.011	0.012	0.015
	(1.04)	(1.55)	(0.81)	(0.95)
Growth	–0.012	–0.012	–0.107***	–0.101***
	(–1.51)	(–1.63)	(–6.27)	(–5.97)
ROE	–0.001	0.002	0.046***	0.059***
	(–0.09)	(0.31)	(2.64)	(3.52)
SOE	0.024**	0.023**	0.003	0.004
	(2.28)	(2.28)	(0.15)	(0.16)
_cons	–0.398***	–0.372***	–7.350***	–7.254***
	(–4.65)	(–4.67)	(–41.89)	(–41.25)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	39,255	39,255	39,255	39,255
R2	0.096	0.194	0.133	0.137
F	22.14***	27.95***	432.53***	438.95***

Notes: This table shows regressions with heteroscedasticity robust standard errors. IDCI denotes independent director corporate interlock. IDFI denotes independent director financial interlock. CEC represents corporate environmental commitment. GPCI denotes green process innovation. GPDI denotes green product innovation. The coefficient and t-statistic are displayed for each independent variable in the top and bottom rows, respectively *** 1%, ** 5%, and * 10% significance.

Table 5 Moderating effect of corporate environmental commitment

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
CEC	0.897**	0.873**	0.073***	0.071***
	(2.52)	(2.46)	(6.22)	(6.05)
IDCI	0.005**			
	(0.01)			
CEC x IDCI	0.780***			
	(2.62)			
IDFI		1.887***		
		(3.83)		
CEC x IDFI		0.740**		
		(2.51)		
IDCI			0.024*	
			(1.77)	
CEC x IDCI			0.052***	
			(5.28)	
IDFI				0.089***
				(5.52)
CEC x IDFI				0.053***
				(5.44)
FirmAge	3.106***	3.002***	0.235***	0.231***
	(5.29)	(5.11)	(12.23)	(11.99)
FirmSize	4.712***	4.646***	0.310***	0.308***
	(15.77)	(15.55)	(31.63)	(31.42)
FirmLev	–4.336***	–4.211***	–0.036	–0.038
	(–3.03)	(–2.95)	(–0.77)	(–0.82)
BoardSize	–0.620	–0.826	–0.009	–0.016
	(–0.8)	(–1.06)	(0.736)	(–0.62)
Dual	0.063	0.0920	0.010	0.012
	(0.13)	(0.18)	(0.64)	(0.73)
Growth	–1.506***	–1.474***	–0.103***	–0.099***
	(–2.76)	(–2.71)	(–5.74)	(–5.55)
ROE	0.541	0.567	0.054***	0.063***
	(0.94)	(1.02)	(2.86)	(3.46)
SOE	0.244	0.259	0.002	0.003
	(0.35)	(0.37)	(0.09)	(0.12)
_cons	–104.145***	–102.239***	–6.966***	–6.884***
	(–17.22)	(–16.86)	(–35.16)	(–34.65)

Note: See notes to Table 4.

Table 5 Moderating effect of corporate environmental commitment (continued)

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs.	39,255	39,255	39,255	39,255
R2	0.167	0.160	0.146	0.149
F	60.44***	61.82***	280.29***	283.17***

Note: See notes to Table 4.

5.1 Robustness check

5.1.1 Alternative dependent variables

Switching the dependent variable, we take into account the number of patent applications as an additional proxy for GPCI, which was adopted by relevant research (Ji et al., 2023), in addition to employing ISO 14001 certification as a parameter for GPCI. Our initial hypothesis H1 and H2, appeared to be validated once again based on the alternative GPCI regression results [see Table 6 model (1) and (2)]. Additionally, as shown in Table 7 [see models (1) and (2)], by changing the proxy for GPCI, the moderating effects are also positive and significant, and support H5 and H6. Furthermore, we also change the proxy for green product innovation, take the number of green citations as an additional measurement for GPDI, the results show positive and significant relationships, and Support to H3, H4, H7, and H8 [see Table 6 model (3), (4) and Table 7 model (3), (4)], proxy adopted by recent research (Qiu and Yu,2023).

It is quite general that when companies cite green patents, it means companies are continuously doing green R&D and producing new green products (Amore and Bennedsen, 2016).

5.2 Endogenous issues

5.2.1 The instrumental variable method

It is possible that endogenous causation exists between independent directors' interlocks and green innovation. An organisation may, for instance, hire an independent director with interlocks due to the requirement for green innovation. To address these endogenous issues, the two-stage ivregress2 model approach is employed. According to Qiu and Yu (2023) research, the instrumental variable in our study is the median of independent directors' interlocks of companies in the same industry that year, excluding the company itself. This was selected because, while independent directors' interlocks should correlate strongly, companies lack direct control over their ability to innovate sustainably and fulfill correlation and externality requirements. Table 8 displays the results of the two-stage regression analysis conducted for the instrumental variables. Results for IDCI are shown in Models (1) and (3), while Models (2) and (4) illustrate the outcomes for IDFI. The LM statistics from the second-stage regression analysis are significant at a 1% level for all four models, with values of 434.317, 127.922, 434.69, and 127.823 respectively. Simply, rejecting the initial presumption of 'not identifiable'. The

significant Wald F-statistics, values are 440.899, 128.455,441.286, and 128.355 respectively, reject the presumption of a 'weak instrument variable'. The assumption of exogeneity for the primary explanatory variable is supported. Furthermore, in the second regression stage, IDI (both for IDCI and IDFI) coefficients remain significantly positive. remain significantly positive.

Table 6 Regression results of alternative proxy for corporate green process and product innovation

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
IDCI	0.032***			
	(4.73)			
IDFI		0.042***		
		(5.16)		
IDCI			0.014**	
			(0.71)	
IDFI				0.110***
				(5.24)
FirmAge	0.031***	0.029***	2.752***	2.740***
	(3.29)	(3.1)	(78.09)	(77.72)
FirmSize	0.028***	0.028***	0.746***	0.742***
	(5.94)	(5.9)	(46.27)	(46.17)
FirmLev	0.010	0.001	–0.425***	–0.426***
	(0.42)	(0.05)	(–5.71)	(–5.78)
BoardSize	–0.014	–0.015	0.042	0.030
	(–1.09)	(–1.19)	(1.18)	(0.85)
Dual	0.001	0.002	0.001	0.004
	(0.12)	(0.22)	(0.06)	(0.17)
Growth	–0.006	–0.002	–0.487***	–0.483***
	(–0.63)	(–0.23)	(–17.43)	(–17.4)
ROE	0.011	0.022**	–0.025	–0.019
	(1.19)	(2.49)	(–0.99)	(–0.76)
SOE	–0.004	–0.004	–0.049	–0.046
	(–0.34)	(–0.34)	(–1.47)	(–1.39)
_cons	–0.558***	–0.526***	–21.645***	–21.53***
	(–5.88)	(5.52)	(–67.51)	(–67.08)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	39,255	39,255	39,255	39,255
R^2	0.123	0.156	0.090	0.0914
F	14.79***	15.26***	144.55***	153.67***

Note: See notes to Table 4.

Table 7 Regression results of alternative proxy for corporate green process and product innovation

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
CEC	–0.019***	–0.02***	0.144***	0.143***
	(–3.11)	(–3.33)	(8.78)	(8.77)
IDCI	0.015**			
	(2.2)			
CEC x IDCI	0.047***			
	(9.39)			
IDFI		0.039***		
		(4.79)		
CEC x IDFI		0.052***		
		(10.69)		
IDCI			0.001*	
			(0.07)	
CEC x IDCI			0.071***	
			(5.61)	
IDFI				0.109***
				(5.21)
CEC x IDFI				0.168***
				(5.48)
FirmAge	–0.014	0.022**	2.632***	2.621***
	(–1.09)	(2.27)	(72.48)	(72.17)
FirmSize	0.018***	0.024***	0.707***	0.703***
	(3.03)	(4.85)	(42.72)	
FirmLev	0.043*	0.014	–0.363***	–0.356***
	(1.76)	(0.59)	(–4.83)	(–4.79)
BoardSize	–0.013	–0.011	0.047	0.035
	(–1.01)	(–0.89)	(1.35)	(0.99)
Dual	0	0.001	–0.002	0.001
	(–0.04)	(0.17)	(–0.09)	(0.04)
Growth	–0.001	–0.004	–0.469***	–0.467***
	(–0.09)	(–0.41)	(–16.82)	(–16.85)
ROE	0.019*	0.021**	–0.029	–0.027
	(1.93)	(2.24)	(–1.11)	(–1.08)
SOE	–0.005	–0.004	–0.0420	–0.039
	(–0.46)	(0.32)	(–1.27)	(–1.19)
_cons	–0.252**	–0.449***	–20.65***	–20.542***
	(–1.21)	(–4.49)	(–62.08)	(–61.73)

Notes: Moderating effect of corporate environmental commitment. See notes to Table 4.

Table 7 Regression results of alternative proxy for corporate green process and product innovation (continued)

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs.	39,255	39,255	39,255	39,255
R^2	0.117	0.154	0.094	0.095
F	44.07***	22.86***	178.52***	178.13***

Notes: Moderating effect of corporate environmental commitment. See notes to Table 4.

Table 8 Regression results of tools variables

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
	Second stage	*Second stage*	*Second stage*	*Second stage*
IDCI	0.123**			
	(2.53)			
IDFI		0.144*		
		(1.44)		
IDCI			0.739***	
			(5.95)	
IDFI				0.437*
				(1.79)
FirmAge	0.010**	0.013**	–0.002	–0.021
	(2.11)	(2.33)	(–0.15)	(–1.53)
FirmSize	0.017***	0.029***	0.305***	0.321***
	(5.35)	(5.95)	(38.02)	(26.91)
FirmLev	–0.057***	–0.096***	0.312***	0.15***
	(–3)	(–6.06)	(6.38)	(3.88)
BoardSize	0.022**	0.046***	–0.062**	–0.048
	(2.04)	(3.24)	(–2.28)	(–1.38)
Dual	0.004	0.004	0.066***	0.073***
	(0.75)	(0.58)	(4.38)	(4.93)
Growth	–0.049***	–0.041***	–0.166***	–0.079***
	(–4.67)	(–4.16)	(–6.21)	(–3.32)
ROE	–0.03	0.022**	–0.273***	0.034
	(–1.33)	(2.46)	(–4.81)	(1.51)

Note: See notes to Table 4.

Table 8 Regression results of tools variables (continued)

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
	Second stage	*Second stage*	*Second stage*	*Second stage*
SOE	–0.062***	–0.059***	–0.141***	–0.144***
	(–11.29)	(–10.01)	(–10.05)	(–10.06)
_cons	–0.269***	–0.476***	–6.694***	–6.694***
	(–5.24)	(–4)	(–51.14)	(–22.4)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs.	39,255	39,255	39,255	39,255
LM	434.317***	127.922***	434.69***	127.823***
F	28.93***	27.97***	590.31***	628.15***
Wald F	440.899***	128.455***	441.286***	128.355***
Endog test	0.075	0.081	0.504	0.512

Note: See notes to Table 4.

5.2.2 Propensity score matching

Propensity score matching (PSM) techniques have been used to account for unobserved variables that may affect IDIs and corporate green innovation performance (He et al., 2021). PSM was applied by matching companies based on their likelihood of having IDIs, as assessed using all control variables from earlier analysis. The treatment group included firms with interlocks, while the control group consisted of firms without interlocks.

Table 9 Regression results of independent director corporate and financial interlocks using PSM

Variables	*(1)*	*(2)*	*(3)*	*(4)*
	GPCI	*GPCI*	*GPDI*	*GPDI*
IDCI	0.024***			
	(3.79)			
IDFI		0.027***		
		(3.41)		
IDCI			0.143***	
			(9.04)	
IDFI				0.336***
				(15.57)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Obs.	39,255	39,255	39,255	39,255
R–Squared	0.171	0.136	0.167	0.139

Note: See notes to Table 4.

Applying the nearest neighbour matching approach (Yousaf et al., 2022; Huang et al., 2021), paired samples were reanalysed using regression techniques. The obtained coefficients continued to be statistically significant across all models (1), (2), (3), and (4), as reported in Table 9.

6 Discussion

This study offers significant insights into the potential advantages of independent directors' interlocking for businesses in the context of green innovation. This research broadens our insight into how independent director interlocks relate to corporate green innovation (measured by GPCI and GPDI) by examining two significant forms of interlocks: IDCI and IDFI. Additionally, we investigate the potential moderating role of CEC.

First, our research findings underscore the favourable influence exerted by the presence of IDCI, IDFI on both GPCI and GPDI. These interlocks fostered by independent directors serve to bridge information gaps, surmount knowledge, and remove financial barriers that firms may encounter when undertaking innovation in emerging domains such as green innovation. Organisations have the opportunity to utilise these connections to engage in the exchange of insights regarding green innovations, enabling them to effectively integrate these ecological innovations into new products, services, and processes to gain competitive advantage. This observation aligns with social network theory, which suggests that the corporate and financial interlocks, characterised by the interconnectedness of independent directors across different firms, serve as a platform for facilitating knowledge sharing, resource mobilisation and collaboration, consistent with previous research (Howard et al., 2017). Through leveraging their connections, independent directors possess the ability to discern emerging trends, technological advancements, and potential collaborations. This capability ultimately enhances the adoption and implementation of green practices (GI) within their respective organisations. This result is in part consistent with Ali et al. (2023) report.

Second, while IDCI and IDFI demonstrated a positive impact on GPCI and GPDI (Qiu and Yu, 2023), this relationship was further strengthened when firms had CEC in their internal systems. CEC can take on diverse forms, including the adoption of eco-friendly technologies, the reduction of greenhouse gas emissions, the conservation of natural resources, the utilisation of clean energy sources, the implementation of waste management and recycling practices, the support of biodiversity conservation efforts, and the promotion of sustainable practices within an organisation. This observation aligns with the principles of the resource-based view of organisations, which emphasise the significance of complementary organisational capabilities and concerns in effectively harnessing the advantages offered by independent directors. CEC signifies the company's acknowledgment of the significance of environmental responsibility and its readiness to surpass regulatory obligations in order to make meaningful contributions towards a sustainable and environmentally friendly future, as reported by Wang et al. (2018).

Overall, these findings highlight the important role that independent directors' interlocks play in fostering firm-level green innovation. Companies should consider the benefits of having both IDCI and IDFI, as these interconnections can stimulate and facilitate sustainable practices. Additionally, fostering a strong CEC can further enrich the positive impact of these interlocks on green innovation.

7 Conclusions

In the realm of encouraging high-quality economic development, promoting green innovation serves as an essential strategic effort for companies aiming for sustainable growth. Moreover, it serves as a motivational catalyst for constructing an ecological civilisation and promoting the vision of a beautiful and economically strong China. While existing scholarly literature acknowledges the pivotal role of social capital in fostering innovative capabilities (Subramaniam and Youndt, 2005). There is a scarcity of research examining the specific impact of IDCI and IDFI, which serve as a reflection of embedded board social capital, on GPCI and GPDI. To achieve this aim, we undertake a preliminary investigation to reveal the underlying mechanism by which the presence of IDI's contributes to the improvement of corporate GPCI and GPDI outcomes. This analysis is based on a sample of 4,902 A-listed firms in China over the research period spanning from 2010 to 2022. More specifically, our findings suggest that the existence of IDCI and IDFI significantly contributes to firm-level green innovation (GPCI and GPDI), highlighting the interconnectedness between interlock connections and corporate low-carbon innovation. Additionally, we identify CEC as a moderator that facilitates the impact of IDCI and IDFI on GPCI and GPDI. These findings make a significant contribution to our current comprehension of how firms' ecological innovation is positively influenced by interlocks, with regard to competitive advantages, which are based on knowledge, information, and finance.

7.1 Practical implications

The research findings of this research have notable practical implications. Firstly, for enterprises aiming to enhance their green innovation capabilities and accelerate their transition towards sustainability, especially heavily polluting and privately-owned firms facing challenges in resource acquisition (Qiu and Yu, 2023), it is advisable to attract independent directors who possess rich interlock relationships. This can be achieved by improving remuneration packages, establishing effective reward and punishment mechanisms, and implementing other relevant measures that incentivise their involvement. Secondly, Knowledge spill-overs are a distinguishing feature of green innovation, enabling enterprises to transition from reliance on specific elements to technology-driven approaches. The transformation of enterprises' production modes, acting as the fundamental pillar of the national economy, has the potential to lift the country from its persistent position at the lower end of the global value chain, which is characterised by the production of products with low quality and limited value addition. This transformation can propel the national economy towards high-quality development.

Green innovation addresses environmental pollution challenges associated with past extensive growth models, and ultimately, this sets the stage for the country to move away from unsustainable rapid growth and embark on a path of comprehensive and sustainable development. Therefore, it is recommended that relevant departments implement corresponding measures, including organising exchange meetings, enhancing companies' oversight, and establishing a robust ecological protection system. These actions are crucial to fostering and promoting green innovation among enterprises. Moreover, the findings reveal that a higher level of CEC strengthens the positive association between IDIs and environmental innovation. This indicates that companies should incorporate CEC into their internal systems to optimise the advantages of external resource

accumulation, facilitate the exchange of knowledge and technology, and proactively introduce necessary equipment and talented individuals for innovation through the interlinking of independent directors. By doing so, enterprises can leverage strategic opportunities in environmental innovation and enhance their overall green innovation capabilities.

7.2 Limitations and future lines

It is imperative to recognise several limits of this study despite the insightful information it provided. Firstly, it is worth noting that the marketplace encompasses various other forms of interfirm, including supply chain partnerships, shareholders interlocks, etc. However, this study solely focuses on IDCI and IDFI. Future research endeavours may find it valuable to explore the potential effects of the aforementioned interfirm on the facilitation of green innovation. Secondly, it is significant to remember that China, the largest developing market economy and the world's leading emitter of carbon dioxide, is the backdrop in which this study is being undertaken. While we posit that our findings have the potential for appropriate extrapolation to other economies that are similar to China's, it is advisable for future research to conduct further verification to ascertain the extent to which our outcomes can be generalised in different settings.

Finally, it is important to recognise the limitations of using patent data as an indicator of corporate green innovation. It is important to recognise that certain low-carbon innovation activities may not be accurately captured through patenting alone (Lu et al., 2022), which implies that relying solely on patent data might lead to an underestimation of an enterprise's green innovation efforts. Furthermore, we did not include a sample of financial sector companies that did not have any patent records. However, it is important to note that the exclusion of these firms does not indicate that these businesses fully withdraw from engaging in forefront green technology-related operations. Therefore, future research endeavours may consider exploring alternative methodologies, such as text-based machine learning, to achieve a more accurate and comprehensive identification of green innovation.

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Nomenclature

Abbreviations and acronyms

IDCI	independent director's corporate interlock
IDFI	independent director's financial interlock
CEC	corporate environmental commitment
GPCI	green process innovation
GPDI	green product Innovation.