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Environmental Legitimacy, Green Innovation, and Corporate Carbon Disclosure: Evidence from CDP China 100

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Abstract Firms worldwide are increasingly required to disclose (and make efforts to reduce) their carbon emissions due to the environmental damage associated with climate change. Because there has been no previous literature focusing on the determinants of corporate carbon disclosure integrating environmental legitimacy and green innovation, the present study attempted to develop an original framework to fill the research gap. This study explored the influence of environmental legitimacy (an external informal mechanism) on corporate carbon disclosure, and investigated the role of green innovation (an internal formal mechanism) as a mediator. With the samples of Carbon Disclosure Project (CDP) in China from 2008 to 2012, the results demonstrate that environmental legitimacy significantly negatively influences the likelihood of corporate carbon disclosure, and that green process innovation mediates the relationship, while green product innovation has no significant mediating effect. It means that environmental legitimacy not only directly affects the likelihood of corporate carbon disclosure, but also indirectly affects it via green process innovation. Hence, companies must increase both informal and formal mechanisms, i.e., external environmental legitimacy and internal green process innovation, to engage in carbon information disclosure and ensure sustainability.

Keywords Environmental legitimacy · Corporate carbon disclosure · Green product innovation · Green process innovation · Carbon Disclosure Project · China · Emerging economies

Introduction

Greenhouse gas (GHG) emission has been proven to be the primary cause of global warming (Depoers et al. 2014). Corporations can be both causes and solutions for carbon emissions, which should be responsible for reducing their negative impact on the environment (Klettner et al. 2014). However, Corporations vary substantially in the way they prioritize either reactive solutions or proactive approaches to climate change (Hart 1995), and with varying levels of success in achieving and promoting environmental sustainability. It is difficult for stakeholders to know the actual environmental performance of a company due to a variety of information asymmetries. The Volkswagen emissions scandal is a typical case of commercial fraud using information asymmetry. Companies are, ideally, expected to communicate publicly regarding their carbon emissions and other activities related to environmental sustainability (Hahn and Lülfs 2014).

As of now, research on corporate carbon disclosure has focused mostly on three major aspects (Stanny and Ely 2008; Luo and Tang 2014). First, studies on information provided by the Carbon Disclosure Project (CDP) or other channels of disclosure, which have found that current carbon information disclosure is highly unstandardized (Kolk et al. 2008; Harmes 2011). Second, studies on the

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factors that affect corporate carbon disclosure, such as stakeholder pressure, company size, nature of ownership, return on assets (ROA), leverage and efficiency, sectors, and other company features (Stanny and Ely 2008; Freedman and Jaggi 2005). Third, studies on the environmental and economic consequences of corporate carbon disclosure (Hrasky 2011; Luo and Tang 2014).

From an organizational perspective, companies have both formal and informal mechanisms to broadcast their level of environmental concern to the public and to disclose their carbon emissions information (Daft 2012; Russo and Tencati 2009). As shown in Table 1, formal mechanisms are, for example, formalized processes, standards, reports, and ISO 14001; informal mechanisms consist of stakeholder engagement, social norms, relationships, and environmental legitimacy (Russo and Tencati 2009; Tachizawa and Wong 2015). Extant research primarily emphasizes external informal drivers based on stakeholder theory, legitimacy theory, and institutional theory (Hahn et al. 2015), while due attention is not paid to the internal formal mechanisms.

The question remains: why even facing the same level of legitimacy pressure, do some firms simply comply with (or even violate) environmental regulations and legislation, while others take a voluntarily proactive approach to reducing and disclosing their carbon emissions? In short, why do companies respond so differently to climate change? How does legitimacy pressure, an external informal mechanism, drive firms to disclose their carbon information? These questions are, in fact, out of reach of the environmental legitimacy theory which only addresses external mechanisms (Hahn et al. 2015), so how do we best answer them? There should be internal formal mechanisms triggering companies to disclose their activities related to climate change and environmental protection, among which green innovation is an important mechanism (Rennings 2000). The present study, with careful consideration of the above, integrated environmental legitimacy, the most prevailing external informal mechanism (Deegan 2002), and green innovation, an important but under-researched internal formal mechanism (Chen et al. 2006), to explore the driving mechanisms of corporate carbon disclosure.

Legitimacy theory has become one of the most important theories related to corporate information disclosure (Mahadeo et al. 2011; Beelitz and Merkl-Davies 2012). Legitimacy is defined as a state where "the actions of an entity are appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman 1995). Environmental legitimacy, a branch of overall corporate legitimacy, is the assumption that a firm's environmental performance is desirable, proper or appropriate (Bansal and Clelland 2004). Scholars have asserted that environmental legitimacy is an important informal driving factor of corporate carbon disclosure (Hrasky 2011; Luo et al. 2012), however, research on specific driving mechanisms rarely involves the effects of environmental legitimacy on corporate carbon disclosure from the angle of media and public opinion. In this study, the driving mechanisms of the effects of environmental legitimacy are analyzed in-depth from the perspective of public pressure.

In order to gain, maintain, and repair environmental legitimacy, corporations will often increase their investment in green innovation. Green innovation involves the generation of new ideas, goods, services, processes, or management systems in effort to reduce environmental pollution and achieve sustainability (Rennings 2000). Green innovation can not only enhance the value of products and offset the costs of environmental investments (Chang 2011), but also enable corporations to meet environmental regulation requirements (Barney 1991) and improve economic performance as well as environmental performance (Chan 2005). Positive environmental performance and adequate financial resources can improve the quality and level of corporate environmental information disclosure (Al-Tuwaijri et al. 2004; Clarkson et al. 2011).

The purpose of this study is to explore approaches to enhancing the likelihood of corporate carbon disclosure. Specifically, we propose an integrated framework of the influences of both external/informal and internal/formal mechanisms that are of strategic importance to carbon disclosure: environmental legitimacy, and green innovation. We argue that the pressure of environmental legitimacy and high level of green innovation can both push and pull firms to disclose carbon information, and that green innovation mediates the relationship between environmental legitimacy and carbon disclosure.

This study offers important contributions to the literature. First, the new research framework on corporate carbon disclosure—the influence mechanism of environmental legitimacy on carbon disclosure is discussed, with green

Table 1 Types of corporate environmental mechanisms and activities

	Internal activities	External activities
Formal mechanism	Formalized processes	Environmental standards
	Environmental reports	Environmental audit
Informal mechanism	Organizational Culture	Stakeholder engagement
	Green visions and missions	Legitimacy-seeking

innovation as a mediating variable, making the first time that these external/informal and internal/formal mechanisms have been linked and studied in tandem. Second, this research concludes that both environmental legitimacy and green process innovation can influence the likelihood of corporate carbon disclosure. Third, it applies a novel method to assess a company's green innovation through "green patent" and ISO14001: to quantify green product innovation, we measure green patents with Chinese characters containing the keywords of "low-carbon", "environmental", "green", "emissions reduction", "energy-saving", "clean", "cycling", "saving", "sustainable", "ecology", "environmental protection", and "environmental pollution" (Cormier and Magnan 2015). Fourth, this study focuses on the Chinese context, which represents a notable diversion from most prior research that has been based on more developed Western countries, and adds value to the theories it discusses as there are considerable differences between developed countries and emerging economies (Li and Liu 2014). Also, considering China, like most emerging economies, has increasingly severe environmental pollution but lacks sound rules or regulations (Peng et al. 2015), this study is of important guiding significance for carbon disclosure in other emerging countries.

The remainder of this paper is structured as follows: the second section contains a literature review and hypotheses, the third section describes the research design, the fourth section presents our empirical results, and the final section provides a discussion and final conclusions.

Literature Review and Hypothesis

Effects of Environmental Legitimacy on Corporate Carbon Disclosure

Firms' environmental initiatives related to external stakeholder engagement (e.g., cooperation, networking, alliancing) represent an external informal attempt to improve eco-efficiency (Russo and Tencati 2009). Among which, legitimacy, a desirable, proper or appropriate perception that is consistent with social norms, values, and beliefs (Suchman 1995), is a prevailing mechanism to reduce carbon emission. Organizations are able to manage their stakeholders' perceptions of their legitimacy by attracting resources, getting internal and external support (Ashforth and Gibbs 1990), establishing and maintaining cooperative relationships with other entities (Alakent and Ozer 2014), and avoiding the reoccurrence of any past illegal activities (Suchman 1995).

As the environmental aspect of organizational legitimacy, environmental legitimacy refers to the generalized perception or assumption, which claims that a company's environmental performance is desirable, proper, or appropriate (Bansal and Clelland 2004). Environmental legitimacy is an important external, informal driver for companies to address climate change issues (Deegan 2002; Russo and Tencati 2009). Tilling and Tilt (2010) demonstrated that companies tend to show environmentally friendly "corporate citizenship" images in order to increase cash flow, government welfare, and community (or public) recognition. De Villiers and Van Staden (2011) showed that an environmental crisis increases corporate carbon disclosure online. This study explores the influence of environmental legitimacy on corporate carbon disclosure based on its three aspects: pressure from government regulations, customer norms and competitor cognition (Caruana and Chatzidakis 2014).

The Chinese government, with an increased awareness of climate change, has been enacting more stringent laws and regulations in recent years. In 2010, the *Environmental Information Disclosure of Listed Companies Guide (Exposure Draft)* was published, requiring corporations to disclose environmental information and publish environmental reports. At the beginning of 2015, China began the implementation of the new *Environmental Protection Law*, which has been called "the most rigorous law in [China's] history".[1] In such situations, if the level of environmental disclosure is generally low, enterprises will be confronted with more pressure from governmental regulations. Thus, companies tend to comply, and also to disclose more carbon emissions information to achieve the requirements of the laws and regulations (Eiadat et al. 2008). At the same time, as consumers increasingly demand for green products and services, legitimacy pressure from customer norms increases (Li and Ding 2013). In order to manage this pressure, enterprises must disclose their emissions information and actively advertise their environmental activities to ensure a favorable reputation and boost their market share (Delmas and Toffel 2008). Also, legitimacy pressure from competitors may compel companies to disclose more carbon information to appease stakeholders (Hofer et al. 2012). In short, a firm with a poor environmental performance will come under a significant amount of pressure from several sources, and be expected to disclose more information to demonstrate its resource conservation and environmental protection efforts. A company with an already excellent environmental profile will confront less legitimacy pressure, and may thus fail to prioritize carbon emissions disclosure. Accordingly, we propose the following hypothesis:

Hypothesis 1 Environmental legitimacy is negatively associated with corporate carbon disclosure.

[1] http://www.gov.cn/xinwen/2014-04/25/content_2666664.htm.

Impact of Environmental Legitimacy on Corporate Green Innovation

As an external informal mechanism, the effect of environmental legitimacy depends on firms' internal response, since environmental pressure does not directly act on the improvement of environmental performance. Many firms adopt green innovation as an internal formal response to environmental legitimacy (Tachizawa and Wong 2015). Green innovation is the improvement of products or processes which reduces environmental burden or achieve sustainability targets (Rennings 2000). There are various types of green innovation, among which green product innovation and green process innovation are the most widely accepted (Chen et al. 2006; Chang 2011; Amores-Salvadó et al. 2014; Lin et al. 2014).

Green product innovation refers to efforts to improve product quality and safety in order not only to address environmental issues, but also to achieve product differentiation by promoting sustainability, which in turn secures competitive advantage and improves profits (Chen 2008). Testa et al. (2011) found that corporations are generally willing to increase their investment in green innovation to improve energy efficiency and reduce environmental impact under regulatory pressure. Yalabik and Fairchild (2011) also demonstrated that corporations increase their investment in green products to maintain competitive advantage. As climate change progresses, environmental regulatory pressure will continue to increase and corporations will face more pressure to comply: this is and will increasingly be reflected by general social attitudes toward environmental legitimacy, which forces corporations to invest more resources in green product innovation and develop more green products to meet regulatory requirements as well as obtain competitive advantage.

Green process innovation involves the modifications made to manufacturing processes and systems in effort to ensure energy savings, pollution prevention, and waste recycling (Kammerer 2009). Berrone et al. (2013) pointed out that legitimacy pressure pushes corporations toward improving environmental performance, particularly with regard to pollutant emissions. In fact, environmental pollution is the evidence that resources are underutilized during processing. The implementation of green process innovation enables corporations to save raw materials, recycle wastes, reduce the use of resources, lower the costs and improve overall resource productivity (Porter and van der Linde 1995; Chen 2008). Environmental legitimacy pressure encourages corporations to think about how to achieve full use of resources, minimize energy usage, and recycle wastes—concerns that are reflected by the continuous improvement of production processes.

Current literature also shows that environmental legitimacy is an important driving factor of green innovation (Jennings and Zandbergen 1995; Delmas and Toffel 2004). Chang (2011) demonstrated that normative legitimacy (environmental ethics) affects green product innovation and green process innovation. Berrone et al. (2013) indicated that regulatory pressure from the government and non-governmental normative pressure are the driving forces for corporations to carry out green initiatives.

In sum, the lower the level of environmental legitimacy is, the higher the environmental legitimacy pressure a company will face, and the more necessary it is to increase green innovation in both products and processes. Accordingly, we deduced the following hypotheses:

Hypothesis 2a Environmental legitimacy is negatively associated with corporate green product innovation.

Hypothesis 2b Environmental legitimacy is negatively associated with corporate green process innovation.

Impact of Green Innovation on Corporate Carbon Disclosure

As an internal formal mechanism to show a firm's environmental concern, green innovation is an environmental management strategy (Hockerts and Morsing 2008) that focuses on the manner in which companies integrate environmental issues into their ethos through innovative products, processes, management, and other aspects in order to gain competitive advantage (Noci and Verganti 1999). Companies improve their economic and environmental performance through green innovation by increasing operational efficiency, lowering costs, and meeting the demands of environmentally sensitive customers (Chen et al. 2006; Chang 2011; Amores-Salvadó et al. 2014; Chan 2005; Eiadat et al. 2008). Hart (1995) proposed that green innovation capacity helps corporations not only to obtain competitive advantage, but to maintain it. Sharma and Vredenburg (1998) argued that green innovation helps companies reduce cost and improve overall performance. Rennings et al. (2006) demonstrated that green innovation has a positive effect on turnover rates.

Firms with more green innovation are more inclined to disclose their carbon information for their confidence, capability and motivation. First, green innovation helps firms to be more confident in disclosing carbon information. Through green innovation, firms can not only improve their financial performance, but also their environmental performance, both of which increase their confidence for carbon disclosure (Al-Tuwaijri et al. 2004; Clarkson et al. 2011; Meng et al. 2014). Second, green innovation helps firms to be more capable of disclosing carbon information. Through green innovation, especially the environmental

management systems, firms can build a routinized framework to report their carbon information and satisfy the needs of different stakeholders. Third, green innovation makes firms to be more urgent to disclose carbon information. Pursuing green innovation activity requires resource investment. Through carbon disclosure, investors, regulators and other stakeholders will appreciate and positively echo to the firms' effort with financing, subsidies, offsets and other resources (Apergis et al. 2013). Thus, the hypotheses are proposed as follows:

Hypothesis 3a Corporate green product innovation is positively associated with carbon disclosure.

Hypothesis 3b Corporate green process innovation is positively associated with carbon disclosure.

Figure 1 below depicts the research model and the hypotheses, showing the influence of the variables on corporate carbon disclosure.

Research Design

Samples

The CDP, first launched by British institutional investors in 2000, is an investigation of corporate responses to climate change, GHG emissions accounting, emissions management, and other relevant aspects. China launched the CDP survey with 100 Chinese listed companies in 2008. This study selected an initial 500 observations from the CDP China 100 between 2008 and 2012 as its sample as these data are highly authoritative, normative, continuative, and easy to access.

Panel A of Table 2 lists details regarding the sample selection procedure. We eliminated three special treatment (ST) observations due to their continuous loss-making over 2 years, then eliminated two observations that lacked annual reports, and eight observations that were listed in the Chinese stock market for <1 year (or their listing was terminated due to excessive earnings management following IPOs). We also eliminated 36 observations with extreme value using the criterion of 3 standard deviations to be conservative (including 4, 11, 8, and 13 extreme value of profitability, growth rate, leverage, and board independence, respectively), and another 31 observations for companies that issued B-shares and/or H-shares, whose financial characteristics and regulatory environments are different. As a result, 80 observations were excluded in total, leaving a sample of 420 observations corresponding to 178 different companies. Panel B of Table 2 shows the sample distribution by year and industry, suggesting no severe year and industry clustering problem.

This study collected data primarily from the RESSET database, annual reports of all listed companies and the Baiteng patent network (http://so.5ipatent.com/). In order to identify the companies that do disclose their carbon emissions information, the CDP reports were collected and focal companies' responses were analyzed (refuse, no response, partial information and complete information). The 420 sampled observations were then divided into two groups: response and no-response. We then conducted a content analysis of public media reports. In total, 32,060 reports were collected and analyzed. We set three possible levels for media coverage: positive, negative, and neutral. Then, Janis–Fadner coefficient was introduced for the calculation of environmental legitimacy. Data for other variables (green product innovation, green process innovation, firm size, ownership, industry type, profitability, growth rate, leverage, leadership structure, and board independence) were also gathered and applied to subsequent analysis.

Operational Definition of Variables

Dependent Variable: Corporate Carbon Disclosure

This study measures corporate carbon disclosure according to whether or not a company responded to the CDP survey

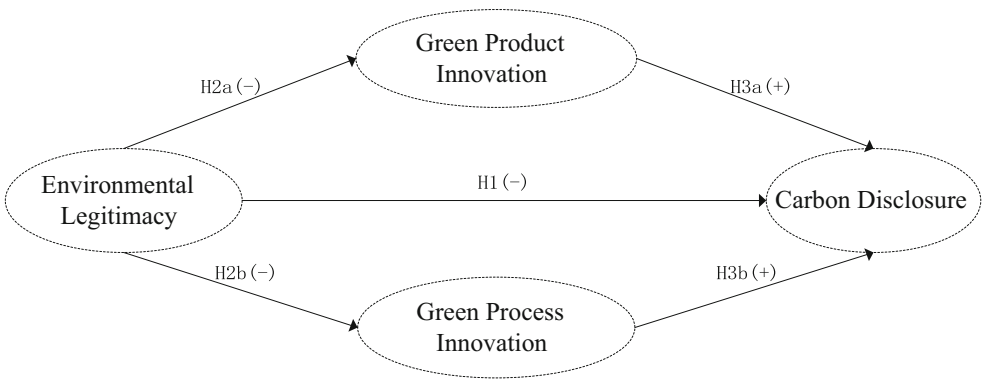

Fig. 1 The conceptual model

Table 2 Sample selection procedure and sample distribution

Panel A: sample selection procedure	
Initial sample from 2008 to 2012	500
Eliminate firm-year observations with special treatment (ST)	(3)
Eliminate firm-year observations whose annual report can't be found	(2)
Eliminate firm-year observations whose listed age is below or equal to 1 year	(3)
Eliminate firm-year observations whose listings are terminated	(5)
Eliminate firm-year observations with extreme value using the criterion of 3 standard deviations to be conservative	(36)
Eliminate firm-year observations who issue shares to foreign investors (B-shares or H-shares)	(31)
Firm-year observations	420
Unique firms	178

Panel B: sample distribution by year and industry

	Year					Subtotal	%
	2008	2009	2010	2011	2012		
Food and beverage	2	6	4	5	4	21	5.00
Leisure and hospitality	1	2	1	2	2	8	1.90
Trade and retail	1	3	3	3	4	14	3.33
Textile, apparel and luxury	3	1	1	1	4	10	2.38
Telecommunication and IT	1	3	5	2	4	15	3.57
Finance	10	13	15	18	25	81	19.29
Construction and material	6	5	5	6	7	29	6.90
Real estate	8	7	6	4	6	31	7.38
Auto manufacture and auto components	4	3	4	3	4	18	4.29
Chemical (industry and fine) and pharmacy	2	1	2	5	3	13	3.10
Transport and transport infrastructure	15	10	4	6	4	39	9.29
Machinery and electric appliance	7	6	7	6	6	32	7.62
Metals and mining	12	13	12	9	4	50	11.90
Oil and natural gas	3	4	3	3	4	17	4.05
Power	6	8	4	3	5	26	6.19
Others	3	0	6	5	2	16	3.81
Total by year	84	85	82	81	88	420	100

Other industries include paper and forestry products, public utilities, and durable consumer goods

(Lee et al. 2013). It is assigned to 1 if a company discloses carbon information, and 0 otherwise (Ben-Amar et al. 2015).

Explanatory Variables

Environmental Legitimacy Public media data are the most salient and prominent source for evaluating corporate environmental legitimacy (Cormier and Magnan 2015; De Villiers and Van Staden 2010). Pellegrino and Lodhia (2012) measured environmental legitimacy strategy using a variety of media types. Kuo and Yi-Ju Chen (2013) analyzed media coverage about corporate environmental issues by searching and classifying the related articles reported (positive, negative and neutral). Accordingly, the extent of media coverage is applied to measure the level of the environmental legitimacy in this study.

The China Core Newspapers Full-text Database (CCND), developed by the China National Knowledge Infrastructure (CNKI), is a relatively authoritative database in China that covers more than 500 national and local newspapers. In this study, 32,060 articles related to the sample companies were selected and encoded (positive, neutral, and negative) according to their content. In order to ensure intercoder reliability, the evaluation and judgment of articles was performed firstly by one of the authors, then by another evaluator; a third party resolved any differences in the evaluation.

Imbalance in the extent of media coverage was examined by calculation with the Janis–Fadner coefficient (Aerts and Cormier 2009; De Villiers and Van Staden 2010). The

value of J–F coefficient ranges from −1 to 1; if the value is closer to 1, the articles are more favorable, and if the value is closer to −1, the articles are less favorable. See the following equation:

$$\text{J–F coefficient} = \begin{cases} \dfrac{e^2 - ec}{t^2}, & \text{if } e > c \\ \dfrac{ec - c^2}{t^2}, & \text{if } e < c \\ 0, & \text{if } e = c \end{cases}$$

where e represents the number of positive reports, c represents the number of negative reports, and $t = e + c$.

Green Innovation Green product innovation can be measured by the number of a company's green patents (Brunnermeier and Cohen 2003). Combined with knowledge of China's economic and social conditions, we considered all patents containing the keywords of "low-carbon", "environment", "green", "emissions reduction", "energy-saving", "clean", "cycle", "savings", "sustainable", "ecology", "environmental protection" and "environmental pollution" to be green patents (Bansal and Clelland 2004). While about 59 % observations (247 out of 420) had no green patent in this study, so it was divided into two categories according to whether the firm had a green patent (1 for firms with one or more green patents, 0 for no green patent). Green process innovation was measured according to whether the corporation passed ISO 14001 certification (Lin et al. 2014).

Control Variables

Firm Size The larger the firm is, the greater the attention it will receive, and the more the media will provide it coverage (Stanny and Ely 2008). Size may affect the legitimacy pressure a firm faces, to this effect. The logarithm of total assets was employed to measure firm size.

Ownership State-owned enterprises (SOEs) are highly influenced by national policies, especially as far as environmental protection. Compared to other firms, SOEs face greater legitimacy pressure. A dummy variable was thus introduced here, 1 for SOEs, 0 for others.

Industry Type The CDP surveyed companies in a verity of industries, including aviation, metals and mining, iron and steel, building products, banking, insurance, and others. Companies in polluting industries face greater legitimacy pressure than those in cleaner industries. According to the "Company Environmental Information Disclosure Guide", a zero–one dummy variable was used: 1 for heavily polluting industries, 0 otherwise.

Profitability The higher a company's profitability is, the more inclined the company is to disclose their emissions information in order to reduce any negative public evaluation of their legitimacy (Belkaoui 1976). It is measured according to the net profit/total assets (NPTA) ratio.

Growth Companies with high growth rate are more capable of realizing corporate social responsibility, which can reduce information asymmetry between the company and external investors (Ben-Amar et al. 2015). It is measured by the ratio of (current POR − previous POR)/previous POR ("POR" refers to prime operating revenue).

Leverage Companies with high financial leverage are more inclined to disclose carbon emissions information, particularly details of any increase in corporate debt caused by carbon emissions reduction (Ferguson et al. 2002). The ratio EBIT/(EBIT − Interest expense) was used for measurement (where "EBIT" refers to earnings before interest).

Leadership Structure The chief executive officer (CEO) and chairperson of the board (COB) represent the interest of shareholders and the focal company, respectively. Separation of the CEO and COB influences a company's quality of information disclosure (Cerbioni and Parbonetti 2007). A dummy variable was introduced: 1 refers to a company whose CEO is not the COB, 0 otherwise.

Board Independence Board independence, which refers to the percentage of independent directors on the board, affects corporate social disclosure (Rashid and Lodh 2008; Ben-Amar et al. 2015). The independent directors/board size ratio was used for measurement (Rashid and Lodh 2008).

Model

To test the hypotheses above, the following econometric models were constructed:

$$CCD_i = \alpha_0 + \alpha_1 \mathrm{EL}_i + \alpha_2 \mathrm{Size}_i + \alpha_3 \mathrm{Own}_i + \alpha_4 \mathrm{Ind}_i + \alpha_5 \mathrm{Pro}_i + \alpha_6 \mathrm{Gro}_i + \alpha_7 \mathrm{Lev}_i + \alpha_8 \mathrm{LS}_i + \alpha_9 \mathrm{Indep}_i + \varepsilon_{1i} \quad (1)$$

$$\mathrm{GI}_i = \beta_0 + \beta_1 \mathrm{EL}_i + \beta_2 \mathrm{Size}_i + \beta_3 \mathrm{Own}_i + \beta_4 \mathrm{Ind}_i + \beta_5 \mathrm{Pro}_i + \beta_6 \mathrm{Gro}_i + \beta_7 \mathrm{Lev}_i + \beta_8 \mathrm{LS}_i + \beta_9 \mathrm{Indep}_i + \varepsilon_{2i} \quad (2)$$

$$\mathrm{CCD}_i = \gamma_0 + \gamma_1 \mathrm{EL}_i + \gamma_2 \mathrm{GPDI}_i + \gamma_3 \mathrm{GPDI}_i + \gamma_4 \mathrm{Size}_i + \gamma_5 \mathrm{Own}_i + \gamma_6 \mathrm{Ind}_i + \gamma_7 \mathrm{Pro}_i + \gamma_8 \mathrm{Gro}_i + \gamma_9 \mathrm{Lev}_i + \gamma_{10} \mathrm{LS}_i + \gamma_{11} \mathrm{Indep}_i + \varepsilon_{3i} \quad (3)$$

where CCD_i is 1 for response, 0 for no response; EL_i is the value of J–F coefficient; $GPDI_i$ is whether firm i had a green patent, 1 for firms with one or more green patents, 0 for no green patent; $GPCI_i$ is whether firm i obtained an ISO 14001 certification, 1 for the certified, 0 for others; GI_i is the green product innovation and green process innovation; $Size_i$ is the log-transformed of firm i's year-end total assets; Own_i is 1 for SOEs, 0 for others; Ind_i is 1 for heavily polluting industries, 0 otherwise; Pro_i is the net profit/total assets (NPTA); Gro_i is (current POR − previous POR)/previous POR; Lev_i is EBIT/(EBIT − interest expense); LS_i is 1 if the CEO is not the COB, 0 otherwise; $Indep_i$ is the percentage of independent directors in the board of firm i; α_0 to α_9 is the coefficients; β_0 to β_{11} is the coefficients; γ_0 to γ_9 is the coefficients; ε_{1i} to ε_{3i} is the error term.

Results

Descriptive Statistics and Correlation Analysis

Table 3 presents the statistics of firms' responses to the CDP. It shows that the number of companies providing information increased from 21 to 42 during the time period between 2008 and 2011, but 5-year cumulatively, only 146 observations provided information to CDP, accounting for 34.76 %.

Table 4 depicts the sample variation by years of data, showing that 82 firms with only 1 year data, 34 with 2-year data, 23 with 3-year data, 22 with 4-year data, and 17 with 5-year data.

Table 5 provides the statistics of environmental legitimacy. The positive, neutral, and negative judgments of sampled companies from 2008 to 2012 are 18,548, 11,375, and 2137, respectively.

Table 6 describes the changes of the key dichotomous variables by year and industry. It shows that observations from different industries behave quite differently. Panel A shows that, though both from "clean" industries, observations in Leisure and Hospitality don't disclose any carbon information, while about 53 % observations in Finance tend to engage in carbon disclosure, which may be because the CDP reports are mainly used by investors, and financial firms are more sensitive to them. Panel B and Panel C both show that observations in "dirty" industries (e.g., Metals and Mining) are more likely to engage in green innovation.

Corporate carbon disclosure, green product innovation, and green process innovation are dichotomous variables. As the key variables of this study, Cross-tabulation analysis was applied to test the correlations between these variables. As shown in Table 7, both green product and process innovation are related with corporate carbon disclosure.

Table 8 presents the descriptive statistics and correlations between the variables. It shows all the correlation coefficients of the matrix are lower than 0.601, reflecting an acceptable level of multicollinearity (Anderson et al. 2013).

The Common Method Bias

Because the media coverage, the number of green patents, and ISO certification information were all collected manually by the authors, the Harman's single factor test was applied to measure the common method bias. Six factors with eigenvalues greater than 1 were extracted with non-rotating analysis and the cumulative total explanatory variables are 66.931 %. The first factor has an eigenvalue of 2.344 and the cumulative total explanatory variables are 19.534 %, indicating that the common method bias in this study was not severe.

Table 3 Questionnaire responses from CDP China 100

	Year					Total
	2008	2009	2010	2011	2012	
Response	21	24	36	42	23	146
No-response	63	61	46	39	65	274
Total	84	85	82	81	88	420

Table 4 Variation of Samples by years of data

Counts	Times					Total
	1	2	3	4	5	
Number	82	34	23	22	17	178
Percentage	46	19	13	12	10	100

Table 5 The environmental legitimacy scores of CDP China 100

	Judgments			
	Positive	Neutral	Negative	Total
2008	4339	1309	523	6171
2009	4669	1888	334	6891
2010	3779	2503	451	6733
2011	3001	2691	419	6111
2012	2760	2984	410	6154
Total	18,548	11,375	2137	32,060
Percentage	0.5785	0.3548	0.067	1

Table 6 Variation of the key dichotomous variables by year and industry

Panel A: variation of corporate carbon disclosure by year and industry

	Corporate carbon disclosure					Subtotal	%
Year:	2008	2009	2010	2011	2012		
Industry							
Food and beverage	0	0	2	4	1	7	5
Leisure and hospitality	0	0	0	0	0	0	0
Trade and retail	0	0	1	1	0	2	1
Textile, apparel and luxury	1	0	0	0	0	1	1
Telecommunication and IT	1	3	3	2	2	11	8
Finance	3	7	12	13	8	43	29
Construction and material	2	2	2	4	0	10	7
Real estate	3	7	2	2	1	10	7
Auto manufacture and auto components	1	1	1	1	1	5	3
Chemical (industry and fine) and pharmacy	1	1	0	3	0	5	3
Transport and transport infrastructure	3	2	3	4	1	13	9
Machinery and electric appliance	0	2	0	3	2	7	5
Metals and mining	1	2	2	0	1	6	4
Oil and natural gas	2	1	2	2	3	10	7
Power	2	1	2	2	3	10	7
Others	1	0	4	1	0	6	4
Total by year	21	24	36	42	23	146	100

Panel B: Variation of corporate green product innovation by year and industry

	Green product innovation					Subtotal	%
Year:	2008	2009	2010	2011	2012		
Industry							
Food and beverage	2	2	2	1	1	8	5
Leisure and hospitality	0	0	0	0	0	0	0
Trade and retail	0	1	2	2	1	6	3
Textile, apparel and luxury	2	0	0	0	0	2	1
Telecommunication and IT	1	2	2	2	2	9	5
Finance	2	3	1	3	1	10	6
Construction and material	0	4	2	6	6	18	10
Real estate	0	0	0	0	1	1	1
Auto manufacture and auto components	3	2	3	3	4	15	9
Chemical (industry and fine) and pharmacy	1	1	1	3	2	8	5
Transport and transport infrastructure	2	1	1	1	1	6	3
Machinery and Electric Appliance	2	4	4	5	5	20	12
Metals and mining	7	8	10	4	4	33	19
Oil and natural gas	3	4	3	3	3	16	9
Power	3	3	2	3	5	16	9
Others	2	0	2	1	0	5	3
Total by year	30	35	35	37	36	173	100

Panel C: variation of corporate green process innovation by year and industry

	Green process innovation					Subtotal	%
Year:	2008	2009	2010	2011	2012		
Industry							
Food and beverage	1	6	4	5	4	20	10
Leisure and hospitality	1	0	0	0	0	1	0

Table 6 continued

Panel C: variation of corporate green process innovation by year and industry

Year:	Green process innovation					Subtotal	%
	2008	2009	2010	2011	2012		
Trade and retail	1	1	1	2	2	7	3
Textile, apparel and luxury	3	1	0	0	0	4	2
Telecommunication and IT	1	1	2	2	1	7	3
Finance	1	3	4	4	5	17	8
Construction and material	4	5	4	6	5	24	12
Real estate	1	1	2	2	1	7	3
Auto manufacture and auto components	4	3	3	3	4	17	8
Chemical (industry and fine) and pharmacy	2	1	2	4	3	12	6
Transport and transport infrastructure	5	1	1	1	1	9	4
Machinery and electric appliance	2	2	3	3	4	14	7
Metals and mining	7	7	6	6	4	30	15
Oil and natural gas	3	4	3	3	3	16	8
Power	5	3	3	3	5	19	9
Others	0	0	1	1	0	2	1
Total by year	41	39	39	45	42	206	100

Table 7 Cross-tabulation of key dichotomous variables

			CCD		Total	Contingency coefficient	χ^2 test
			CCD = 0	CCD = 1			
GPDI	GPDI = 0	Count	177	70	247	0.159***	10.905***
	GPDI = 1	Count	97	76	173		
GPCI	GPCI = 0	Count	156	58	214	0.162***	11.286***
	GPCI = 1	Count	118	88	206		

*** $p < 1$ %

Hypothesis Testing

As longitudinal (unbalanced panel or repeated measurement) data with binary outcome variables, generalized estimating equations (GEE) approach was applied to test the hypotheses above, which derive maximum likelihood estimates and accommodate non-independent observations (Liang and Zeger 1986).

Main Effect

This part tests the main effect between environmental legitimacy and corporate carbon disclosure. As shown in Table 9, environmental legitimacy is significantly negatively correlated with corporate carbon disclosure ($\beta = -0.205$, $p < 0.05$), which suggests that the lower a company's environmental legitimacy is, the higher the probability of carbon disclosure; so H1 is supported.

Mediating Effect

This section tests the mediating effect of green innovation between environmental legitimacy and corporate carbon disclosure. As shown in Table 9, Model 2 indicates a significant negative relationship between environmental legitimacy and corporate carbon disclosure. Model 5, the GEE model of independent variables on green product innovation, shows that environmental legitimacy is significantly positively correlated with green product innovation ($\beta = 0.037$, $p < 0.1$), so H2a is not supported. Model 6, the GEE model of environmental legitimacy on green process innovation, reveals that environmental legitimacy is significantly negatively correlated with green process innovation ($\beta = -0.173$, $p < 0.05$), so H2b is supported. Model3 tests the effects of green product innovation and green process innovation on corporate carbon disclosure, and the results indicate that green

Table 8 Descriptive statistics and correlations

	1	2	3	4	5	6	7	8	9	10	11	12
1. CCD	1.000											
2. EL	−0. 601**	1.000										
3. GPDI	−0.011**	0.082**	1.000									
4. GPCI	−0.003***	−0.022**	−0.071	1.000								
5. Size	0.301***	0.069	0.001	−0.235***	1.000							
6. Own	0.002	−0.049	0.046	−0.094*	0.140***	1.000						
7. Ind	−0.098**	−0.012	0.013	0.330***	−0.146***	0.107**	1.000					
8. Pro	−0.096**	0.090*	0.033	0.103**	−0.386***	−0.156***	0.040	1.000				
9. Gro	−0.005	0.054	−0.004	−0.029	−0.003	−0.028	−0.014	0.045	1.000			
10. Lev	0.202***	−0.010	−0.002	−0.221***	0.527***	−0.016	−0.255***	−0.310***	0.051	1.000		
11. LS	−0.009	−0.013	0.003	0.072	0.165***	0.076	0.035	−0.131***	0.019	0.120**	1.000	
12. Indep	−0.032	0.082*	0.038	0.050	−0.033	0.034	0.026	−0.005	0.089*	−0.127***	−0.112**	1.000
Min	0.000	−0.612	0.000	0.000	9.361	0.000	0.000	−0.213	−0.877	−16.062	0.000	0.714
Max	1.000	1.000	1.000	1.000	13.244	1.000	1.000	0.581	3.688	28.810	1.000	0.800
Mean	0.348	0.688	0.412	0.490	11.035	0.830	0.230	0.057	0.240	5.169	0.919	0.381
SD	0.477	0.360	0.493	0.501	0.823	0.375	0.419	0.073	0.413	2.792	0.273	0.079

* $p < 10$ %. Two-tailed; ** $p < 5$ %; *** $p < 1$ %

Table 9 Generalized estimating equation results

Dependent variables	Generalized estimating equation					
	Corporate carbon disclosure				Green product innovation	Green process innovation
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1. Control variables						
Size	0.837***	−0.886***	0.888***	0.937***	0.402**	0.411***
Ownership	0.248	−0.279	−0.157	0.192	0.319*	−0.713**
Industry	0.351	−0.358	−0.546*	0.551*	0.053	0.704***
Profitability	0.011	−0.040	−0.011	0.038	−0.080	−0.033
Growth	0.007	−0.015	−0.014	0.023	0.027	0.077
Leverage	−0.202	−0.227	0.198	−0.223	−0.070	0.042
Leadership structure	0.512	−0.515	−0.615*	0.619*	0.066	0.952**
Independence	−0.074	0.061	0.086	−0.074	−0.071	−0.137
2. Independent variable						
Environmental legitimacy		−0.205**		−0.194**	0.037*	−0.173**
3. Mediating variables						
Green product innovation			0.013			
Green process innovation			0.500**	0.479**		

* $p < 10$ %. Two-tailed; ** $p < 5$ %; *** $p < 1$ %

process innovation is significantly positively correlated with corporate carbon disclosure ($\beta = 0.500$, $p < 0.05$), while the effect of green product innovation is not evident ($\beta = 0.013$, $p > 0.1$); so H3b is supported, and H3a is not. Model 4 was generated based on Model 2 by introducing the mediating variable. The results show that environmental legitimacy remains significantly negatively associated with corporate carbon disclosure ($\beta = -0.194$, $p < 0.05$), while green process innovation is significantly positively correlated with the corporate carbon disclosure ($\beta = 0.479$, $p < 0.05$).

Sobel Tests

Based on the coefficients of equations and their standard errors (S.E.), Sobel tests calculate the magnitude of the unstandardized indirect effect and its significance. The sample size of this study was larger than 400, so Sobel tests were further applied to test the indirect effect of environmental legitimacy on corporate carbon disclosure (Preacher and Hayes 2008). Supporting Model 4, the Sobel test results show that this effect is indeed significant ($z = 6.107$, $p < 0.01$). Therefore, it can be deduced that environmental legitimacy is significantly negatively correlated with green process innovation and green process innovation is significantly positively correlated with corporate carbon disclosure. These results altogether demonstrate that environmental legitimacy has both a direct and indirect effect on the likelihood of corporate carbon disclosure, and that green process innovation mediates the relationship of environmental legitimacy to corporate carbon disclosure.

Discussion and Conclusion

General Discussion

This study analyzed the external/informal and internal/formal mechanisms of environmental legitimacy and green innovation on corporate carbon disclosure. Using a sample of 420 observations obtained from CDP China 100 during the time period between 2008 and 2012, it was found that environmental legitimacy is negatively correlated with corporate carbon disclosure, and that green process innovation plays a mediating role in the relationship between environmental legitimacy and carbon disclosure.

First, environmental legitimacy can negatively influence the likelihood of corporate carbon disclosure. It means that under the external informal environmental legitimacy pressure due to an initially low level of environmental sustainability, companies are more likely to disclose carbon information, since it helps companies build favorable reputations, gain the trust of investors and consumers, and enjoy preferential government policies, and finally reduce environmental legitimacy pressure (Cho et al. 2014).

Second, the results demonstrate that external informal environmental legitimacy has a mixed impact on the

internal/formal green innovation of a company, i.e., a negative effect on green process innovation, but a positive impact on green product innovation. The former result is in accordance with Sezen and Çankaya (2013), while the latter is consistent with Amores-Salvadó et al. (2014). Sezen and Çankaya (2013) point out that under the pressure of being 'greener', companies increasingly prioritize their green process innovation. However, Amores-Salvadó et al. (2014) argue that, in order to make external environmental commitment, enterprises tend to invest greater efforts to increase green product innovation. The possible reason may be that increased environmental legitimacy improves external support for a company's environmental commitment (Amores-Salvadó et al. 2014), which benefits the company's ability to gain external resources, increase liquidity, and enhance future capability for green product innovation.

Third, green process innovation is positively associated with corporate carbon disclosure, while the effect of green product innovation is not evident. These results are consistent with Sezen and Çankaya (2013) and Amores-Salvadó et al. (2014), but inconsistent with Cheng and Shiu (2012). Cheng and Shiu (2012) asserted that both green product innovation and process innovation are conducive to improving corporate environmental performance. The results of present study suggest that green process innovation affects environmental performance more significantly by enhancing firms' confidence for disclosing carbon information. What green product innovation can do for corporations, then, is to bring in more competitive advantage in the financial performance (Rennings 1998); high financial performance, though favorable, obviously, does not generate proactive environmental initiatives (González-Benito and González-Benito 2005).

Finally, the results of this study also suggest that green process innovation plays a mediating role between environmental legitimacy and corporate carbon disclosure. Under the external/informal environmental legitimacy pressure, companies tend to conduct more comprehensive internal/formal eco-friendly management. Systematic green process innovation is conductive to improving the overall level of a company's environmental performance, increasing the likelihood to disclose carbon emissions information (Chang 2011). The mediating result also shows that, to influence corporate carbon disclosure, it is not enough for external informal mechanisms such as environmental legitimacy, but internal formal mechanisms (e.g., green innovation, environmental committee) are also needed to improve the likelihood of carbon disclosure. Or to say, external informal mechanism should be collaborated with internal formal mechanism to efficiently transform the external pressure into firms' environmentally responsible actions.

Practical Implications

The findings above have several implications. Firstly, the results indicate that corporate disclosure is affected by external/informal environmental legitimacy. Companies with a higher level of environmental legitimacy are more capable of obtaining government incentives, market share, and competitive advantage. Consequently, we can strengthen the environmental legitimacy to manage corporate carbon disclosure activities. For example, government can formulate and implement more stringent environmental laws to significantly affect the environmental profile of corporations. Customers and NGOs can also strengthen the environmental supervision.

Secondly, the results demonstrate that the level of green product innovation of sampled companies as-is is barely satisfactory. There are 247 observations with no green patents whatsoever and 15 observations with more than 100 green patents, demonstrating a quite large variation, and further, inadequate management of green product innovation overall. Because patent protection in China is still a developing practice and remains fairly weak, patented inventions are easily stolen and imitated. We could be devoted to creating a sounder innovation environment, especially the environment of patent protection.

Thirdly, the results of this study also define the mediating role of green process innovation—it is extremely important for enterprises to focus on promoting internal/formal green process innovation to manage external/informal environmental legitimacy pressure. Through green process innovation, companies can cultivate their ability of using clean energy, recycling, and disposing waste to enhance economic performance and environmental performance, and ultimately increase the likelihood of corporate carbon disclosure.

Limitations and Future Research Opportunities

This study has several limitations for future research. First, corporate carbon disclosure is the result of multiple formal and informal, external and internal factors, such as cultural background, market uncertainty and organizational redundancy. We only examined the effects of environmental legitimacy and green innovation, however. Further studies should examine a more comprehensive set of multiple factors. Second, corporate carbon disclosure was measured as a dummy variable, i.e., whether the company surveyed responded to the CDP questionnaire or not, which only measured the likelihood of carbon disclosure and omitted many other potential insights into the quality of the disclosure. Future studies should adopt a more comprehensive measurement method that explores the quality as well as quantity of corporate carbon disclosure (Hahn et al. 2015).

Third, we only focused on Chinese companies, so the findings may not be applicable to other countries. In China, the CDP is at a relatively low level and the innovation environment is not particularly mature. This situation differs notably from developed countries, which does limit the application of our research results. Future research should focus on other, more developed countries' companies, and establish a comparison with the findings of this study.

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