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ABSTRACT
Green innovation is essential for addressing climate change and environmental deterioration challenges. We focus on whether and how environmental management systems (EMS), in particular, the ISO 14001 standard, influences corporate green innovation by considering the moderating role of environmental regulation. With a sample of the top 100 listed companies in China from 2008 to 2012, we find that EMS is significantly positively correlated with corporate green innovation and that environmental regulation strengthens this relationship. Thus, this research provides an important contribution to the literature on green innovation, environment management and emerging economies.

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Environmental management system; ISO 14001; green innovation; environmental regulation

1. Introduction

Climate change and environmental deterioration are the challenging problems the world faces nowadays (Li et al. 2018a). Innovation, especially green innovation, has recently been regarded as essential to addressing such environmental problems (Inoue, Arimura, and Nakano 2013). Green innovation is the improvement of processes or products in order to reduce negative environmental impacts to achieve sustainability (Rennings 2000; Li et al. 2018b). And implementing green innovations is challenging since it usually commands the acquisition of new resources and competences that differ significantly from what they possess now (Calza, Parmentola, and Tutore 2017). As it is considered a 'double externality', i.e. leaking the knowledge of the firm to other parties and reducing environmental impacts at its own costs (Rennings 2000), why do firms, agents of profit maximisation, still engage in green innovation?

There have been numerous studies exploring the antecedents of green innovation from different perspectives (Horbach 2008; Cai and Zhou 2014), these include institutional theory (Cai and Li 2018; Chen et al. 2018; Ramanathan, Ramanathan, and Bentley 2018), stakeholder theory (Guoyou et al. 2013) and the resource-based view (Qi et al. 2010; Xavier et al. 2017). As to the specific driving factors, external variables such as environmental regulation and stakeholder pressure are the most frequently targeted ones, while internal characteristics are less explored (Inoue, Arimura, and Nakano 2013). To address this inadequacy, some recent studies turned to examine the internal mechanisms of green innovation, such as CEOs' personal characteristics (Bantel and Jackson 1989; Chen 2013), organisation slack (Berrone et al. 2013; Chen et al. 2018) and voluntary actions (quality management system and environmental management systems) (Li et al. 2018b; Kawai, Strange, and Zucchella 2018).

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Many studies discuss that CEOs' personal characteristics can help firms pursue uncertain and unconventional strategies, such as corporate innovation (Hirshleifer, Low, and Teoh 2012; Arena, Michelon, and Trojanowski 2018). A large stream of literature posits that firms engage in more experimentation and green innovation in the presence of slack (Chen et al. 2018; Keegan and Turner 2002). Some studies investigated the effects of quality management system on corporate green innovation (Ziegler and Nogareda 2009; Talib, Rahman, and Qureshi 2011). A small (but growing) body of research investigates the impact of environmental management system (EMS) on environmental innovations (Rennings et al. 2006; Demirel and Kesidou 2011; Blind 2012). However, this stream of research is still underdeveloped with inconclusive findings, and largely situated in the developed countries (Wagner 2008; Horbach 2008), while neglecting investigations in the emerging economies (Boiral et al. 2018).

We aim to fill this research gap by investigating whether and how environmental management systems foster corporate green innovation. With a data set of China's top 100 listed companies, we argue and find that the adoptions of ISO 14001 promotes corporate green innovation and that environmental regulation strengthens this relationship.

This study makes several contributions. First, it contributes to green innovation research by investigating both internal environmental management systems and external environmental regulations, an area largely neglected but which deserves deep exploration. Second, we help to clarify the consequences of environmental management systems by exploring the green innovation impact of ISO 14001. While the prior literature on this relationship is confined to correlations rather than causation due to its cross-sectional, one-wave survey data with the endogeneity problem unsolved, our study tackles this problem by applying a longitudinal dataset because the research samples were China's top 100 listed companies from 2008 to 2012, which gives a clear picture of the causal relationship (Ziegler and Nogareda 2009; Inoue, Arimura, and Nakano 2013). Third, we contribute to literature on emerging economies by examining a new research context, China, a country experiencing excessive pollution while lacking sound regulations, which is different from the frequently studied setting of Western developed countries (Wei et al. 2017), thus adding value to theoretical completeness and also shedding light on other emerging economies.

2. Conceptual framework

2.1. Environmental management systems and corporate green innovation

Environmental Management Systems (EMS) are a tool that is being increasingly utilised among organisations operating in different sectors (Iraldo, Testa, and Frey 2009). It refers to a set of environmental management procedures that helps an organisation to reduce its environmental impacts (Li and Wu 2017; Marshall, Cordano, and Silverman 2005).

The ISO 9001 standards and 14001 standards are among the ISO's most widely known standards contributing to firm performance (Boiral and Henri 2012; Heras-Saizarbitoria and Boiral 2013; Heras-Saizarbitoria, Landín, and Molina-Azorín 2011), and ISO 14001 is one of the standards for an EMS, which was issued in 1996 and revised in 2004 by the IOS (International Organisation for Standardisation) (Inoue, Arimura, and Nakano 2013). In recent decades, firms have been increasingly criticised for their causing of severe environmental pollution and ecological devastation by various stakeholders such as the regulators, consumers, and community (Berrone et al. 2013). To respond to these pressures, firms are actively pursuing the certification of ISO 14001: now more than 300,000 organisations have certificated this system (ISO 2014). The goal of ISO 14001 is to reduce a firm's environmental impact and improve its environmental performance (Inoue, Arimura, and Nakano 2013). If a firm wants to get the ISO 14001 certification, it must undergo premier reviews of the environmental practices and promise to keep on-going commitments. There is a cycle of continuous improvement, widely known as the PDCA ('Plan–Do–Check–Act') cycle. Firms, once certified, must define their environmental policy and create plans ('Plan'), implement the plans ('Do'), check the results ('Check'), and make corrections based on those checks ('Act'). Through this continuous

PDCA cycle of ISO 14001 certification, firms will probably improve their environmental management and performance (Rehfeld, Rennings, and Ziegler 2007; Christmann and Taylor 2006). ISO 14001 enables firms to get a full understanding of their influence on the natural environment and the critical requirements for improving both environmental and economic performance (Darnall 2006), and through this procedure, firms may sense and seize further green innovation opportunities (Inoue, Arimura, and Nakano 2013).

However, despite its popularity, the impact of the standard is still inconclusive (Heras-Saizarbitoria and Boiral 2013). Some scholars argue that ISO 14001 is beneficial for both corporate financial and environmental performance, compared to non-adopters (Potoski and Prakash 2005; Dasgupta, Hettige, and Wheeler 2000; Arimura, Hibiki, and Katayama 2008); others questioned the positive effects, claiming that some of the adoption of ISO 14001 may be symbolic, legitimacy-seeking and 'greenwashing', and does not necessarily contribute to environmental performance (Boiral and Henri 2012; Prajogo, Tang, and Lai 2012; Zobel 2013). We argue the reason of this inconclusiveness may be that ISO 14001 does not directly lead to better or worse environmental or financial performance, but in an indirect way and depends on substantive implementation: it may change the process of innovation in products, technologies, or management modes towards sustainable development, a well-known notion of green innovation (Rennings 2000).

Green innovation is the generation of new, processes, products services, or systems to reduce environmental impacts (Li et al. 2018a; Rennings 2000). Compared to non-green innovation, it has a 'double externality effect', which means besides the positive technological spillovers usually linked with general R&D investments, green innovation also produces other positive externalities that reduce external environmental costs (Rennings 2000).

According to the resource-based view of the firm, the implementation of ISO 14001 is knowledge-based and can evolve as time passes, and is accumulated as a firms' internal capability that is rare, valuable, and difficult to imitate or substitute (González-Benito and González-Benito 2005; Zhu, Cordeiro, and Sarkis 2013). The implementation of EMS enables the generation of strategic knowledge, resources and capabilities, which positively influences general innovation capabilities and corporation environmental performance thus also green innovations (Wagner 2008; Psomas, Fotopoulos, and Kafetzopoulos 2011). EMS can even help to alleviate organisational failure by identifying and revealing profitable green innovation opportunities (Huang et al. 2016; Porter and Linde 1995). Many scholars have also pointed out that EMS fosters a firm's capabilities such as stakeholder integration, continuous innovation, and high-order learning, which are all useful for green innovation (Kesidou and Demirel 2012; Demirel and Kesidou 2011). Montabon, Sroufe, and Narasimhan (2007) found that firms adopt EMS tend to decrease structural costs and exploit business opportunities brought by stakeholders, which makes environmental practices the vehicle through which innovation occurs. Shu et al. (2014) and Frondel, Horbach, and Rennings (2007) pointed out that EMS encourages product innovation by creating opportunities for innovation. Therefore, firms can minimise environmental impacts by making use of EMS (Severo, de Guimarães, and Dorion 2017; Darnall, Jolley, and Handfield 2008).

Taken together, the inner mechanism of ISO 14001 helps firms to continuously seek new ways of environmental improvement, and firms that adopted ISO 14001 are likely to behave in a more environmentally friendly manner, which may enable them to sense and seize opportunities for green innovation (Inoue, Arimura, and Nakano 2013; Zhu, Cordeiro, and Sarkis 2013). This implies that EMS implementation should have a positive effect on firms' propensity to invest in green innovations, we thus propose the following hypotheses:

Hypothesis 1. Environmental management system adoption fosters corporate green innovation.

2.2. The moderating effect of environmental regulation

The impact of EMS on green innovations may depend on its context, so it is necessary to find the contingent factors that may moderate this relationship. Since government regulation plays a vital role in transitional economies, and China is characterised with powerful governmental intervene but lose environmental regulation (Li et al. 2018a), we draw from institutional theory to explore the moderating effect of environmental regulation to examine whether it is playing its role in China.

Institutional theory holds that firms are dependent on contingencies in the institutional environment; they should conform to social norms, rules, and patterns to gain legitimacy (Dimaggio and Powell 1983; Berrone et al. 2013). One of the prevailing institutions influencing Chinese firms is the government, which owns and allocates abundant resources, and spurs firms to fulfil its priorities and supervises their progress (Li et al. 2018a). Among these methods, environmental regulation is an important policy tool for corporate environmental behaviours (Berrone et al. 2013).

Studies show that the government corrects the pollution behaviour of firms by means of environmental regulation and requires firms to reduce and control the degree of pollution through technology innovation (Cole and Peter 1999). Cleff and Rennings (1999) link 'soft' environmental regulation tools with green innovation; Berrone et al. (2013) demonstrate that 'strict' environmental regulation can force firms to adopt environmentally friendly business methods, such as actively participating in green innovation. Hu et al. (2017) discussed the positive impact of government environmental regulations on green innovation. Norberg-Bohm and Rossi (1998) argued environmental regulation is a driver of technological change. Wagner (2008) found that assistant programmes done by the government encouraged firms to adopt ISO 14001; Inoue, Arimura, and Nakano (2013) also demonstrate that environmental regulations is one of the reasons promoting environmental research and development. Moreover, Demirel and Kesidou (2011) found that the adoption of ISO 14001 had an influence on the expenditures positively both in terms of 'pollution control technologies' and 'green R&D'.

We argue that environmental regulation positively moderates the EMS–green innovation relationship. Firms often prioritise their financial profits rather than their impact of natural environment (Zhang et al. 2018). Lax environmental regulation together with insufficient implementation induces free-riding environmental behaviours (Ford, Steen, and Verreynne 2014). Accordingly, the value of EMS for a focal firm would be decreased, resulting in less investment in green innovation. On the contrary, stringent regulation creates a sound market demand for environmental products, and assures the long-term value of responsible initiatives such as EMS (Berrone et al. 2013). This would encourage EMS certified firms with more confidence and capability to investing in green innovation.

As for our context of China, the former Chinese governments focused on economic development, and the environmental regulations were relatively 'soft', resulting in increasingly serious environmental problems. This situation altered as president Xi Jinping came to power in 2012. He vowed to 'build a beautiful China'. Since then, a series of environmental regulations are designed and implemented (Li et al. 2018a). For example, in 2015, China implemented the toughest new environmental protection law in history (Wong, Miao, and Cui 2018; Li et al. 2018a), making more firms turn their attention to environmental behaviour. Accordingly, firms are beginning to adopt and substantively implement ISO 14001 to truly invest in green innovation and improve environmental performance, rather than use it as a symbolic legitimacy-seeking tool. Thus, the positive relationship between EMS and green innovation is positively moderated by the stringency of environmental regulations. So we propose:

Hypothesis 2. Environmental regulation strengthens the positive effect of environmental management system on corporate green innovation in China.

3. Methods

3.1. Data

The research samples were China's top 100 listed companies from 2008 to 2012. We excluded firms that: (1) issued B shares and/or H-shares (70 observations); (2) with incomplete data (35 observations);

(3) in clean industries whose environmental impact is not so large as those dirty industries, where green innovation is not that important (15 observations in finance industry, 7 in life insurance industry, and 76 in tourism industry). The final sample was comprised of 297 observations corresponding to 131 companies. Table 1 shows the sample distribution by year and industry.

The data of ISO 14001 certification is manually collected from the website of Certification and Accreditation Administration of the People's Republic of China (http://www.cnca.gov.cn/), the data of green patent is manually coded from China National Intellectual Property Administration (www.cnipa.gov.cn), the data of environmental regulation is collected from China Environmental Statistics Yearbook, and the other data are obtained from CSMAR (China Stock Market & Accounting Research Database), a leading database in China offering data on the China stock markets and the financial statements of China's listed companies.

3.2. Measurements of variables

Corporate green innovation. Scholars use different proxies to measure green innovation, such as eco-labelling (Lin et al. 2014), green R&D (Lee and Min 2015), and green patents (Li et al. 2018a; Berrone et al. 2013). Since there is no statistical data specific to green R&D or eco-labelling in China, we

Table 1. Sample distribution by year and industry.

	Year						
Industry type	2008	2009	2010	2011	2012	Subtotal	%
Real estate industry	5	7	6	4	3	25	8.42
Manufacture of non-metallic mineral products	3	2	1	1	1	8	2.69
Water transportation industry	4	3	1	2	2	12	4.04
Manufacture of metal products	1	0	0	0	0	1	0.34
Metal smelting and rolling processing	2	1	4	4	3	14	4.71
Manufacture of communication equipment, computers and other electronic equipment	2	1	1	1	2	7	2.36
Manufacture of special purpose machinery	1	3	3	3	2	12	4.04
Manufacture of automotive	3	1	4	5	4	17	5.72
Manufacture of medicines	0	1	2	5	2	10	3.37
Manufacture of paper and paper products	1	0	0	0	0	1	0.34
Power, thermal production and supply	3	3	2	3	4	15	5.05
Wine, beverages and refined tea manufacturing	2	4	3	4	5	18	6.06
Electrical machinery and equipment manufacturing	0	3	3	3	2	11	3.70
Smelting and pressing of ferrous metals	4	5	3	1	2	15	5.05
Chemical (industry and fine) and pharmacy	0	1	0	1	2	4	1.35
Processing of food from agricultural products	0	1	0	0	1	2	0.67
Coal mining and dressing	3	4	6	4	7	24	8.08
Retail industry	0	1	1	2	1	5	1.68
Architectural decoration and other construction industry	0	0	0	0	1	1	0.34
Manufacture of general purpose machinery	4	1	1	2	1	9	3.03
Aeronautics transportation industry	3	2	0	1	1	7	2.36
Road transportation industry	4	0	0	0	0	4	1.35
Oil and gas extraction	2	2	2	2	3	11	3.70
Telecommunications, broadcast television and satellite transmission services	0	1	1	1	1	4	1.35
Civil engineering construction industry	0	3	3	5	5	16	5.39
Manufacture of railway, ship, aerospace and other transport equipment	1	1	0	0	4	6	2.02
Non-ferrous metals mining and dressing	0	2	4	4	5	15	5.05
Auxiliary mining activity	0	2	1	1	2	6	2.02
Production and supply of gas	0	1	1	0	0	2	0.67
Processing of petroleum, coking and processing of nuclear fuel	1	0	0	0	0	1	0.34
Wholesale industry	0	1	1	1	0	3	1.01
Manufacture of textile	1	0	0	0	0	1	0.34
Manufacture of foods	0	0	1	1	1	3	1.01
Comprehensive	0	1	0	0	0	1	0.34
Railway transportation industry	1	2	1	1	1	6	2.02
Total by year	51	60	56	62	68	297	100

employ green patent as the proxy of green innovation (Brunnermeier and Cohen 2003; Li et al. 2017). With a literature review and consultation with experts, we regard a patent as 'green patent' if it contains one of the following Chinese keywords: 'clean', 'cycling', 'ecology', 'emission reduction', 'energy saving', 'environmental', 'environmental pollution', 'environmental protection', 'green', 'low carbon', 'saving', and 'sustainable' and (Cormier and Magnan 2015; Li et al. 2018a). We adopt green patents for inventions to measure green innovation (noted as GI), and use the total of all the three categories of green patents (patent for invention, patent of appearance, and patent of utility model) for our robustness test (Li et al. 2018b).

Environmental management system (*EMS*). An EMS is a set of practices and procedures for environmental management. There are many environmental management systems, and the ISO 14001 standard was the mostly widely adopted (Orecchini 2000). Thus, we measure environmental management system by a dummy variable, EMS, 1 for firms that have passed the ISO 14001 certification, and 0 others.

Environmental regulation. Environmental investments and sulphur dioxide removal rate are frequently adopted measures of environmental regulation (Swinton 1998). A number of studies have shown that one the most important manifestations of the intensity of environmental regulation is pollutants removal (Aiken and Pasurka 2003), so we employed sulphur dioxide removal rate to measure environmental regulation, noted as ENR.

Prior studies found that many factors have an impact on corporate green innovation (Wagner 2008; Inoue, Arimura, and Nakano 2013; Guoyou et al. 2013). Therefore, this study also incorporates the following control variables:

Firm scale (the logarithm of total assets, noted as FS). Larger corporations can easily get access to many resources, which would promote green innovation (Liang and Liu 2017).

Financial performance (ROA, return on assets). The higher a firm's profitability is, the more inclined firms is to participate in green practices because of the lack of resources (Li and Tang 2010).

Leverage (liabilities/total assets, noted as LEV). High leverage will force firms to take measures such as green innovation to meet the requirements of stakeholders for sustainable development (Li et al. 2018b).

Slack (current assets/current liabilities ratio, noted as SLA). Organisational slack positively impacts on green innovation (Li et al. 2017).

Board independence (the number of independent directors/total number of directors on the board, noted as IND). Board independence has significant influences on corporate social and environmental behaviour.

industry type. Compared to cleaner industries, companies in environmentally sensitive industries are under more stringent supervision of the government (1 for environmentally sensitive industries, 0 otherwise, noted as INT) (Boesso and Kumar 2007).

3.3. Model

We constructed the following models to test the hypotheses:

Main Effect Model:

$$\mathrm{GI} = a_0 + a_1\mathrm{EMS} + a_2\mathrm{ENR} + a_3\mathrm{ROA} + a_4\mathrm{LEV} + a_5\mathrm{FS} + a_6\mathrm{INT} + a_7\mathrm{IND} + a_8\mathrm{SLA} + \varepsilon_{1i}$$

Moderating Effect model:

$$\mathrm{GI} = a_0 + a_1\mathrm{EMS} + a_2\mathrm{ENR} + a_3\mathrm{EMS} \times \mathrm{ENR} + a_4\mathrm{ROA} + a_5\mathrm{LEV} + a_6\mathrm{FS} + a_7\mathrm{INT} + a_8\mathrm{IND} + a_9\mathrm{SLA} + \varepsilon_{2i}$$

where GI is patents for green inventions, EMS is whether the firm passed the ISO 14001 certification, ENR is sulphur dioxide removal rate, ROA is the proxy for financial performance, LEV is a firm's leverage, FS is a firm's scale, INT is industry type, IND is board independence; SLA is slack.

4. Results

4.1. Descriptive statistics analysis

As shown in Table 2, the mean, minimum, and the maximum value of green innovation are 27.909, 0, and 768, respectively, which indicates that firms behave quite differently in green innovation. The mean value of environmental management system is 0.438, which demonstrates that nearly a half of the observations has obtained the ISO14001 certification. The mean value of environmental regulation is 0.609, the minimum value is 0.054, and the maximum value is 0.957. We also calculated the variance inflation factor (VIF) of the variables. All VIF values were lower than 2, with a mean of 1.1. Therefore, the multicollinearity among these variables is not a serious problem.

4.2. Hypotheses testing

4.2.1. Main effect

The Poisson model is widely used to deal with the count nature of dependent variables (Ahuja and Katila 2001). Since our dependent variable is the number of green patents, we employed panel poison model regression to test the hypotheses. Table 3 presents the results of the panel Poisson estimation.

Model 2 of Table 3 shows a significant positive relationship between environmental management system and green innovation ($\beta = 0.563$, $p = .000$), thereby supporting Hypothesis 1. The result indicates that firms with ISO 14001 certification adopt more green innovations than their non-certificated peers, suggesting that environmental management system fosters corporate green innovation.

4.2.2. Moderating effects

Model 4 shows that the interaction between environmental management system and environmental regulation is significantly positive ($\beta = 2.241$, $p = .000$), suggesting that environmental regulation strengthens the positive relationship between EMS and green innovation. Thus, H2 is also supported.

We plotted the moderating effect to have a better illustration. Figure 1 shows that when environmental regulation is high, the EMS–green innovation relationship is positive and the slope is steep; while environmental regulation is low, the focal relationship becomes less positive and the slope is flatter. The result suggests that the higher the level of environmental regulation, the more positive the relationship between EMS and green innovation.

Table 2. Descriptive statistics and correlation matrix.

	1	2	3	4	5	6	7	8	9
1GI	1.000								
2EMS	0.014	1.000							
3ENR	0.087	0.144**	1.000						
4ROA	−0.076	0.076	0.048	1.000					
5LEV	0.030	0.074	−0.003	−0.135**	1.000				
6FS	−0.143**	−0.100*	0.073	−0.146**	0.134**	1.000			
7INT	0.141**	0.063	0.037	0.012	0.120**	0.102*	1.000		
8IND	−0.092	0.134**	0.010	−0.063	0.023	0.019	−0.109*	1.000	
9SLA	−0.089	−0.032	−0.020	0.388***	−0.067	−0.062	0.149**	−0.080	1.000
Min	0	0	0.054	−0.213	−1.1	21.623	0	0.125	0.8
Max	768	1	0.957	0.315	14.897	28.175	1	0.869	17.761
Mean	27.909	0.438	0.609	0.07	1.204	24.764	0.38	0.388	2.267
SD	76.855	0.497	0.113	0.073	0.962	1.236	0.486	0.081	1.802

***$p < .01$.
**$p < .05$.
*$p < .1$.

Table 3. Regression results.

	GI			
Variable	Model 1	Model 2	Model 3	Model 4
EMS		0.563***	0.585***	−0.751**
		(0.0989)	(0.0991)	(0.301)
ENR			−0.594**	−1.870***
			(0.302)	(0.407)
ENR × EMS				2.241***
				(0.478)
ROA	−2.249***	−2.217***	−2.397***	−1.865***
	(0.633)	(0.633)	(0.643)	(0.650)
LEV	0.0588***	0.0580***	0.0577***	0.0595***
	(0.0101)	(0.0101)	(0.0102)	(0.0102)
FS	−0.0729***	−0.0701***	−0.0654***	−0.0664***
	(0.0111)	(0.0111)	(0.0113)	(0.0113)
INT	0.429***	0.413***	0.409***	0.394***
	(0.0729)	(0.0733)	(0.0733)	(0.0736)
IND	−0.581	−0.311	−0.343	−0.573
	(0.467)	(0.474)	(0.474)	(0.478)
SLA	−0.762***	−0.773***	−0.769***	−0.763***
	(0.0706)	(0.0713)	(0.0712)	(0.0710)
Cons	6.219***	5.872***	6.146***	7.000***
	(0.424)	(0.431)	(0.453)	(0.489)
Chi^2	347.21	377.91	381.55	403.76
Observations	297	297	297	297

Note: Standard errors in parentheses.
***$p < .01$.
**$p < .05$.

4.3. Robustness tests

We undertook further robustness tests by adopting alternative operationalizations of variables. Given that the number of total green patents is another widely used measurement of corporate green innovation, we replaced green patents for inventions as the sum of all kinds of green patents (patents for

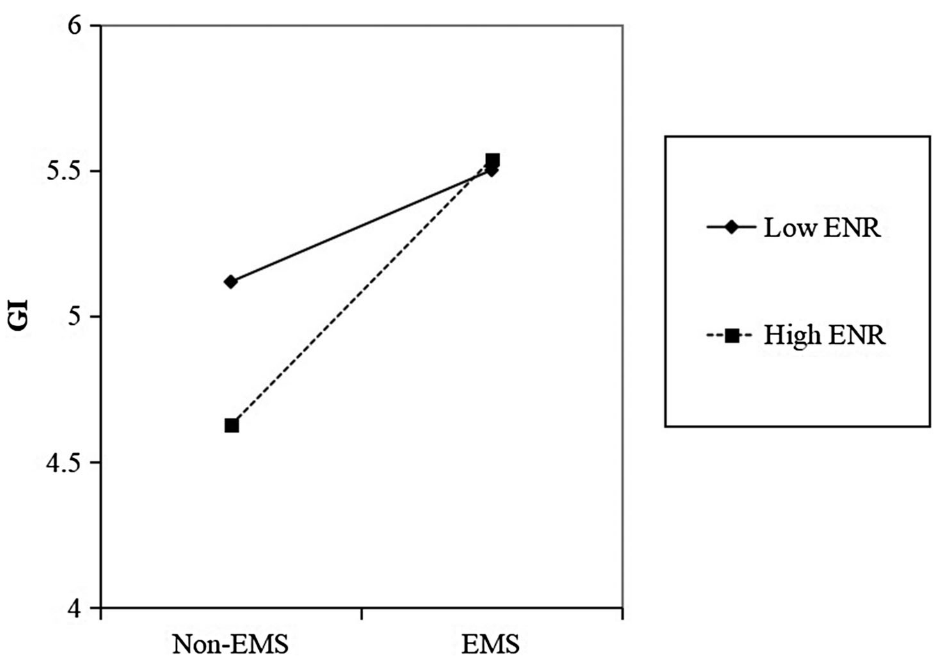

Figure 1. Moderating effect of environmental regulation.

Table 4. Robustness test results of alternative measurements of green innovation.

	GI			
Variable	Model 5	Model 6	Model 7	Model 8
EMS		0.373***	0.424***	−1.236**
		(0.140)	(0.140)	(0.485)
ENR			−1.629***	−3.429***
			(0.360)	(0.622)
ENR × EMS				2.681***
				(0.749)
ROA	−2.934***	−2.939***	−3.706***	−2.847***
	(0.795)	(0.794)	(0.829)	(0.859)
LEV	0.0576***	0.0571***	0.0561***	0.0583***
	(0.0122)	(0.0122)	(0.0123)	(0.0123)
FS	−0.113***	−0.111***	−0.0958***	−0.100***
	(0.0154)	(0.0154)	(0.0156)	(0.0156)
INT	0.415***	0.412***	0.403***	0.377***
	(0.104)	(0.104)	(0.105)	(0.105)
IND	−1.120*	−0.955	−0.945	−1.423**
	(0.631)	(0.638)	(0.636)	(0.654)
SLA	−0.542***	−0.544***	−0.546***	−0.545***
	(0.0938)	(0.0942)	(0.0943)	(0.0936)
Cons	6.377***	6.119***	6.821***	8.190***
	(0.554)	(0.564)	(0.583)	(0.701)
Chi^2	182.95	189.94	209.61	222.44
Observations	297	297	297	297

Note: Standard errors in parentheses.
***$p < .01$.
**$p < .05$.
*$p < .1$.

inventions, patents for utility models, and patents for appearance) in Models 1–4. Table 4 shows that the magnitude and significance of the coefficients remain similar to prior results.

We also lagged one year of green patents to test the robustness of the results. As shown in Model 9, Model 10, Model 11 and Model 12 of Table 5, the results are similar to previous ones.

4.4. Endogeneity controls

As our samples are firms with green patents, endogenous problems of sample selection bias must be considered. Heckman two-stage model was introduced to address the endogeneity of this bias (Heckman 1979). The Heckman model is used by scholars to resolve sample selection bias, and studies using this method has increased by more than 700% over the last decade (Certo et al. 2016). The first stage regression generated 'Inverse Mill Ratio (IMR)' (Katmon and Al Farooque 2017), and the IMR was employed in the second stage of all models to control the endogenous problems. Panel A of Table 6 is the result of the first-step probit regression. In this model, we set the independent variables as OWN (1 for State-owned enterprises, 0 others); GRW (growth rate of operating revenue); FS (the logarithm of total assets), and the dependent variable was 'corporate green innovation Dummy', 1 for the firms obtain green patent, 0 otherwise. As shown in Panel B of Table 6, the results of the second-step regression indicate that the coefficients of IMR are insignificant and our models do not have a problem with sample selection bias (Katmon and Al Farooque 2017). Therefore, the results also support H1and H2.

5. Discussion

5.1. Conclusions

This article explores the influence of EMS on corporate green innovation by introducing the effect of environmental regulation in China. This study was conducted on 297 observations of China's top 100

Table 5. Robustness test results of lagged green innovation.

	GI_{t+1}			
Variables	Model 9	Model 10	Model 11	Model 12
EMS		1.036***	1.028***	−0.176
		(0.366)	(0.369)	(0.448)
ENR			0.0599	−3.309***
			(0.384)	(0.634)
ENR × EMS				5.914***
				(0.847)
ROA	7.373***	7.558***	7.534***	8.935***
	(1.029)	(1.034)	(1.045)	(1.045)
LEV	−0.0268*	−0.0269*	−0.0269*	−0.0234
	(0.0160)	(0.0160)	(0.0160)	(0.0157)
FS	0.200***	0.198***	0.198***	0.169***
	(0.0181)	(0.0181)	(0.0182)	(0.0188)
INT	0.205***	0.209***	0.209***	0.200***
	(0.0673)	(0.0676)	(0.0676)	(0.0677)
IND	0.798	0.748	0.763	0.381
	(0.555)	(0.556)	(0.564)	(0.570)
SLA	−0.684***	−0.695***	−0.694***	−0.658***
	(0.0738)	(0.0742)	(0.0743)	(0.0728)
Cons	−1.007*	−1.358**	−1.402**	1.142
	(0.593)	(0.605)	(0.670)	(0.818)
Chi^2	320.48	327.16	327.00	382.68
Observations	150	150	150	150

Note: Standard errors in parentheses.
***$p < .01$.
**$p < .05$.
*$p < .1$.

listed companies between 2008 and 2012, and we find that environmental management system has a positive impact on green innovation. In addition, environmental regulation strengthens the EMS–green innovation relationship.

First, the results show that environment management systems is significantly positively related with corporate green innovation, indicating adoption of EMS fosters corporate green innovation. This is in accordance with the majority of the research, such as Demirel and Kesidou (2011), Inoue, Arimura, and Nakano (2013), and Hamdoun, Jabbour, and Othman (2018), who find positive correlations between EMS and green innovation, which is manifested as environmental R&D. However, our finding is contradictory to Ziegler and Nogareda (2009), who conclude that the casual relationship is ambiguous. The reasons may be that, according to the resource-based view, the implementation of EMS generates the necessary resources and capabilities for the initiation of green innovation. Also to the best of our knowledge, prior literature on the EMS–green innovation relationship relies on cross-sectional, one-wave survey data, which makes it impossible to address the endogeneity issue of the relationship. Our study resolves this problem by using a longitudinal data set and a manually collected green patent data as measures of green innovation. Thus, this study gives a clear picture of the causal relationship between EMS and green innovation since theoretically, we rely on the resource-based view which clarifies the underlying mechanisms and empirically, we address the endogeneity issue and get a causation rather than correlation relationship. Moreover, though this study is situated in the Chinese context, it is an obvious diversion from current literature that grounded on Western countries, which shows the strong vitality of ISO 14001 and contributes to the environmental management literature in emerging economies.

Second, environmental regulation positively moderates the relationship between environmental management and green innovation, demonstrating that regulation in China is acting its necessary roles. This research is in accordance with many previous studies in developed countries (Berrone et al. 2013; Demirel and Kesidou 2011). The possible reasons for this may be that, first, the strict environmental regulation strengthens the punishment of illegal firms and the cost of violations is

Table 6. Results with Heckman two-stage procedure.

Panel A: the first-step regression-model employed to estimate inverse Mills						
Variable	OWN	GRO	FS	*N*	Pseudo R^2	LR chi^2
GI_dummy	0.0596 (0.218)	0.000466 (0.258)	−0.0775 (0.0602)	297	0.0042	1.69

Panel B: the second-step regression-after introducing to inverse Mills			
	GI		
Variable	Model 13	Model 14	Model 15
EMS	−20.37*	0.826	−1.795
	(10.95)	(9.166)	(41.47)
ERN		42.75	41.27
		(36.03)	(42.10)
ERN × EMS			4.353
			(67.01)
ROA	−34.96	−56.98	−57.09
	(59.23)	(60.24)	(60.38)
LEV	1.738	1.960	1.959
	(3.238)	(3.470)	(3.474)
FS	−1.237	−12.69	−12.83
	(3.039)	(17.49)	(17.63)
INT	16.48*	18.37**	18.33**
	(8.908)	(8.986)	(9.013)
IND	−12.17	−27.21	−27.19
	(52.96)	(53.97)	(54.09)
SLA	−2.997	−3.451	−3.455
	(2.370)	(2.404)	(2.410)
IMR	−127.9***	117.0	120.0
	(34.06)	(375.9)	(378.9)
Constant	154.6**	243.5	245.7
	(70.67)	(184.5)	(187.8)
Observations	297	297	297

Note: Standard errors in parentheses.
***$p < .01$.
**$p < .05$.
*$p < .1$.

increasing. Second, the implementation of green innovation in China can obtain relevant government subsidies, which can reduce the cost of EMS projects. Third, environmental regulation will force firms to substantively adopt and implement environmental management systems rather than simply symbolically seeking legitimacy, and thus increase their investment in environmental protection projects and promote green innovation.

5.2. Practical implications

There are some practical implications according to the findings. First, the result shows that though inherently a 'standard', the ISO 14001 system fosters corporate green innovation. This calls for an encouragement of firms to actively adopt ISO 14001 certification to achieve *Sustainability*. The initiator, the International Organisation for Standardisation, should carefully design and adjust the standard according to the success and failures by the firms, also according to the latest information technologies which may change the whole process. Firms should seriously adopt and implement the system, build specific departments dedicated to EMS, and make a full commitment to implement the system rather than engage in symbolic legitimacy-seeking and 'greenwashing'.

Second, environmental regulation strengthens the EMS–green innovation relationship, which is of great significance for government departments to guide enterprises to initiate effective and substantive environmental activities. The government should not only formulate efficient environmental regulation policies and strengthen the environmental governance of firms, but also formulate proper fiscal policies and financial policies to motivate and promote the investment of innovative resources, to support firms to be active in green innovation to reduce their energy consumption and pollutant emissions. Governments should also offer effective assistance programmes to increase the adoption and success of ISO 14001 and green innovation activities.

5.3. Limitations and research directions

There are also some limitations in this study which deserves future research. First, green innovation is affected by a variety of factors, such as stakeholders and top managers, which should be further explored. Second, we just considered whether firms adopted ISO 14001 or not, but did not explore the maturity or level of implementation of the system, which leaves profitable research areas open. Third, the short period of time taken for analysis and limited availability of data limits the value of this study which should be further addressed. Fourth, the findings were based on large firms in China, and future research should include companies of different scales in different countries.

Disclosure statement

No potential conflict of interest was reported by the authors.

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