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Impact of quality management on green innovation

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ABSTRACT

Regarded as the main contributor to various environmental issues, firms face increasing pressure from various stakeholders to incorporate green management into their business practices. This study aims to provide preliminary evidence regarding the impact of corporate quality management on green innovation and the moderating role of environmental regulation on this relationship. Data on top 100 listed companies from 2008 to 2014 in China indicate that quality management exerts significant negative effects on the likelihood of implementing corporate green technology innovation and green management innovation. Environmental regulation significantly mitigates the negative effects of quality management on both green management innovation and green technology innovation.

1. Introduction

Both product and environmental quality are critical to the welfare of human beings. Advances in quality awareness were motivated by the superior quality of Japanese products in the late 20th century (O'Neill et al., 2016), while environmental awareness was motivated by extreme ecological deterioration worldwide in recent decades. As the largest developing country, China experiences severe energy shortage and environmental pollution, which have overwhelmingly affected people's health and normal lives. Regarded as the main contributor to various environmental problems, firms are facing tremendous pressure from the government, consumers, media, environmental non-government organizations, and other stakeholders (Bansal and Clelland, 2004) to incorporate both quality management and environmental management into their business practices (Li et al., 2017).

Do firms need to reinvent the wheel to incorporate environmental innovation into existing systems? Ample evidence demonstrates that quality improvement practices (such as total quality management) help achieve sustainable development (Yang et al., 2010; Jackson et al., 2016; Siva, 2016). However, studies on this relationship present conflicting viewpoints: some argue that quality management fosters green innovation, whereas others assert that it hinders green innovation (Prajogo and Sohal, 2001). This discussion prompts asking the following questions: Does quality management foster or hinder green innovation? If quality management does the latter, have measures been established to mitigate the negative impact of quality management on green innovation?

Current literature mainly focuses on the effect of quality management on general innovation and presents contradictory findings (López-Mielgo et al., 2009). The effect of quality management on green innovation or the contingencies in the context of sustainability are rarely investigated. Therefore, the objective of this study is two-fold: (i) to explore the impact of quality management on green innovation; and (ii) to incorporate the moderating role of firm size and environmental regulation in the relationship by combining the resource-based view and institutional theory.

This study provides significant contributions. First, though research on the impact of quality management on sustainability has been extensive for more than a decade, only a limited number of studies focus specifically on the impact of quality management on green innovation. Green innovation is one of the key factors to achieve environmental sustainability (Dangelico, 2016). One way in which companies can contribute to the achievement of environmental sustainability objectives is the development of green products. Due to its double-externality nature and importance to sustainable development, green innovation deserves further

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investigation (Rennings, 2000; Dangelico, 2016; Li et al., 2017). To the best of our knowledge, this study is among the first to theoretically and empirically explore the impact of quality management on green innovation. Second, on the basis of institutional theory, the moderating effects of environmental regulation are evaluated. China currently faces increasingly serious environmental problems with a lax regulation, which is important to test whether the government is playing the role it should be.

The remainder of this paper is organized as follows: The second section presents a literature review and hypotheses, the third section explains the research design and methodology, the forth section offers the empirical analysis, the fifth section shows the discussion, and the final section provides the research conclusions and implications.

2. Literature review and research hypotheses

2.1. Quality management and green innovation

Firms nowadays can rarely ignore the term "quality management", which refers to various management measures and plans that are implemented to improve quality, reduce costs, and promote productivity, as well as to enhance corporate performance and competitiveness (Samson and Terziovski, 1999). In the early 1980s, William Edwards Deming, an early proponent of quality management, emphasized the significance of improving quality management and created 14 points on quality management to help companies improve their quality and productivity (Anderson et al., 1994). The most common practices identified in the literature include leadership, people management, planning, information and analysis, process management, supplier management, focus on customers/stakeholders and design; some of these practices motivate sustainable development and green innovation (Sila, 2007; Molina-Azorín et al., 2015).

The most frequently quoted definition of sustainable development is given by the World Commission on Environment and Development (1987: 27): "economic development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs." A similar definition that seeks for a balance between profit, planet, and people is provided by the EPA (2003): "Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations." Green innovation is "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives" (OECD, 2009: 19). It can be seen that, sustainable development is a broad concept containing an ecological, economic and social dimension and requires substantial innovation (Rennings, 2000), and green innovation is a specific tool to achieve sustainable development. Under the circumstances of environmental deterioration, green innovation, as well as total quality management, has become increasingly crucial in gaining corporate competitive advantage and reaching sustainable development (Prajogo and Sohal, 2006; Bon and Mustafa, 2013).

Green innovation refers to innovation in technologies, products, services, organizational structures or management modes adopted by enterprises to achieve sustainable development (Rennings, 2000). Apart from the general innovation concerning the content of change neutrally and in all directions, green innovation emphasizes innovation toward sustainability, contributing to efforts in reducing environmental burdens (Klemmer et al., 1999), and has a "double externality effect", i.e., knowledge spill-over externalities and positive environmental impacts, which makes firms more reluctant to invest in it themselves alone, but rather seeking for subsidies from the government (Rennings, 2000; Li et al., 2017).

To achieve a sustainable advantage in the globalized market, companies need to address both technological innovation and administrative innovation (Teece, 2000). Therefore, green innovation is divided into two major categories: green technology innovation and green management innovation (Qi et al., 2010; Rennings, 2000). Green technology innovation is technological innovation concerned with environmental protection. It intends to apply scientific environmental knowledge and technology to achieve a harmonious development of the economy and the environment in the production process. These efforts include developing technologies and products that help save energy and raw materials, using energy efficiently, and implementing biodegradable packaging (Kammerer, 2009). In addition to technology, an important nature of innovation from the administrative perspective is that it can integrate organizational structures, management systems, and social aspects (Kim et al., 2012; Siva, 2016). Green management innovation refers to adopting new organizational structures or management systems, thereby improving production and management processes to reduce negative environmental impacts (Qi et al., 2010). Examples of such an innovation are comprehensive environmental management systems and energy conservation (Qi et al., 2010; Damanpour and Aravind, 2012).

Quality management and green innovation are two methods by which competitive advantage is gained in an environment-constrained society; however, the assessment of the relationship between the two has been inconclusive (Prajogo and Sohal, 2001; Castillo-Rojas et al., 2012; Manders et al., 2016). Some studies have adopted an optimistic perspective in contending that quality management is strongly linked with the promotion of sustainable development in general, and green innovation in particular (Siva et al., 2016; Zeng et al., 2017). This view claims that quality management is a foundation for the firms' contributions to sustainable development, an innovation in itself and the implementation of quality management in a firm is usually related with considerable innovations. In contrast, the more pessimistic view argues that quality management tools and methodologies, especially those standards such as ISO 9001, which are based on formalization and systematization, actually hinder green innovation since they tend to increase bureaucracy (Castillo-Rojas et al., 2012).

Quality management systems such as ISO 9001 encompasses "hard" and "soft" elements, which can be related to the contrasted mechanistic versus organic views of the organization (Abrunhosa and Sa, 2008). If the "hard" elements—closely linked to the mechanistic model—prevail, quality management can be an obstacle to green innovation. On the other hand, if the "soft" models are highly valued, the implementation of quality management principles and practices will provide a fertile environment for firms to innovate and becomes in fact a strong driver of green innovation (Zeng et al., 2017).

We argue that quality management could "trap" companies in environmental improvement or green innovations for several reasons. First, quality management leads to cost-effective rather than differentiation strategy, which hinders green innovation. Innovation may need a huge number of investments with an uncertain outcome, which is not the favor of a cost-effective strategy (Prajogo and Sohal, 2006). Thus, such firms tend to be followers rather than leaders in green innovation to avoid risk and reduce costs, thereby limiting the capacity and opportunity for green innovation investment (Hung et al., 2011; Zhang et al., 2012).

Second, quality management could hinder firms from creative because of enforcement of formalization (Prajogo and Sohal, 2001; Zeng et al., 2017). The standard-oriented philosophy of quality management easily leads firms to take a myopic perspective and focus on their current popular products and services instead of creating unprecedented solutions (Wind and Mahajan, 1997; Castillo-Rojas et al., 2012). Quality management aims at incremental changes and establishes control and stability by requiring standardization or formalization, which would inhibit the innovative change in organizational structure or process management system from the present situation to an entirely new one that is conductive to sustainability development (Zeng et al., 2015).

Third, the philosophy of continuous improvement advocated by quality management would hinder firms from radical green innovations (Jha et al., 1996; Steiber and Alänge, 2013). Continuous improvement is analytical; by contrast, innovation is experimental, allowing errors due to uncertainty. Thus, quality management practices can lead to a situation where employees are constrained within an existing pre-designed production regime and attach importance to the details of quality process rather than new ideas that change the structural ways of working (Prajogo and Sohal, 2001). For example, customer focus philosophy of quality management has received considerable attention in relation to its negative impact on innovation since they will focus on meeting the needs of existing customers and fail to drive the search for innovative and novel solutions by ignoring the unserved potential in their markets (Prajogo and Sohal, 2006).

Fourth, firms tend to build hard quality management systems rather than cultivating soft elements, especially in China (Zu et al., 2011). Meta-standards such as ISO 9001 can be superficially implemented since Chinese firms are mostly driven by the quest for social legitimacy rather than for improvement of internal practices (Heras-Saizarbitoria and Boiral, 2013). Chinese firms often do the copycat work and implement mechanically, and the prescriptive of standardization inhibits creativity (Zu et al., 2011). Thus the following hypotheses are proposed:

Hypothesis 1a. Quality management negatively affects corporate green technology innovation in China.

Hypothesis 1b. Quality management negatively affects corporate green management innovation in China.

2.2. Moderating effects of environmental regulation

The relationship between quality management and green innovations is moderated by its context. If quality management hinders the green innovation activities of a firm, the contingent factors that may weaken this negative effect need to be identified (Prajogo and Sohal, 2001). In this study, we intend to investigate the role of environmental regulation in China–typically characterized with strong governmental intervene but lax environmental regulation–to see whether it is effective (Demirel and Kesidou, 2011; Jackson et al., 2016).

Institutional theory addresses how social influence toward conformity affects the actions of organizations (Berrone et al., 2013). The theory holds that the mandatory and normative nature of institution can induce the preferred direction of rational behavior and that the firm will be consistent with the legislation and rules, actively or passively, similar to "being institutionalized" (Meyer and Rowan, 1977; DiMaggio and Powell, 1983). One of the prevailing institutions affecting firms in Chinese-like emerging economies is the government, whose regulatory pressure exerts powerful influence on the environmental behavior of the firm (Li et al., 2016). Given the power exerted by the government on organizations within its jurisdiction, non-compliance with environmental regulation could be costly to the firm (Berrone et al., 2013).

Though confronted with serious environmental damages, the former Chinese governments are reluctant to admit this problem and have done little in environmental improvement but focus on economic development. However, this has been changed with the inauguration of President Xi Jinping in 2012, who vowed to "fight a war with pollution", and accelerated environmental governance and enacted a series of environmental regulations. The new Environmental Law, launched at the beginning of 2015, was called "the most rigorous law in China's history": those law-breakers would be heavily fined and even jailed (Li et al., 2016). Environmental regulation plays a significant role in corporate green innovation (Demirel and Kesidou, 2011). Driven by maximization of corporate profit, firms often prioritize their own interests and not the environmental welfare of the whole society, resulting in a gap between private and social returns to green innovation (Hall and Helmers, 2010). Lax supervision induces free-riding behaviors of enterprises on green innovation (Ford et al., 2014). Under strict environmental supervision, the negative externality of green innovation can be alleviated because implementing green innovation can then be regarded as a cooperative effort to implement environmental regulation and obtain regulatory legitimacy (Lin et al., 2014). Stringent environmental regulation induces the certainty of the value of green innovation investments and creates a demand for environmental products or services, all of which encourage new green technology management innovations. Consequently, strict environmental regulation forces quality-certified firms to conduct responsible initiatives, such as the active participation in environmental practices and investment in green innovations (Berrone et al., 2013). Thus the hypotheses are proposed as follows:

Hypothesis 2a. Environmental regulation mitigates the negative impact of quality management on corporate green technology innovation.

Hypothesis 2b. Environmental regulation mitigates the negative impact of quality management on corporate green management innovation.

Fig. 1 below presents the research model and the hypotheses, showing the influence of quality management on green technology innovation and green management innovation, and the moderating role of internal firm size and external environmental regulation.

3. Research design

3.1. Data

This study selected the top 100 listed companies of China between 2008 and 2014 as its sample, as these data are highly authoritative, normative and easy to access. The samples were screened according to the following criteria: excluding firms that issued B shares and/or H-shares (101 observations); excluding firms with incomplete data (51 observations); excluding firms in clean industries which requires no green innovations (109 in finance industry, 22 in life insurance industry, 10 in tourism industry, respectively). Finally, we got a sample of 407 observations corresponding to 145 companies.

The data required in this research are obtained from CSMAR, annual reports of listed companies, the Baiteng patent network (http://so.5ipatent.com/) and the Certification and accreditation unified business information search platform (http://cx.cnca.cn/rjwcx/web/cert/index.do).

Fig. 2 shows the sample distribution by year and industry. It indicates that Manufacturing and Mining account for the highest proportion, with 49.63% and 18.67% observations, respectively.

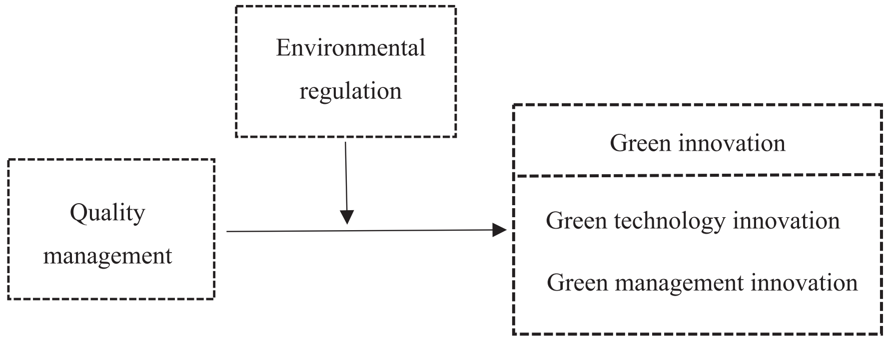

Fig. 1. Research model.

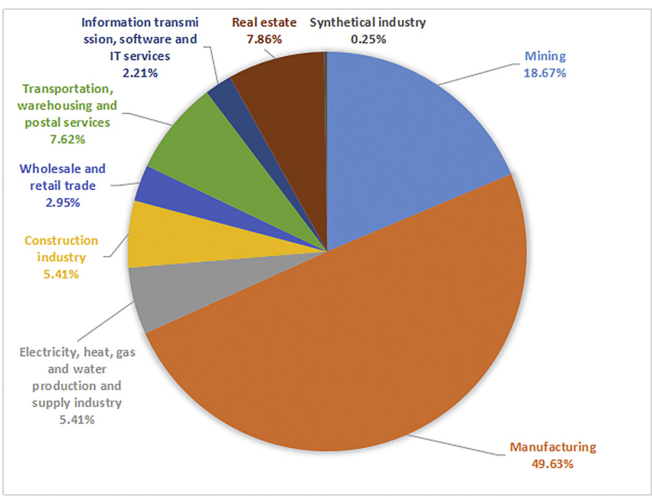

Fig. 2. Sample distribution of total observations by industry.

Synthetical industry is the least represented industry, which only has 1 sampling observation, Shanghai Zhangjiang Hi-Tech Park Development Corporation, in a seven year Range.

3.2. Measurements of variables

3.2.1. Dependent variable

3.2.1.1. Green innovation. As discussed in Section 2, most studies decompose green innovation into green technology innovation (GTI) and green management innovation (GMI). As to GTI, most previous studies employed green patents as a proxy (Brunnermeier and Cohen, 2003). Firstly we searched all three kinds of application patents which include patent of appearance, patent of utility model and patent for invention. Secondly based on the reality of China's economic conditions, green patents of sample observations were selected using the following Chinese keywords: “environmental”, “green”, “sustainable”, “ecology”, “clean”, “cycling”, “saving”, “low carbon”, “emission reduction”, “energy saving”, “environmental protection”, and “environmental pollution” (Bansal and Clelland, 2004; Cormier and Magnan, 2015; Li et al., 2016). In this study, there were about 32.2% observations (131 out of 407) which had no green patents. Thus, we divided them into two categories: 1 for firms with one or more green patents, 0 for no green patent. We also lag one year to avoid endogeneity.

Management innovation refers to the application of new ideas to improve organizational structures and systems, and processes pertaining to the social structure of an organization (Damanpour, 1987; Weerawardena, 2003). The implementation of the Environmental Management Systems such as ISO 14001 will help corporations improve the efficiency of operation and reduce environmental pollution (Qi et al., 2012; Searcy et al., 2012). We measure GMI by whether the corporation passed ISO 14001 certification lagging one year (Lin et al., 2014), 1 for firms which passed the certification, 0 for others.

3.2.2. Independent variable

3.2.2.1. Quality management. Empirical studies focus on ISO 9001 certification and total quality management to address quality management (Pereira-Moliner et al., 2012). The ISO9001 standard is based on eight quality management principles: customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making and mutually beneficial supplier relationships (ISO, 2005, 2012). Since ISO 9001 contains the basic requirements for a quality management system, we measure quality management according to whether the corporation passed ISO 9001, 1 for firms which passed the certification, 0 for others.

3.2.3. Moderating variable

Environmental regulation Firms' environmental initiatives are influenced by the political institutions, especially in China. Some scholars adopt pollution abatement investment and operating costs of pollution control facilities to measure environmental regulation (Morgenstern et al., 2002; Cole and Elliott, 2007). The investment of pollution control that directly impacts the enterprise production behavior reflects the intensity of environmental regulation (Ren et al., 2016). Therefore we employed the logarithm of each province's actual investment of pollution control which includes industrial pollution control investment, construction project “three simultaneous” environmental protection investment and the operating costs of pollution control facilities to measure environmental regulation. The data of these indicators can be directly obtained from *China Yearbook on Environment*.

3.2.4. Control variables

The corporate properties, industry type and region would affect firms' investment behavior. Therefore, this study incorporates the following variables to control their possible effects.

3.2.4.1. Firm size. Larger firms face greater pressure from the government, the media and NGOs. These stakeholders discourage them from conducting irresponsibility activities (Liu and Anbumozhi, 2009). On the other hand, larger firms can easily get access to various resources, which would promote investments in green innovation (Liang and Liu, 2017). We employed the logarithm of total assets to measure firm size.

3.2.4.2. Ownership. State-owned enterprises (SOEs) are highly influenced by national policies, especially as far as sustainable development (Li et al., 2016). They face greater environmental regulation pressure compared to other firms. A zero–one dummy variable was used: 1 for SOEs, 0 for others.

3.2.4.3. Financial performance. The higher a corporation's profitability is, the more inclined the corporation is to participate in green practices with the support of resources (Li and Tang, 2010). We adopt ROA (return on assets) as the proxy for financial performance.

3.2.4.4. Shareholder concentration. Shareholder concentration has significant influences on corporate social and environmental behavior (Li et al., 2016). It is measured according to the shareholding proportion of the largest shareholders.

3.2.4.5. Leverage. Companies with high financial leverage face a high asset-liability ratio, and high leverage will force companies to take measures such as green innovation to meet the requirements of stakeholders for sustainable development. Here leverage is measured as liabilities/total assets.

3.2.4.6. Industry type. The sample companies involve a variety of industries such as Mining, Manufacturing, Construction industry, Wholesale and retail trade and so on. Compared to cleaner industries, companies in environmentally sensitive industries are under more stringent supervision of the government (Boesso and Kumar, 2007). According to the Ministry of Environmental Protection of China, the following industries are environmentally sensitive industry, including "Production and Supply of Electric Power and Heat Power", "Manufacture of Textile", "Manufacture of Non-metallic Mineral Products", "Smelting and Pressing of Ferrous Metals", "Manufacture of Chemical Fibres", "Manufacture of Raw Chemical Materials and Chemical Products", "Manufacture of Liquor, Beverages and Refined Tea, Mining and Washing of Coal, Production and Supply of Gas", "Extraction of Petroleum and Natural Gas", "Processing of Petroleum", "Coking and Processing of Nuclear Fuel", "Manufacture of Medicines, Smelting and Pressing of Non-ferrous Metals", and "Manufacture of Paper and Paper Products". A dummy variable is introduced here, 1 for environmentally sensitive industries, 0 otherwise.

3.2.4.7. Region. There are huge differences in social, culture and economic conditions among Chinese eastern, central and western regions. As the eastern region is the most developed but polluted area, it has the capacity and motivation to participate in green innovation. A dummy variable is introduced here, 0 for the eastern region and 1 for central and western regions.

Table 1 illustrates the symbols and measurements of the variables used in this study.

3.3. Model

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

Main Effect Models:

$$GTI_{i+1} = \alpha_0 + \alpha_1 QM_i + \alpha_2 Size + \alpha_3 Own_i + \alpha_4 Ind_i + \alpha_5 \mathrm{Reg}_i + \alpha_6 FP_i + \alpha_7 Lev_i + \alpha_8 SC_i + \varepsilon_{1i}$$

$$GMI_{i+1} = \beta_0 + \beta_1 QM_i + \beta_2 Size + \beta_3 Own_i + \beta_4 Ind_i + \beta_5 \mathrm{Reg}_i + \beta_6 FP_i + \beta_7 Lev_i + \beta_8 SC_i + \varepsilon_{2i}$$

Moderating Effect models:

$$GTI_{i+1} = \chi_0 + \chi_1 QM_i + \chi_2 ER_\mathrm{i} + \chi_3 QM_i \times ER_i + \chi_4 \mathrm{Size}_i + \chi_5 Own_i + \chi_6 Ind_i + \chi_7 \mathrm{Reg}_i + \chi_8 FP_i + \chi_9 Lev_i + \chi_{10} SC_i + \varepsilon_{3i}$$

$$GMI_{i+1} = \delta_0 + \delta_1 QM_i + \delta_2 ER_i + \delta_3 QM_i \times ER_i + \delta_4 \mathrm{Size}_i + \delta_5 Own_i + \delta_6 Ind_i + \delta_7 \mathrm{Reg}_i + \delta_8 FP_i + \delta_9 Lev_i + \delta_{10} SC_i + \varepsilon_{4i}$$

where: GTI_{i+1} is whether firm i had a green patent, 1 for firms with one or more green patents, 0 for no green patent; GMI_{i+1} is whether firm i obtained an ISO 14001 certification, 1 for the certified, 0 for others; $\mathrm{QM_i}$ is whether firm i obtained an ISO 9001 certification, 1 for the certified, 0 for others; $\mathrm{Size_i}$ is the log-transformed of firm i's year-end total assets; $\mathrm{ER_i}$ is the logarithm of each province's actual investment of pollution control; $\mathrm{Own_i}$ is 1 for SOEs, 0 for others; $\mathrm{Ind_i}$ is 1 for heavily polluting industries, 0 otherwise; $\mathrm{Reg_i}$ is 0 for firms that located in Eastern China, and 1 otherwise; $\mathrm{FP_i}$ is measured by ROA; $\mathrm{Lev_i}$ is total liabilities divided by total assets; $\mathrm{SC_i}$ is the shareholding proportion of the largest shareholder; α_0 to α_8 is the coefficients; β_0 to β_8 is the coefficients; χ_1 to χ_{10} is the coefficients; δ_1 to δ_{10} is the coefficients; ε_{1i} to ε_{4i} is the error term.

4. Empirical analysis

4.1. Descriptive statistics analysis

Table 2 describes the changes of the key dichotomous variables by year and industry. It shows that observations from different industries behave quite differently. Panel A reflects that, only 12.5% observations (4 out of 32) in Real estate have green patents, while about 82.18% observations (166 out of 202) in Manufacturing with one or more green patents. Panel B and Panel C both present that observations in environmental sensitive industries (e.g., Mining, Manufacturing) are more likely to apply for environmental management and quality management certification.

As shown in Table 3, we apply Cross-tabulation analysis to test the correlations between the key dichotomous variables (corporate

Table 1
Measurements of variables.

Variables	Symbols	Measuring methods
Green technology innovation	GTI	Dummy variable lagging one year, 1 for firms with one or more green patents, 0 for no green patent.
Green management innovation	GMI	Dummy variable lagging one year, 1 for firms which passed ISO14001, 0 for others.
Quality management	QM	Dummy variable, 1 for firms which passed ISO 9001, 0 for others.
Environmental regulation	ER	measured by the logarithm of each province's actual investment of pollution control
Firm size	Size	measured by the logarithm of total assets
Ownership	Own	Dummy variable, 1 for state-owned enterprises (SOEs) and 0 for others.
Industry Type	Ind	According to Ministry of Environmental Protection of China, 1 for environmentally sensitive industries, 0 otherwise.
Region	Reg	Dummy variable, 0 for firms that located in Eastern China, 1 otherwise.
Financial performance	FP	measured by ROA (return on assets).
Leverage	Lev	measured by total liabilities divided by total assets.
Shareholder concentration	SC	measured by the shareholding proportion of the largest shareholder.

Table 2
Variation of the key dichotomous variables by year and industry.

Panel A: Variation of corporate green technology innovation by year and industry

Year:	Green technology innovation							Subtotal	total observations	%
	2009	2010	2011	2012	2013	2014	2015			
Construction industry	0	1	2	3	5	2	2	15	22	68.18
Electricity, heat, gas and water production and supply industry	1	1	1	2	4	2	2	13	22	59.09
Information transmission, software and IT services	0	1	1	1	1	2	2	8	9	88.89
Manufacturing	19	20	21	24	27	25	30	166	202	82.18
Mining	5	9	10	9	10	10	6	59	76	77.63
Real estate	0	2	0	0	0	1	1	4	32	12.50
Synthetical industry	0	0	0	0	0	0	0	0	1	0.00
Transportation, warehousing and postal services	1	1	1	1	1	1	0	6	31	19.35
Wholesale and retail trade	0	1	0	2	0	2	0	5	12	41.67
Total by year	26	36	36	42	48	45	43	276	407	67.81

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

Year:	Green Management innovation								total observations	%
	2009	2010	2011	2012	2013	2014	2015	Subtotal		
Construction industry	0	3	3	5	6	3	2	22	22	100.00
Electricity, heat, gas and water production and supply industry	2	2	1	1	2	2	2	12	22	54.55
Information transmission, software and IT services	0	0	0	0	0	1	1	2	9	22.22
Manufacturing	14	16	16	19	17	20	25	127	202	62.87
Mining	1	4	5	6	10	5	3	34	76	44.74
Real estate	1	1	1	1	0	0	0	4	32	12.50
Synthetical industry	0	1	0	0	0	0	0	1	1	100.00
Transportation, warehousing and postal services	1	0	0	0	1	0	0	2	31	6.45
Wholesale and retail trade	0	0	0	0	0	0	0	0	12	0.00
Total by year	19	27	26	32	36	31	33	204	407	50.12

Panel C: Variation of corporate quality management by year and industry

Year:	Quality management								total observations	%
	2008	2009	2010	2011	2012	2013	2014	Subtotal		
Construction industry	0	3	2	4	3	2	1	15	22	68.18
Electricity, heat, gas and water production and supply industry	2	2	1	1	2	2	1	11	22	50.00
Information transmission, software and IT services	0	0	0	0	0	1	1	2	9	22.22
Manufacturing	12	16	15	20	20	19	20	122	202	60.40
Mining	1	4	5	7	10	7	4	38	76	50.00
Real estate	1	1	1	1	0	0	0	4	32	12.50
Synthetical industry	0	1	0	0	0	0	0	1	1	100.00
Transportation, warehousing and postal services	3	1	1	1	2	0	1	9	31	29.03
Wholesale and retail trade	0	0	0	0	1	1	1	3	12	25.00
Total by year	19	28	25	34	38	32	29	205	407	50.37

Table 3
Cross-tabulation of key dichotomous variables.

			QM		Total	Contingency coefficient	χ^2 test
			QM = 0	QM = 1			
GTI_{t+1}	GTI = 0	Count	87	44	131	0.225**	21.76**
	GTI = 1	Count	115	161	276		
GMI_{t+1}	GMI = 0	Count	164	39	203	0.528**	157.271**
	GMI = 1	Count	38	166	204		

Notes: †p<10%, *p<5%, **p<1%. Two-tailed. N = 407.

green technology innovation, green management innovation and quality management). It reveals that both green technology innovation and green management innovation are related with quality management.

Table 4 provides the descriptive statistics and correlation analysis of all variables. As shown in the table, all the correlation coefficients are lower than 0.622, which reflects an acceptable level of multicollinearity.

4.2. Hypothesis testing

As the data is unbalanced panel data with binary outcome variables which does not fulfill the assumption of multivariate normality, we apply generalized estimating equations (GEE) approach to test our hypotheses. The GEE model is an extension of generalized linear models to the case of correlated data, which accounts for autocorrelation (e.g. yearly measurements of the same corporations) by estimating the correlation structure of the error terms (Liang and Zeger, 1986).

4.2.1. Main effect

This section tested the effect of quality management on green innovation. As shown in Table 5, Model 1 and Model 5 include all the control variables. Then, the independent variable, quality management, is added in Model 2 and Model 6. Model 2 suggests that quality management is significantly negatively correlated with green management innovation ($\beta = -2.920$, $p < 0.01$), and Model 6 shows that quality management is significantly negatively

Table 4
Descriptive statistics and correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11
1.GTI_{t+1}	1										
2.GMI_{t+1}	0.217**	1									
3.QM	0.231**	0.622**	1								
4.ER	−0.069	0.140**	0.111*	1							
5.Size	−0.063	−0.129**	−0.075	−0.139**	1						
6.Own	0.025	−0.058	−0.003	−0.268**	0.021	1					
7.Ind	0.077	0.013	0.019	−0.120*	0.077	0.08	1				
8.Reg	−0.032	0.100*	0.032	−0.122*	−0.119*	−0.068	0.111*	1			
9.FP	0.006	0.090+	0.004	0.170**	−0.116*	−0.096†	0.014	0.316**	1		
10.Lev	0.051	0.108*	0.145**	−0.055	0.041	0.004	−0.249**	−0.244**	−0.609**	1	
11.SC	0.100*	−0.074	−0.01	−0.367**	0.052	0.329**	0.203**	−0.08	−0.089+	−0.035	1
Min	0	0	0	11.770	20.734	0	0	0	−0.213	0.056	6.467
Max	1	1	1	15.604	28.446	1	1	1	0.315	1.151	86.419
Mean	0.678	0.501	0.504	14.115	24.771	0.830	0.391	0.307	0.072	0.533	44.027
SD	0.468	0.501	0.501	0.818	1.293	0.376	0.489	0.462	0.070	0.182	18.793

Notes: +p<10%, *p<5%, **p<1%. Two-tailed. N = 407.

correlated with green technology innovation ($\beta = -0.979$, $p < 0.01$). Therefore, both H1a and H1b were supported. What should be noted is that the effect of firm size on green innovation is not significant ($\beta = -0.175$, $p > 0.1$; $\beta = -0.102$, $p > 0.1$), indicating size is not a decisive factor of green innovation.

4.2.2. Moderating effects

This section tested the effect of environmental regulation on green innovation. Model 3 and Model 7 include the main independent variable, moderating variables and the control variables. Model 3 and Model 7 showed that quality management was still significantly negatively correlated with green management innovation ($\beta = -2.897$, $p < 0.01$) and green technology innovation ($\beta = -1.027$, $p < 0.01$), as environmental regulation are introduced.

Table 5
Generalized estimating equations results.

Dependent Variables	Green Management Innovation$_{t+1}$			
	Model 1	Model 2	Model 3	Model 4
1. Control Variables				
Own	0.130	0.224	0.150	0.193
Ind	−0.431	−0.282	−0.306	−0.337
Reg	−0.330	−0.364	−0.446	−0.475
Lev	3.482**	2.446+	2.501+	2.564+
SC	−0.005	−0.008	−0.006	−0.007
FP	7.143*	6.836*	6.434*	6.289*
Size	−0.183†	−0.175	−0.160	−0.145
2. Independent Variable & Moderating Variable				
QM		−2.920**	−2.897**	−2.918**
ER			0.197	−0.089
3. Moderating Effect				
QM × ER				0.809+
Dependent Variables	**Green Technology Innovation$_{t+1}$**			
	Model 5	Model 6	Model 7	Model 8
1. Control Variables				
Own	0.041	0.037	0.132	0.196
Ind	−0.457	−0.392	−0.382	−0.449
Reg	0.211	0.268	0.371	0.234
Lev	1.535	0.892	0.857	0.935
SC	0.011	0.012	0.008	0.005
FP	2.974	2.031	2.530	2.288
Size	−0.127	−0.102	−0.121	−0.100
2. Independent Variable & Moderating Variable				
QM		−0.979**	−1.027**	−0.994**
ER			−0.268	−0.805*
3. Moderating Effect				
QM × ER				1.089*

Notes: +p<10%, *p<5%, **p<1%. Two-tailed. N = 407.

Model 4 was generated based on Model 3 by introducing the interactive items of independent variable and moderating variables. The results indicated that environmental regulation have moderating effects on the relationship between quality management and green management innovation ($\beta = 0.809$, $p < 0.1$).

Model 8 was generated based on Model 7 by introducing the interactive item of quality management and environmental regulation. The results indicated that environmental regulation has a moderating effect on the relationship between quality management and green technology innovation ($\beta = 1.089$, $p < 0.05$). Therefore, H2a and H2b were supported.

In order to demonstrate the moderating effects of environmental regulation, we plotted the relationships at two levels of the moderator (i.e., above and below one standard deviation from mean, representing high and low levels, respectively) (Li and Tang, 2010). Figs. 3 and 4 present these plots. Fig. 3 shows the moderating effect of environmental regulation: when environmental regulation is high, GMI declines only from −0.659 to −0.762; when environmental regulation is low, the GMI declines from 0.652 to −1.235. Fig. 4 displays that when environmental regulation is high, GTI increases from −0.080 to −2.339, but the GTI declines from 0.061 to −3.523 when environmental regulation is low.

5. Discussions

First, quality management exhibits a significant negative correlation with both green management innovation and green technology innovation, as demonstrated by Lynn et al. (1996) but contradictory to the study by López-Mielgo et al. (2009). This result

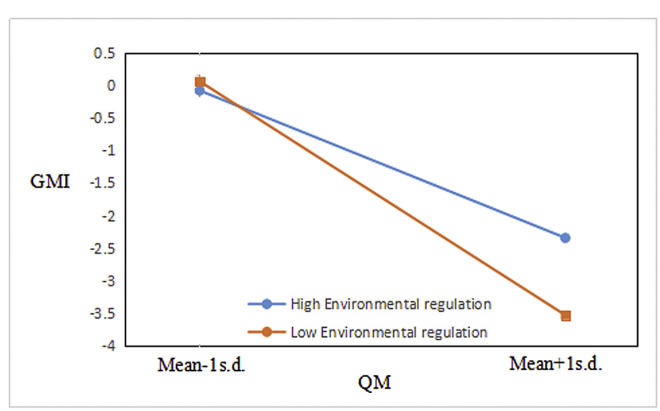

Fig. 3. Moderating effect of environmental regulation on QM-GMI relationship.

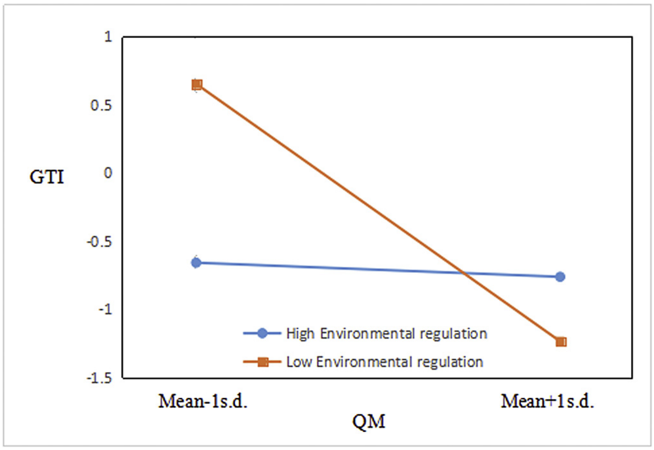

Fig. 4. Moderating effect of environmental regulation on QM-GTI relationship.

may be attributed to the double externality problem of green innovation—i.e., the derivation of social benefits from profit-motivated innovations. Given the philosophy of customer focus and continuous improvement of quality management, corporate internal practices for adoption mainly cover general product improvement aimed at satisfying existing demands from customers, government, or other stakeholders and without special concern on the environmental aspect. In ISO 9001 quality management system standards, the entire process is almost under control to eliminate accidents and correct the deviation, ultimately reaching the predetermined target. This standardization and normalization can hinder corporate innovation to a certain extent. With cost efficiency and risk avoidance considered, more resources and capabilities are provided toward the continuous improvement advocated by quality management rather than searching for a breakthrough in green technology or management.

Second, environmental regulation significantly reduces the negative effects of quality management on green management innovation and green technology innovation, indicating that the Chinese government is playing its role as expected. This may be because that a series of rigorous environmental regulations increases the punishment to those law-breakers, and strict environmental regulation reduces the uncertainty of investing in the green innovation and mitigates the negative externality of green innovation, to promote the implementation of corporate environmentally-friendly practices for obtaining environmental regulatory legitimacy. This result is consistent with many previous studies that have demonstrated the positive effect of environmental regulation on corporate environmental or ecological innovation in developed countries (Demirel and Kesidou, 2011; Berrone et al., 2013).

6. Research conclusions and implications

6.1. Conclusions

This study analyzed the impact of quality management on green innovation by considering the moderating role of environmental regulation. With a sample of 407 observations obtained from the top 100 listed companies of China from 2008 to 2014, we found that quality management was both significantly negatively correlated with green technology innovation and green management innovation. In addition, environmental regulation significantly mitigates the negative impact of quality management on both green management innovation and green technology innovation.

6.2. Practical implications

The aforementioned findings have several implications. First, the results indicate that quality management limits corporate focus on developing the existing production and management systems instead of exploring green innovation aimed at corporate sustainable development. Corporate quality management tools and practices need to be aligned with sustainability considerations (Maxwell and Van der Vorst, 2003; Luttropp and Lagerstedt, 2006). Moreover, quality management principles have to be incorporated into sustainability management to create an “integration”. Firms should further research the integration of green innovation or sustainability approaches with their core business processes (Asif et al., 2013).

Second, the significant mitigating effect of environmental regulation illustrates the importance of enhanced institutional design and implementation. Companies should comply with environmental regulation to maintain social license to operate (Ford et al., 2014). The appropriate environmental standards and strict environmental supervision could trigger green innovation within companies that might be lower the costs of compliance. The Chinese government has the responsibility and ability to play its expected role; thus, it should formulate stricter environmental regulations and implement them rigorously to induce firms into implementing green innovation. Simultaneously, the government should increase its financial support for corporate green innovation.

6.3. Limitations and future research opportunities

This study has several limitations that future research can help to clarify. First, corporate green innovation is the result of multiple factors, such as market competition, environmental legitimacy, the dynamic capabilities of senior executives. This study only focused quality management and environmental regulation. Future study should take multiple factors into consideration to have a comprehensive study. Second, we only focused on the Chinese listed companies, so the findings may not be applicable to other countries. Future research should establish a comparison with the findings of relevant studies in developing and developed countries.

Conflict of interest

Author Dayuan Li declares that he has no conflict of interest.
Author Yini Zhao declares that she has no conflict of interest.
Author Lu Zhang declares that she has no conflict of interest.
Author Xiaohong Chen declares that he has no conflict of interest.
Author Cuicui Cao declares that he has no conflict of interest.

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