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Green process innovation, green product innovation, and corporate financial performance: A content analysis method☆

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ABSTRACT

Green technology innovation has received continuous attention from the business sector in recent years, yet few studies have examined the internal mechanisms and contingent conditions that link green technology innovation to a firm's financial performance. Using data from 209 listed companies that belong to heavily polluting manufacturing industries, collected via the content analysis method, we find that green process innovation has a positive impact on green product innovation, and that both green process innovation and green product innovation can improve a firm's financial performance. We also find that green product innovation mediates the relationship between green process innovation and a firm's financial performance, and that a firm's green image moderates the relationship between green product innovation and financial performance. However, our study shows that the moderating effect of green subsidies on the relationship between green product innovation and a firm's financial performance is not supported. Based on these findings, we provide several recommendations for managers and government entities to effectively implement green technology innovation.

1. Introduction

Green technology innovation has received continuous attention from the business sector because of the growing concern over the state of the environment (Abdullah, Zailani, Iranmanesh, & Jayaraman, 2016). In fact, it is essential that manufacturing firms, especially those in heavily polluting manufacturing industries, shoulder the responsibility of protecting the environment. In addition to benefits from adjusting their processes to protect the environment, firms should also consider customer needs and corporate social responsibility (Woo, Chung, Chun, Han, & Lee, 2014).

In certain respects, pollution can be seen as evidence of the inefficient use of resources (Chen, 2008), which affects firms' profits. New technology has been credited with solving environmental problems by mitigating the effects of pollutants (Jaffe, Newell, & Stavins, 2005). Here, green innovation has been deemed essential in dealing with environmental issues (Kong, Feng, & Ye, 2016). Environmental sustainability is imperative, and provides an opportunity to improve competitiveness using win-win logic (Porter & Van der Linde, 1995), with companies that are pioneers in green innovation strategies potentially achieving and sustaining competitive advantages (Albort-Morant, Leal-Millán, & Cepeda-Carrión, 2016). According to Rekik and Bergeron (2017), implementing green practices is beneficial to small and medium-sized enterprises (SMEs) in terms of both financial performance and environmental performance.

Green technology innovation is expected to produce a double dividend: limiting the environmental burden while contributing to the technological modernization of the economy (Rennings, Ziegler, Ankele, & Hoffmann, 2006). According to Ziegler and Nogareda (2009), particular criteria must be met in order for green technology innovation to work effectively: first, it must be based on new technological knowledge, and second, it must already be in place (i.e., new products must have already been introduced into the market or new processes must have already been introduced within the firm). Many manufacturing firms have started to implement both process-oriented, environmentally-beneficial strategies and product-oriented,

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environmentally-beneficial strategies.

Generally, green technology innovation is often divided into green process innovation and green product innovation (Salvadó, de Castro, Verde, & López, 2012, p.39). Previous research has examined the impacts of different types of green technology innovation, suggesting that both green process innovation and green product innovation are performance predictors (e.g., Chan, Yee, Dai, & Lim, 2016; Cheng, Yang, & Sheu, 2014; Kam-Sing Wong, 2012; Xie, Huo, Qi, & Zhu, 2016). However, much of the literature has ignored the internal mechanisms and contingent conditions of the relationships between green technology innovation and firm performance (e.g., Chang, 2011; Chen, Lai, & Wen, 2006; Chiou, Chan, Lettice, & Chung, 2011; Kam-Sing Wong, 2012; Sezen & Çankaya, 2013). Part of the problem is that green technology innovation involves a lot of uncertainty because of the so-called "double externality" problem (Rennings, 2000): on the one hand, the potential positive effect of green innovation on a firm's financial performance takes time to materialize (Aguilera-Caracuel & Ortiz-de-Mandojana, 2013), while on the other hand, the transformation of green technology innovation into financial rewards depends on many underlying mechanisms and contingent conditions. Given that innovation failure has become an increasingly important topic, especially pertaining to heavily polluting industries (Dai & Zhang, 2017), it is worth investigating the factors that can affect firms' financial returns after applying green strategies. Thus, two research questions are addressed in this study: (a) First, what are the relationships between green process innovation, green product innovation, and firms' financial performance? (b) Second, are there contingent factors that affect the relationship between green product innovation and firms' financial performance?

Theoretical and empirical evidence suggests that the rate and direction of technological advances are influenced by market and regulatory incentives, as well as by economic, incentive-based policies (Jaffe et al., 2005). The present study first investigates the implementation of green product innovation from the perspective of market incentives resulting from the interaction between innovation and sustainability (Dangelico & Pujari, 2010). Next, our study focuses on the perspective of regulatory incentives. According to Jaffe et al. (2005), market failures provide a strong rationale for a suite of public policies that foster emissions reductions, as well as the development and adoption of environmentally beneficial technology. In this way, green subsidies are viewed as important tools that governments can use to motivate and support green innovation strategies (Xie et al., 2016), accomplished by decreasing the financial burden on firms during the implementation of green innovations.

According to Chen (2010), appearing "green," or presenting a "green image" is defined as "a set of perceptions of a brand in a consumer's mind that is linked to environmental commitments and environmental concerns" (p.309). A green image can help firms attract more customers by affecting consumer choice and improving consumer brand loyalty (Chang & Fong, 2010). Many consumers want to buy products from environmentally friendly firms, although there are, of course, some who will not pay premium prices for green products (Dangelico & Pujari, 2010). Nonetheless, generally speaking, having a green image is more important than ever for firms to win over more customers who are willing to pay more for the newest green products.

To fill the aforementioned research gap and to extend our understanding of how green technology innovation can improve firms' financial performance, we propose a comprehensive theoretical framework that examines the mediating mechanisms and contingent conditions of the relationship between green technology innovation and financial performance. This study thus expands our current understanding of the ways in which firms can improve the financial returns from green technology innovation by examining the mediating effect of green product innovation and the moderating effects of a firm's green image and green subsidies. Next, we measure green process innovation and green product innovation at the firm level by using the content analysis method, thus making our findings more specific and more meaningful. Finally, we provide a discussion of the implications for firms and governments that implement green technology innovation and increase the financial rewards of applying green technology innovation, which can help policymakers design more powerful tools to guide green innovation practices.

2. Theoretical framework and hypotheses

2.1. The two types of green technology innovation

Green technology innovation includes two primary strategies: green process innovation and green product innovation (Salvadó et al., 2012, p.39). Green product innovation aims to change or modify product designs by using nontoxic compounds or biodegradable materials during the production process in order to reduce the disposal impact on the environment and to improve energy efficiency (Lin, Tan, & Geng, 2013). Green product innovation requires a fresh view of the product life cycle, from the manufacturing process to distribution, and from use to disposal or reuse/recycling—in other words, a "cradle to grave" approach (Noci & Verganti, 1999). More specifically, green product innovation includes improvements in the durability or recyclability of products, the reduction of raw materials, the selection of environmentally healthier raw materials, and the removal of hazardous substances (Kivimaa & Kautto, 2010). Meanwhile, green process innovation aims to reduce energy consumption during the production process or during the process that converts waste into an article of value (Salvadó et al., 2012, p.39). Particularly, green process innovation includes reducing air or water emissions, lessening water consumption, improving resource and energy efficiency, and switching from fossils fuels to bioenergy (Kivimaa & Kautto, 2010). By doing so, those firms pioneering green technology innovation strategies can achieve and sustain various competitive advantages (Albort-Morant et al., 2016), obtaining not only cost efficiency but also profitability (Chan et al., 2016).

Prior research has suggested that a firm's process innovation is closely linked to its product innovation (Oke, 2007). We posit that a firm's green process innovation is positively related to its green product innovation for several reasons. First, because green process innovation requires systematic improvements to the entire operational and managerial processes to improve the efficiency of resources (Li et al., 2017), it may also promote the design and production of green products while laying the foundations for implementing green product innovation. According to Kam-Sing Wong (2012), green process innovation can help firms achieve success in producing new green products by developing a green product competitive advantage. Second, process innovation can help firms improve their product quality, widen product assortment, or produce entirely new products, thus allowing them to enhance their market share (Bigliardi & Ivo Dormio, 2009; Damanpour, 2010). Hence, process innovation plays an important role in product innovation (Martinez-Ros, 1999). Thus, we advance the following hypothesis:

Hypothesis 1. The level of a firm's green process innovation is positively correlated to its level of green product innovation.

2.2. Green process innovation and a firm's financial performance

Green process innovation tends to be more internally sourced and costlier to implement, but has also proven to be more effective than other green practices (Gopalakrishnan, Bierly, & Kessler, 1999). Green process innovation can be an additive solution (e.g., smokestack scrubbers) or can be integrated into the production process through substituting inputs, optimizing production, or reclaiming outputs (Rennings, 2000).

Previous research has shown that green process innovation has a

positive impact on firms' competitive advantage and sustainability (Chen et al., 2006; Cheng et al., 2014; Sezen & Çankaya, 2013). Thus, overall, it makes good business sense for firms to invest in green process innovation (Li et al., 2017). Therefore, we posit that a firm's green process innovation practices are conducive to enhancing its financial performance. First, green process innovation improves existing production processes or adds new processes to reduce adverse environmental impacts, thus improving a firm's environmental compliance and bringing differentiation advantages (Cheng et al., 2014). Furthermore, Xie et al. (2016) found that clean technologies and end-of-pipe technologies that are essential aspects of green process innovation are positively related to financial performance. Thus, we hypothesize:

Hypothesis 2. A firm's green process innovation is positively correlated to its financial performance.

2.3. The mediating role of green product innovation

Green product innovation or the introduction of new or improved products, such as improvements in technical components or materials (Cheng et al., 2014; Pujari, 2006), aims to reduce environmental impacts during a product's life cycle (Christensen, 2011), and satisfy market needs by creating new products (Cheng et al., 2014). In recent years, green product innovation has been recognized as one of the key factors in achieving growth and environmental sustainability (Dangelico & Pujari, 2010).

Additionally, investing in green product innovation can help prevent companies from facing environmental protests and legal penalties while also allowing them to develop new market opportunities and achieve new green product success (Chiou et al., 2011; Kam-Sing Wong, 2012). Moreover, green product innovation is critical for developing green competency, strengthening a firm's green image, and improving its financial performance (Ar, 2012; Chen et al., 2006; Cheng et al., 2014; Huang & Jim Wu, 2010; Lin et al., 2013).

As discussed in H1 and H2, we hypothesize that green process innovation is key for improving a firm's financial performance and facilitating green product innovation. When high levels of product innovation are simultaneously backed by high levels of manufacturing process innovation, this strategy provides the strongest competitive advantage by far (Kotabe & Murray, 1990). In addition, according to Damanpour (2010), the integrative view of research on green process innovation and green product innovation reflects the so-called "resource-based view" (RBV), in which the synergistic influence of a firm's internal resources—including its product and process knowledge resources—positively impacts the firm's competitive advantage and performance.

Green process innovation requires the systematic improvement of the whole operational and managerial process, which demands high levels of financial investment (Li et al., 2017). This type of innovation is also time-consuming and can produce effects that are not always perfectly direct or evident (Li et al., 2017). Despite this, we propose that green process innovation can promote green product innovation (see H1), which can be invested into producing new products, thus easily translating into increased revenue and technological advantage (Li et al., 2017). Hence, we argue that green process innovation can improve a firm's financial performance by encouraging green product innovation, leading to the following hypothesis:

Hypothesis 3. Green product innovation mediates the relationship between green process innovation and a firm's financial performance.

2.4. The moderating role of a green image

A firm's corporate image can be understood as the desired general impression of the firm in the minds of its key stakeholders (Amores-Salvadó, Martín-de Castro, & Navas-López, 2014). A firm's corporate green image involves the stakeholders' perception of the firm's positive environmental or green characteristics. A green image is viewed as an important determinant of consumer satisfaction, and firms that invest in improving their green image not only avoid the potential trouble of environmental protests and legal penalties but also enhance consumer expectations about environmental friendliness and sustainability (Chen, 2010). What is more, a green image can help firms generate a more positive public image, which, in turn, can enhance sales and increase stock prices (Zhu & Sarkis, 2006). Many companies in China have recently tried to establish themselves as "green" due to increasing environmental awareness and greater public pressure (Zhu & Sarkis, 2006).

Green product innovation has a positive impact on firm performance (Lin et al., 2013). However, a firm's green product innovation efforts only pay off when they are adequately promoted (Amores-Salvadó et al., 2014). According to both De Medeiros, Ribeiro, and Cortimiglia (2014) and Lin, Zeng, Ma, Qi, and Tam (2014), consumer pressure and expectation fulfillment are success factors. However, Rehfeld, Rennings, and Ziegler (2007) found that the higher prices—not lower quality or diminished reliability—of green products appear to be one of the major reasons for low market performance. According to Dangelico and Pujari (2010), consumers are often not willing to pay a premium price for green product attributes. Thus, maintaining or improving customer loyalty can be a challenge when firms begin to implement green product strategies.

In this regard, a firm's corporate image could be an important criterion to judge the quality of an unfamiliar product (Chang & Fong, 2010), and it may lead to increased consumer trust and, in turn, greater influence over consumers' purchasing decisions (Chen, 2010). A green image might also lead consumers to feel an increased affinity for a company or a specific product, causing brand loyalty to grow (Zhu & Sarkis, 2006). As a consequence, a firm's green image can potentially increase overall customer satisfaction (Chang & Fong, 2010)—meaning the more favorably a customer perceives a company's corporate image, the more positively they will perceive the company's reputation (Foroudi, Melewar, & Gupta, 2014; Heinberg, Ozkaya, & Taube, 2018). Given that customer loyalty and corporate reputation are crucial factors that influence potential return (Chang & Fong, 2010; Dangelico, 2016), a firm with a better green image can gain more economic return from its green product innovation, leading us to the following hypothesis:

Hypothesis 4. A green image moderates the relationship between a firm's green product innovation and its financial performance.

2.5. The moderating role of green subsidies

Green product innovation, which involves minimizing environmental impacts by conserving energy and resources (Lee & Kim, 2011), is viewed as an important factor in achieving environmental and economic success. Amores-Salvadó et al. (2014), however, found that a firm's commitment to green product innovation has a positive, but not statistically significant effect on performance, suggesting that any financial compensation resulting from the initial product innovation investment could be considered insufficient by some managers. Thus, determining what green product technologies might achieve technical and commercial success is not without significant risk and uncertainty (Dangelico & Pujari, 2010; Lin, Zeng, Ma, & Chen, 2015). It is also important to note that a substantial investment in resources is necessary to obtain strong green product development performance (Chen, Chang, Lin, Lai, & Wang, 2016). Because of the high costs, only those companies with deep pockets can afford to invest in green product innovation (Dangelico & Pujari, 2010). Adding to the challenge, many consumers exert continuous pressure on firms to encourage green product innovation (Lin et al., 2014), yet they are often unwilling to pay premium prices for green product attributes (Dangelico & Pujari, 2010).

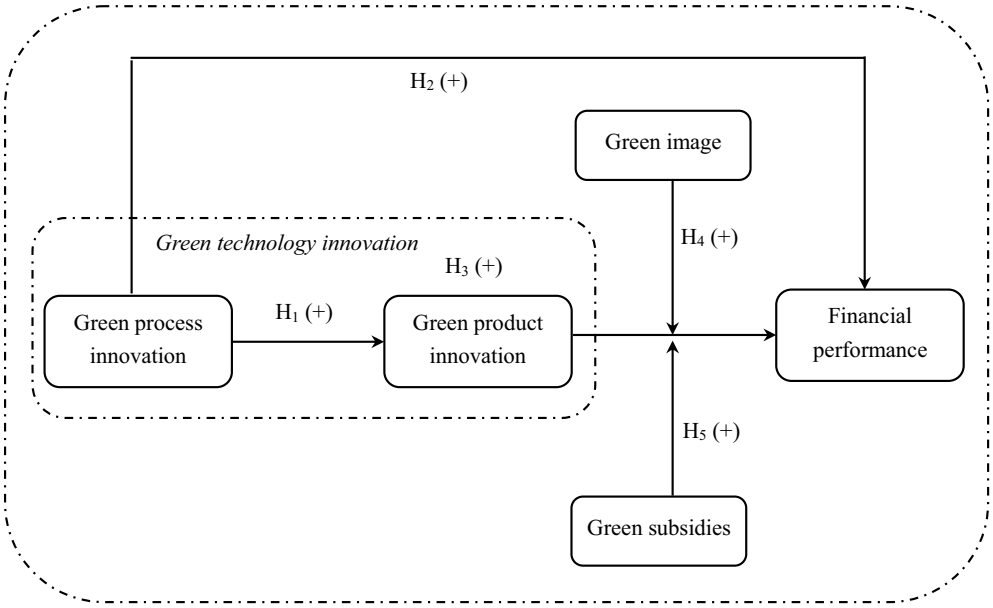

Fig. 1. Conceptual model.

Environmental law and policy are critical for the implementation of green product innovation (Chen, 2001; De Medeiros et al., 2014; Rehfeld et al., 2007). While a meaningful internal or external environmental standard is needed, unilaterally pursuing environmental goals without considering economic incentives could put firms in the "danger zone," where stricter standards may lead to lower overall environmental quality (Chen, 2001). Green subsidies—subsidies that manufacturing industries receive from the government to fund or aid their environmental practices (Xie et al., 2016)—can address market failures (Green, 2006). They can also be an effective way to balance regulatory strictness and innovation-friendliness. First, green subsidies can help firms internalize environmental costs while rewarding green investment (Horbach, Rammer, & Rennings, 2012; Xie et al., 2016), as well as mitigate financial pressures triggered by investing in green practices, which, in turn, encourages firms to develop greener products and practices. Second, green subsidies can help firms internalize green innovation practices (Horbach, 2008), support ecological responsibility, and fuel the active engagement of the resources necessary for developing green products.

Overall, green subsidies can help firms smooth away the difficulties caused by developing green products and encourage them to invest more resources in green product innovation, which, in turn, allow them to benefit more from green product innovation, which leads to the following hypothesis:

Hypothesis 5. Green subsidies moderate the relationship between a firm's green product innovation and its financial performance.

The conceptual model is shown in Fig. 1.

3. Data and variables

3.1. Data

For our research, we used the industry classification results of listed firms on the China Securities Regulatory Commission official website,[1] choosing an initial 1585 manufacturing firms from the list. Based on the environmental protection verification status of industries published by the Ministry of Environmental Protection of the People's Republic of China (2008, no. 373),[2] we chose 17 manufacturing industries in need of environmental protection verification. Companies listed as special treatment (ST) and particular transfer (PT) firms were omitted because these firms had experienced unusual financial performance. We also omitted firms that did not publish *Corporate Social Responsibility Reports* in 2013, which we needed to obtain data pertaining to green process innovation, green product innovation, and green image. Finally, using the content analysis method, we obtained a data set of 209 firms listed in the publication *Stock A Markets of Shanghai or Shenzhen Stock Exchange* in 2013. Data concerning green subsidies, financial performance, financial constraints, total assets turnover, age, and size of firms were obtained from the firms' annual reports.

3.2. Variables

3.2.1. Dependent variable: financial performance

Return on assets (ROA) is a standard accounting measure of financial performance commonly used in the green innovation literature, indicating the outcomes of specific past and present actions (Amores-Salvadó et al., 2014). ROA is more stable than sales growth or return on sales in measuring financial performance because of both the managerial effect of short-term activities and uncertainty about the external environment in emerging markets (Li & Wong, 2003). Thus, because of its stability and reliability, we used ROA to measure the financial performance of the firms.

3.2.2. Independent variable: green process innovation

In this study, green process innovation was divided into clean technologies and end-of-pipe technologies (del Río González, 2005; Rennings et al., 2006; Salvadó et al., 2012). According to Frondel, Horbach, and Rennings (2007), Hammar and Löfgren (2010), Klassen and Whybark (1999), and Lee and Rhee (2005), clean technologies were measured by three indexes, and following del Río González (2005), Frondel et al. (2007), and Hart (1995), end-of-pipe technologies were measured by two indexes (see Table 1). Data from both items were determined according to the description of a firm's *Corporate Social Responsibility Report* by using the content analysis method, whereby each item was scored 0 to 2: 0 if there was no related description; 1 if

[1] http://www.csrc.gov.cn/pub/newsite/scb/ssgshyfljg/201304/t20130402_223006.html.

[2] http://www.zhb.gov.cn/gkml/hbb/bgth/200910/t20091022_174891.htm#.

Table 1
Variables and measurements.

Variables	Measurements	Data sources	Sources
Firm size	Total assets (billion)	Firms' Annual Reports	Lin et al. (2015)
Financial constraints	Asset-liability ratio	Firms' Annual Reports	Xie et al. (2016)
Total assets turnover	Ratio of main business income to total assets	Firms' Annual Reports	Lucas and Noordewier (2016)
Firm age	Number of years listed in the Chinese stock market to year 2013	Firms' Annual Reports	Lin et al. (2015)
Green process innovation	PROC1. Aiming to reduce the consumption of resources and energy and improve resource and energy efficiency PROC2. Using recycled materials, recycling techniques, and environmental technologies PROC3. Applying environmental campaigns PROC4. Using pollution-control equipment PROC5. Adopting pollution-control projects and technologies	Firms' Corporate Social Responsibility Reports	Frondel et al. (2007); Klassen and Whybark (1999) Frondel et al. (2007); del Río González (2005)
Green product innovation	PROD1. Making changes to product designs in order to avoid polluting or toxic compounds within production processes PROD2. Improving and designing environmentally-friendly packaging for existing and new products PROD3. Making product design modifications aimed to improve energy efficiency during usage	Firms' Corporate Social Responsibility Reports	Amores-Salvadó et al. (2014); Chiou et al. (2011); Kam-Sing Wong (2012)
Green image	GI1. Complying with environmental regulations and having a high awareness of environmental risks GI2. Demonstrating strength in improving energy efficiency via corresponding environmental performance GI3. Demonstrating the ability to reduce waste via corresponding environmental performance	Firms' Corporate Social Responsibility Reports	Amores-Salvadó et al. (2014)
Green subsidies	Amount of subsidies related to environmental protection (billion)	Firms' Annual Reports	Lin et al. (2015)
Financial performance	Return on assets (ROA)	Firms' Annual Reports	Amores-Salvadó et al. (2014); Li and Wong (2003)

there was only a plain description without implementation details (e.g., detailed plans, an implementation process, or quantitative terms, thus indicating a firm was indeed conducting a related type of innovation); and 2 if there was a related description with rich details (i.e., numerical indicators to describe corresponding environmental practices). We computed the value of green process innovation as the average of clean technologies and end-of-pipe technologies.

3.2.3. Mediator: green product innovation

According to Amores-Salvadó et al. (2014), Chiou et al. (2011), Lin et al. (2013), and Kam-Sing Wong (2012), we measured green product innovation using three indexes (see Table 1). In our study, the three items were scored using the content analysis method described above.

3.2.4. Moderators

3.2.4.1. Green image. Amores-Salvadó et al. (2014) used items related to a firm's awareness of environmental risks and environmental achievements to capture their green image. Thus, in our study, green image was measured using three items (see Table 1). The three items were also scored using the content analysis method.

3.2.4.2. Green subsidies. Subsidies are most frequently used in environmental policy instruments by the government to incentivize environmental practices (Lin et al., 2015). Using the firms' annual reports, green subsidies were measured by the number of government subsidies related to environmental protections (Lin et al., 2015).

3.2.5. Controls

We controlled for the following variables that may influence financial performance. This first variable was firm size, used to consider the tendency of larger firms to achieve better performance (Chun, Shin, Choi, & Kim, 2013). Following Lin et al. (2015), we used a firm's total assets to measure its size. The second variable was financial constraints, used to control for the effect of a firm's financial structure and any lack of resources (Chun et al., 2013). Following Xie et al. (2016), we used the asset-liability ratio to measure financial constraints, which reflects the extent to which a firm's assets are financed by debt. The third variable was total assets turnover, which is an important indicator of a firm's operational performance. Following Lucas and Noordewier (2016), we used the ratio of main business income to total assets to measure total assets turnover in order to assess a firm's financial performance at the firm-level. The fourth control variable was firm age, as firms can lose their ability to compete and innovate over time, even though they can also bring knowledge, skills, and specialization to innovation (Isidro & Sobral, 2015). Following Lin et al. (2015), we measured firm age using the number of years from its initial listing in the Chinese stock market to the year 2013.

3.3. Reliability test

The data on green process innovation, green product innovation, and green image were obtained by using the content analysis method manually. The data were then coded by two coders. Following Hussain, Rigoni, and Orij (2018), we calculated the Krippendorff's alpha as the reliability measure for the data of the three variables discussed above; the value of alpha should have registered > 0.67 for us to draw useful conclusions. Following Hayes and Krippendorff (2007), we used KALPHA macro in SPSS to compute the Krippendorff's alpha.[3] Initially, 60 reports were coded by the two coders, and the inter-coder reliability was measured by these data. The values of Krippendorff's alpha for the indexes on green process innovation, green product innovation, and green image were all greater than the threshold value of 0.67, and thus, the reliability of the data was supported.

4. Results

Table 2 presents the descriptive statistics and Pearson correlation coefficients of the variables. The results show that green process innovation is significantly correlated with green product innovation. The results also show that a firm's green image and green subsidies are significantly related to its green process innovation, as well as to its green product innovation.

Table 3 illustrates the regression results of the green product innovation's mediating effect. The results of model 5 in Table 3 show that

[3] The macro is available at http://www.afhayes.com.

Table 2
Descriptive statistics and correlations.

Variables	Descriptive statistics		Correlations								
	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Financial performance	0.042	0.057	1.000								
2. Firm size	20.443	39.368	−0.031	1.000							
3. Financial constraints	0.469	0.206	−0.516***	0.295***	1.000						
4. Total assets turnover	0.838	0.653	0.118*	0.088	0.011	1.000					
5. Firm age	17.153	4.137	0.074	0.013	0.043	0.024	1.000				
6. Green process innovation	0.959	0.412	0.048	0.250***	0.198***	−0.017	0.090	1.000			
7. Green product innovation	0.359	0.394	0.104	0.245***	0.081	0.025	−0.034	0.245***	1.000		
8. Green image	1.014	0.549	0.094	0.175**	0.234***	0.011	0.105	0.405***	0.196***	1.000	
9. Green subsidies	0.095	0.218	0.015	0.619***	0.232***	0.052	−0.043	0.221***	0.247***	0.163**	1.000

*** Correlation is significant at the 0.01 level (2-tailed).
** Correlation is significant at the 0.05 level (2-tailed).
* Correlation is significant at the 0.1 level (2-tailed).

Table 3
Regression results of the mediating effect of green product innovation.

Variables	Financial performance			Green product innovation	
	Model 1	Model 2	Model 3	Model 4	Model 5
Controls					
Firm size	0.122** (1.993)	0.094 (1.513)	0.073 (1.161)	0.242*** (3.398)	0.199*** (2.777)
Financial constraints	−0.558** (−9.114)	−0.575*** (−9.406)	−0.574*** (−9.424)	0.011 (0.157)	−0.016 (−0.221)
Total assets turnover	0.111* (1.898)	0.117** (2.004)	0.115** (1.991)	0.004 (0.062)	0.012 (0.183)
Firm age	0.094 (1.602)	0.083 (1.424)	0.088 (1.527)	−0.038 (−0.554)	−0.054 (−0.812)
Predictors					
Green process innovation		0.133** (2.192)	0.111* (1.810)		0.204*** (2.92)
Green product innovation			0.105* (1.732)		
R squared	0.304	0.320	0.330	0.062	0.100
Adjusted *R* squared	0.291	0.304	0.310	0.043	0.077
F-value	22.297***	19.131***	16.6***	3.353**	4.486***
Change in R^2	0.304	0.016	0.010	0.062	0.038
Change in *F*-statistic	22.297***	4.804**	3.000*	3.353**	8.525***

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

green process innovation is positively related to green product innovation, thus providing support for H1. Innovation types (such as process innovation and product innovation) are complementary, and influence organizations jointly; hence, each type cannot truly be understood without understanding its interrelationship with other types (Damanpour, 2010). Unlike Klepper (1996), who argued that devoting more effort to process innovation will make product innovation shrink, we believe that green process innovation can facilitate green product innovation. Product innovation typically refers to an assembled product that can be sold to a consumer when manufactured, whereas process innovation creates new products or enhances the cost/performance attributes of existing products (Maine, Lubik, & Garnsey, 2012). It is important to note that, according to Lin et al. (2013), the success of green product innovation depends on sustainable business operations. Green process innovation is such a process, in which all aspects experience deep change with the aim of reducing the environmental impact of production, beginning at the source (Gopalakrishnan et al., 1999). Because of this, green process innovation lays the foundation for other environmental practices, including green product innovation. From RBV, we know that a firm's resources and capabilities are key determinants of their competitive advantage and success. Consequently, the efficient use of resources is of great value to firms. Because green process innovation can facilitate green product innovation, firms can begin with green process innovation when they implement environmental strategies in order to leverage it to make full use of firm resources.

The results of model 2 in Table 3 demonstrate that green process innovation is significantly related to financial performance. Thus, H2 is supported. Both green process innovation and green product innovation have a positive influence on financial improvement (see models 2 and 3). From RBV, when firms conduct green process innovation and green product innovation, they can accumulate product and process knowledge resources, thereby improving their financial performance by increasing their unique and valuable resources. As one can see, the two green innovation strategies used in tandem promote better financial performance overall.

Moreover, the results show that green product innovation mediates the relationship between green process innovation and financial performance (Baron & Kenny, 1986). On one side, green process innovation is positively associated with financial performance (see model 2 in Table 3), and has a positive influence on green product innovation (see model 5 in Table 3). On the other side, green product innovation is positively associated with financial performance (see model 3 in Table 3), with the coefficient of green process innovation becoming smaller when green product innovation is entered into model 3. From this, we find that H3 is supported. The results demonstrate that green process innovation not only has the potential to affect financial performance directly but also to influence financial performance via green product innovation. As a differentiation strategy, green product innovation can enable firms to create new businesses, seize green opportunities, and lead in their markets (Chang, 2016). Green process innovation can help firms develop greater competency (e.g., by using innovative tools, devices, and knowledge) when upgrading required manufacturing processes for new green product development, which, in

Table 4
Regression results of moderating effects.

Variables	Financial performance				
	Model 1	Model 2	Model 3	Model 4	Model 5
Controls					
Firm size	0.122** (1.993)	0.073 (1.161)	0.054 (0.705)	0.055 (0.730)	0.027 (0.320)
Financial constraints	−0.558** (−9.114)	−0.574*** (−9.424)	−0.566*** (−9.152)	−0.560*** (−9.078)	−0.561*** (−9.089)
Total assets turnover	0.111* (1.898)	0.115** (1.991)	0.116** (1.996)	0.121** (2.096)	0.122** (2.114)
Firm age	0.094 (1.602)	0.088 (1.527)	0.095 (1.623)	0.100* (1.711)	0.097* (1.663)
Predictors					
Green process innovation		0.111* (1.810)	0.130** (1.990)	0.133** (2.033)	0.134** (2.052)
Green product innovation		0.105* (1.732)	0.108* (1.755)	0.106* (1.727)	0.106* (1.724)
Moderators					
Green image			−0.062 (−0.951)	−0.058 (−0.906)	−0.061 (−0.942)
Green subsidies			0.036 (0.486)	0.020 (0.268)	0.107 (0.816)
Green image × green product innovation				0.099* (1.702)	0.106* (1.801)
Green subsidies × green product innovation					−0.087 (−0.809)
R squared	0.304	0.330	0.334	0.344	0.346
Adjusted *R* squared	0.291	0.310	0.307	0.314	0.313
F-value	22.297***	16.6***	12.535***	11.57***	10.46***
Change in R^2	0.304	0.010	0.004	0.010	0.002
Change in *F*-statistic	22.297***	3.000*	0.558	2.898*	0.654

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.10$.

turn, can lead to new green products in the marketplace (Cheng et al., 2014). Consequently, green process innovation encourages green product innovation by increasing product differentiation. Further, firms willing to undertake green product innovation can take advantage of the positive effect of green process innovation, thereby developing a greater competitive advantage. Therefore, it is clear that firms should enhance their green process innovation and green product innovation jointly in order to improve their financial performance.

The results of model 4 in Table 4 show that green image enhances the relationship between green product innovation and financial performance. Thus, H4 is supported. Fig. 2 illustrates that the positive impact of green product innovation on financial performance is stronger among firms with a better green image, indicating that green product innovation is more beneficial when firms have a better green image. However, as Amores-Salvadó et al. (2014) showed, green product innovation efforts only yield dividends when those efforts are adequately promoted. In China, environmental regulation has grown increasingly rigorous, and a firm's green image is more important than ever, especially because of the rise of environmentally conscious consumers and strict international environmental protection regulations (Chen, 2010). A firm's green image is now a crucial factor affecting strategy and performance, and those firms with a better green image will have less trouble with either environmental protests or legal

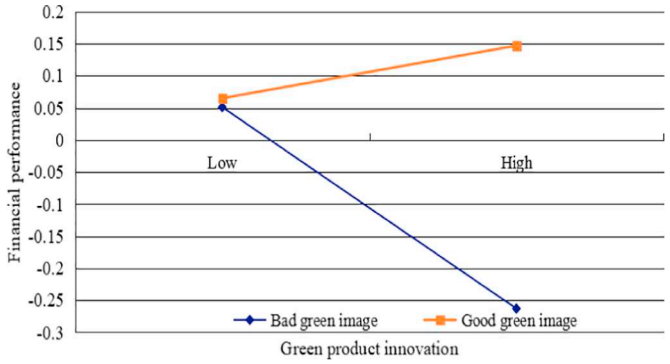

Fig. 2. Moderating effect of green image on the relationship between green product innovation and a firm's financial performance.

punishments (Chen, 2010). Additionally, a company's green image is an important criterion when judging the quality of an unfamiliar product, so a better green image can yield a higher level of customer satisfaction (Chang & Fong, 2010). Because of this, a better green image will help firms undertake green product innovation in order to increase their market performance, and will, if promoted effectively, attract environmentally conscious consumers who want to buy green products, thus further encouraging firms to implement green product innovation.

Interestingly, we found that green subsidies did not moderate the relationship between green product innovation and financial performance (see model 5 in Table 4). Thus, we find that H5 is not supported. This result is consistent with previous research that indicated that green subsidies might weaken the positive relationship between green process innovation and financial performance (Xie et al., 2016). There are several possible reasons for this. First, most Chinese manufacturing firms are still in the beginning stages of implementing green product innovation. With rising environmental awareness, the government has just begun to use green subsidies as a tool to motivate environmentally friendlier strategies. However, thus far, motivation is somewhat limited, and it will never be enough to support firms' reluctance to invest in what they perceive to be risky practices or to depend on green subsidies alone. Further, given that green production requires more time and money than traditional methods, the use of green subsidies is not a great incentive for firms just starting green practices, as they are faced with far more capital investment. Second, in addition to financial barriers, there are technological barriers that also prevent firms from conducting green product innovation thoroughly and successfully. Third, due to the general higher price of green products, there are plenty of consumers who are unwilling to pay extra for the green product attributes after the products have been produced (Dangelico & Pujari, 2010). Hence, the use of green subsidies is not a powerful enough incentive for many Chinese manufacturing firms just beginning to implement green innovation strategies (Xie et al., 2016).

5. Discussion and conclusions

In this study, using the content analysis method to capture the data of listed firms in China, we find that green process innovation has a positive impact on green product innovation and, further, that both kinds of innovation can improve firms' financial performance. The

theory of RBV, institutional theory, and stakeholder theory can help explain the positive impact of green technology innovation on firms' financial performance (Prakash, 2002). According to RBV, green process innovation and green product innovation can be seen as two types of organizational resources (Cheng et al., 2014). Since green process innovation is process-oriented and green product innovation is product-oriented, the implementation of these two complementary innovations will bring a greater competitive advantage to those firms applying both. From the perspectives of both institutional theory and stakeholder theory, green innovation strategies will help a firm gain the trust and support of external institutions and key stakeholders by taking into account the interests of external parties rather than just the firm's economic goals (Prakash, 2002).

We also find that green product innovation mediates the relationship between green process innovation and financial performance. Green process innovation facilitates the implementation of green product innovation, with the latter helping to translate the former into revenue. Hence, green process innovation should be complemented with green product innovation in order to ensure substantial profits from green technology innovation.

Moreover, we find that a green image moderates the relationship between green product innovation and firms' financial performance, but that a lack of customer awareness can prove a key challenge that firms must overcome (Dangelico & Pujari, 2010). In this case, a better green image can influence purchasing decisions (Chen, 2010) and can increase the demand for green products. Thus, a firm's investment in its green image will pay off by achieving more financial gains from its green product innovation.

Unexpectedly, there is no empirical evidence supporting the moderating effect of green subsidies on the relationship between green product innovation and financial performance. According to Hou, Chen, and Xu (2017), the overall level of green innovation growth in China's manufacturing sector is relatively low, so manufacturing firms in China are short of effective support and suffer from high risk and uncertainty. Furthermore, because environmental policies in developing countries change periodically (Dai & Zhang, 2017), manufacturing firms should increase their numbers of green products rather than depending heavily on external factors (e.g., subsidies) (Yu, Han, & Hu, 2016).

5.1. Theoretical contributions

The theoretical contributions of our study are twofold. First, our findings extend previous research (e.g., Lin et al., 2013; Xie et al., 2016) by investigating the indirect effect of green process innovation on firms' financial performance. In our study, we divide green technology innovation into “green process innovation” and “green product innovation” and then explore the relationship between these two kinds of innovation, as well as the mediation effect of green product innovation in the process, which helps bridge the gap between different types of green strategies by conducting in-depth analysis on the relationship between them.

The second contribution of our study lies within our framework of the theoretical and empirical analyses by examining how a firm's green image and green subsidies interaction with green product innovation can have profound effects on financial performance. The external implementation environment of green product innovation is still somewhat uncertain, and thus far, firms have done little to motivate consumers to buy their more expensive green products (Rehfeld et al., 2007). Yet, our results reveal that a firm's green image can strengthen the positive impact of green product innovation on its financial performance, which shed light on the contingent mechanism that green product innovation improves financial performance.

5.2. Managerial implications

There are several managerial implications that can be drawn from this study. First, in recent years, companies have faced growing pressure to be “greener” and more environmentally friendly (Sezen & Çankaya, 2013). Because of this, firms should take advantage of both kinds of green technology innovation to improve their financial performance. In addition, since green process innovation can promote green product innovation, firms should prioritize green process innovation, especially when there are resource constraints.

Second, firms should attach more importance to cultivating a green image, which will increase consumers' willingness to pay for green products; in so doing, firms can increase their market share and improve their financial performance. However, a huge challenge here is how companies can incorporate their environmental vision into their corporate strategies, rather than seeking ways to promote their green brands alone (Chen, 2010). Furthermore, to build a better green image, firms should advertise their environmental practices—such as how they recycle, conserve water and energy, avoid disposable goods, or reduce emissions released into the air, water, and soil—to consumers (Han, Hsu, & Lee, 2009).

Third, the government should design more effective tools beyond green subsidies to motivate and support green strategies, and should investigate why green subsidies have not been as effective as expected. Firms receiving green subsidies should be placed under scrutiny in order to increase the probability that the subsidies are being used in the most advantageous ways (Lin et al., 2015). Next, instead of designing policies drawn from a particular theory, government authorities should spend time listening to practitioners to better understand the difficulties that firms face when implementing green strategies.

5.3. Limitations and further research

This study provides an important theoretical framework for green innovation management in transition economies. However, there are some limitations that need to be addressed. First, the measurements of green process innovation, green product innovation, and green image are based solely on the content in the firms' *Corporate Social Responsibility Reports*. Future research should seek more valid measurements and collect panel data to measure these variables to better explore the dynamic relationship between green technology innovation and firms' financial performance. Second, due to limited data, we only examine the effects of green process innovation and green product innovation. Green management innovation, which is another kind of green innovation (Wahba, 2008), needs to be analyzed as well. Particularly, the interdependence between these three kinds of green innovation should be examined in the future in order to provide a more holistic understanding of green innovation. Third, future studies could use more variables to measure firm performance, for instance, applying Tobin's Q ratio.

In spite of these limitations, our research is crucial for both firms and government agencies, as the desire to have greener enterprises to protect the earth seems likely to continue unabated.

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