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Green Process Innovation and Innovation Benefit: The Mediating Effect of Firm Image

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Abstract: By evaluating green process innovation and its innovator's benefit including short- and long-term dimensions, we first analyzed the relationship between green process innovation and its benefits. Second, we set up a regression model to test the hypotheses using 267 survey data from coal mining firms in China. Finally, we verified the positive relationship between green process innovation and its long-term benefit, and the non-significant relationship between green process innovation and its short-term benefit, and the mediating effect played by firm image in the long run.

Keywords: green process innovation; firm benefit; firm image; mediating effect

1. Introduction

Green innovation, which is also called environmental innovation or eco-innovation in literature, is defined as "new or modified processes, techniques, systems, and products to avoid or reduce environmental harm" [1]. It can be divided into green product innovation and green process innovation [2–6]. Green product innovation refers to new or modified products aimed at reducing environmental impacts [6] and green process innovation refers to new or modified production equipment, together with methods and procedures that minimize environmental load [3]. Compared with other types of innovation, green innovation has significant externalities because it can lead to a cleaner and safer world [2].

One of the most important issues on green innovation is its relationship with innovator's performance. The researchers divide green innovator's performance into two dimensions, environmental performance and financial performance [2–21]. A positive relationship between green innovation and environmental performance has been confirmed (e.g., [2,4,10,14]). However, the relationship between green innovation and economic performance is inconclusive [15–21]. Some literature supports the hypotheses that green innovation positively affects financial performance (e.g., [14,18]), while others do not (e.g., [6,20,21]). It seems inevitable that green innovation can create a better environmental performance and the innovators may pay more attention to how to appropriate the innovation returns. So a further investigation on the relationship between green innovation and innovation benefit will be helpful.

Another relevant issue is how to accrue the innovation benefit, especially green innovation because of its significant externalities [3,9]. Different innovation practices lead to different kinds of benefit [16,17], it is important to focus on specific practices and the particular advantages associated with them [10,16]. A few scholars have researched the relationship between green product innovation and its economic performance from the perspective of dynamic capabilities [3,9,22–24] but little is known about green process innovation.

Industry is the major sector that consumes resources and emits pollution [1]. Green process innovation helps to solve environmental problems in the manufacturing process. It can

increase resource productivity as well as energy usage efficiency and decrease pollution during production [3,10]. In addition, green process innovation is also a necessary condition for green product innovation [11–13]. Product innovation is often accompanied by process innovation. No matter whether in the R&D stage, the pilot production stage or the large-scale production stage, all need process innovation to provide condition [14]. As long as firms have first made significant progress in the implementation of process innovation, they will be able to successfully adopt product stewardship [12]. Green process innovation is the most basic building block of green innovation [10]. In spite of its important role, the research on green process innovation in prior literature has been relatively insufficient [7–9]. In this study we focus specially on green process innovation.

We aim to empirically assess the effect of green process innovation on firm benefit and how such an effect occurs. The firm's decision makers can look forward to more benefit from proper green strategies based on a better understanding of the relationship between these constructs. Specially, we address the following research questions: (1) Does an innovator benefit from green process innovation? (2) How can green process innovation bring these benefits to its innovator?

Although organization capability is often seen as a dominant factor in influencing green innovation performance, such as [3,9,22–24], the same applies to other types of innovation [25]. Considering the environmental externality of green process innovation and its potential positive effect on firm image [4,6], we try to research the above relationship from the perspective of firm image.

This study advances our understanding of green innovation in several ways. First, we contribute to green innovation by concentrating on green process innovation which has been underestimated in prior research. Second, unlike available literature, we describe the innovator's benefit in two dimensions, short- and long-term benefits. It will help us perceive firms' green innovation performance through this differentiation. Third, we explore how green process innovation can result in improved firm benefit. To the best of our knowledge, current research has provided insights into the relationship between green innovation and its economic performance, but little about how green process innovators achieve the desired benefits.

The survey data used in this paper is from Chinese coal mining firms. The study of green process innovation in this industry is important. As a primary energy industry, coal mining and processing is crucial in China [26]. Coal mining firms are considered to make a major contribution to environmental issues, especially in water pollution and land deterioration [27]. Environmental protection policy is the main driver of green process innovation [5,13,17]. A variety of environmental policies have been issued to regulate coal mining firms in China since 2005. These policies included Circulation Economy Promotion Law, Cleaner Production Promotion Law, Solid Waste Pollution Prevention Law, Land Reclamation Law, etc. The Coal Law was revised in 2011. Environmental standards, including mining recovery ration, water recycling utilization rate, and land reclamation rate, are set up in the revised edition. Only those firms who meet these standards can get mining permits [26,28–30]. In order to reduce the discharge of waste and meet the environmental standards, many coal firms, especially the large coal firms, have changed the traditional linear development mode of "resource- product-waste" and formed a circular development mode of "resource- product-renewable resources" [29]. To fundamentally solve the environmental issues caused by coal mining, great breakthroughs have been made by using green mining technology [27,31]. It is in this industry that green process innovation is highly appreciated [16].

The remainder of this paper is organized as follows. We present some literature reviews and hypotheses in Section 2. We demonstrate the methodology and measurement in Section 3. We carry out some empirical analyses in Section 4. Conclusions and policy implications in Section 5 conclude the paper.

2. Literature and Hypotheses

2.1. Green Process Innovation and Firm Benefit

Green process innovation is purposefully focused on the production process. Although it is novel to the focal firm, it can be exploited or applied to reduce environmental risk, pollution emission, and other negative impacts [32]. The literature has identified some forms of green process technology such as clean production, pollution control, pollution prevention, eco-efficiency, and recirculation [23].

Although performance, including economic performance and environmental performance, is widely used by most prominent literature to measure the business outcome derived from firms' green innovation [2,6,33,34], an improved eco environment cannot be appropriated by the green innovators completely considering the externality feature of environmental issues [2]. Environmental performance may not bring in economic performance directly [34]. As economic entities, firms' managers and shareholders may pay more attention to its benefit when they devote to green innovation [35]. So we use benefit to measure the outcome of firms' green process innovation.

It will be of good benefit to innovators according to the potential opportunity of cost reduction and a better relationship between the focal firm and its stakeholders [36]. To capture different aspects of the benefits derived from green process innovation, timeframe should be considered [37]. So we divide the benefit related to green process innovation into two dimensions, short- and long-term benefits [24,38]. The short-term benefit primarily indicates the market success and can be reflected in the firm's financial performance directly, such as increase in market share and decrease in product cost [39,40]. It is comparable to the term "financial performance" which is often used in other literature (e.g., [4,9]). The long-term benefit denotes to the ongoing presence of the firm, the potential long-term viability and the sustainable competitiveness [41,42]. It is comparable to the term "survival performance" used by Richard et al. [37], "potential financial benefit" used by Labuschagne et al. [43] and "non-financial performance" used by Wagner and Weng et al. [13,24].

2.2. Green Process Innovation's Direct Effect on Firm's Benefit

Firms can reduce their costs through green process innovation [36]. Pollution is usually caused by resources waste, materials not being fully used, or energy lost [44,45]. Re-evaluation of the firm's production processes and innovation can lead to an improvement of their resource utilization efficiencies and a significant cost reduction. For instance, 3M saved $1 billion from its pollution prevention practices in 2005 [46]. An earlier example can be seen in Ecover, a Belgian manufacturer, who uses the environmentally sound manufacturing system to minimize waste at source [3]. On the other hand, less pollution means lower liability costs, avoiding potentially costly litigation and fines and clean-up costs [34].

Besides reducing production costs and avoiding liability costs, green process innovation may represent a source of differentiation advantage and may allow the firm to increase market share and its revenue [17,36]. Some case studies show that firms with green performance can attract more down-stream clients [36,46]. For instance, IBM, Body Shop, and Wal-Mart always evaluate their suppliers' environmental performance when they make business decisions [47]. Proactive green innovators can attract more clients. Then the market share of these focal firms will increase.

More stringent environmental policies have been issued since 2005 in China [28,30]. In order to reduce environmental pollution, firms need to develop and apply new technologies in their production process. These technologies include end-of-pipe pollution control, such as installing equipment for the capture of toxic emissions, and eco-efficiency approaches, involving changing the process to reduce wastes at source, reducing energy and materials usage during the mining process [26,30].

Take waste water reduction as an example, pollution-intensive industries, including the mining industry, have been detected online since 2006 in China. Real time monitoring equipment is installed at the sewage outfall. The focal firms will be penalized heavily or even shut down if the pollutant in the discharged water exceeds normal standards. Mining firms have to install sewage treatment equipment.

Although the investment of this equipment is very high, coal mining firms can avoid potential loss. Besides the end-of-pipe pollution control, proactive innovators use recirculation technology in their operations. By using this recirculation technology, the water consumption and wastewater discharge can be reduced simultaneously.

Consistent with these ideas, we hypothesize that:

Hypothesis 1a (H1a). *Firms' green process innovation will be positively related to their short-term benefit.*

In the long term, proactive green process innovation can improve a firm's competitive position through these channels as follows.

First, proactive green process innovation can enhance the influence of the innovators in the industry. The reactive firms need to renew their operation systems to adapt to stringent regulation policies. This reactive adaption will lead to disorders in these firms' daily operation [48]. Contrary to the reactive firms, proactive innovators can avoid time-compression diseconomies [22,49] because their environmental performance always exceeds the regulation standard. Due to the earlier practices, they also have an advantage in setting industry clean production technology standards. These will enhance the influence of proactive innovators in the industry.

Second, proactive green process innovators will find it easier to improve their relationship with government. As a transition economy, there is still environmental uncertainty in China [28]. Government in transition economy guides economic activities by devising industry development plans and setting regulatory policies [50,51]. Firms with better environmental performance may obtain approvals from the government more rapidly to extend the size of a new plant or build a new one [36]. Furthermore, pioneer green innovation coal mining firms can even lobby slow-moving governments for more stringent environmental regulations [16].

Third, proactive process innovators can recruit and retain competent employees. In order to realize environmentally sound processes, proactive innovators need to address environmental concerns of their employees. As far as personnel training is considered, empirical literature confirms that the more proactive the green innovators, the higher the share of trained employees [32]. Anecdotal evidence is also provided that a formalized environmental management system which is often utilized by a proactive process innovator has significant effects on employees' morale [49]. Case studies also show that firms with a good environmental performance can attract qualified staff easily [23]. These competent employees will be invaluable for firms' sustainable development.

Through the above analysis we can see that green process innovation can help innovators to enhance their influence in the industry, improve the relationship with government and retain competent employees. Although these benefits cannot be directly reflected in the short-term financial performance, it will help the focal firm to enhance its competitive advantage in the industry as well as improve its sustainability.

This account suggests the following hypothesis:

Hypothesis 1b (H1b). *Firms' green process innovation will be positively related to their long-term benefit.*

2.3. Green Process Innovation and Firm Image

Green process innovation is involved in energy-saving, pollution-prevention, and waste recycling which can be used to improve the firm's environmental performance to satisfy the environmental requirement of the public [4]. Green process innovation can prove a firm is acting with social responsibility [52–54]. These practices are perceived to be sincere by external stakeholders [55]. Firm's image is defined as the current image of the firm in the minds of the public [6]. It always involves the features of the firm that the public perceive [24]. Firms' image improvement is one of the outcomes generated by green process innovation [4,54]. It can contribute to differentiation in developing a positive firm image [38]. A firm's image can be boosted through proactive green innovators

gaining environmental legitimacy under the tendency of popular environmentalism consciousness of consumers and severe regulations [3,13,52]. Therefore, this study asserts that green process innovation has a positive influence upon firm image. Given the above arguments, a second hypothesis can be proposed.

Hypothesis 2 (H2). *Green process innovation is positive related to firm image.*

2.4. Firm Image and Firm Benefit

Resource-based theory is widely accepted among strategic management scholars for explaining firm competition and success [56]. This theory emphasizes that a firm's resources are crucial for a firm's success. From the resource-based view, firm image is an intangible asset and a source of competitiveness because it is valuable, rare, and inimitable [22]. A good image can help the firm obtain the stakeholders' trust and gain social and economic benefit [57]. From the financial perspective, market investors are willing to give the firms with good images a high premium [58]. From the sustainable development perspective, good firm images can not only improve the relationship between the focal firms and their business partners but also help the firms attract competent applicants [16]. The public are inclined to allocate more and better resources to firms with good images [34]. Therefore, good images can help firms to gain benefit [57].

Based on previous arguments, this study proposes the following hypotheses:

Hypothesis 3a (H3a). *The relationship between firm image and short-term benefit is positive.*

Hypothesis 3b (H3b). *The relationship between firm image and long-term benefit is positive.*

A research model based on above hypotheses is depicted in Figure 1.

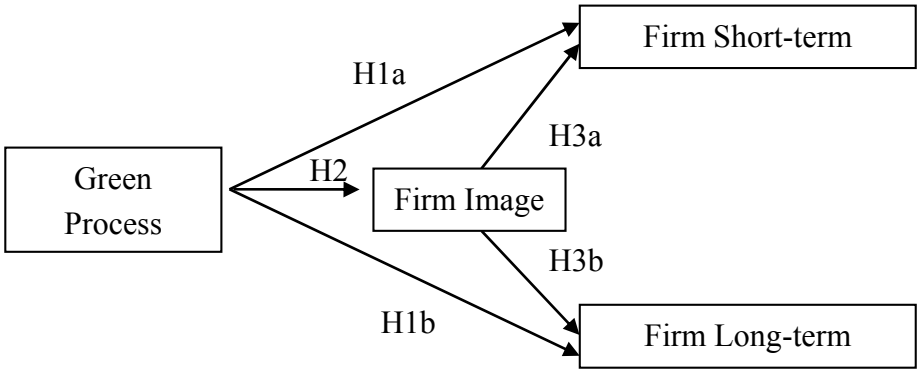

Figure 1. Overview of research models.

3. Methodology and Measurement

3.1. Choice of Industry

As mentioned in Section 1, we select the mining industry as our population. This industry is selected for two reasons. Firstly, pollution-intensive industries are always paid more attention in the literature and in practices [3], such as the forestry industry [23], as well as the energy and chemical industries [6,16]. Secondly, mining industries have been under stringent environmental regulation in China. A variety of environmental policies have been issued to govern the environmental impacts in this industry in recent years. Green process innovation is highly appreciated in this industry.

3.2. Data Collection and Sample

The unit of analysis in this study is the firm level. In the context of green innovation research, some studies use information from open database, such as the Community Innovation Surveys of the European Commission [59,60], the Spanish Technological Innovation Panel carried out by the Spanish National Statistics Institute [1]; others use survey data carried out by the research team [6,24,34,61]. Because there is no such special innovation database in China, we designed the questionnaire on the basis of prior research and carried out the survey. A mail questionnaire survey of managers is used in this study. Due to the influence of human cognition, subjective measures were questioned [62] while, with the broadening normative aspect of firm performance, this method is widely used [37]. The relationship between objective and subjective measures of firm performance is found to be moderately to strongly positive [63]. Considering the reasons mentioned above, a questionnaire may be the most appropriate method to assess green innovation results. In order to reduce the potential cognitive biases, we selected well-informed respondents and triangulated the survey-based measures for two key variables, green process innovation and firm image, with firm information obtained from their websites and the China National Coal Association. This helps to reduce potential cognitive biases [64].

An initial, theory-based questionnaire was first developed then it was sent to six scholars and experts to assess the relevance of the items used in the questionnaire. Subsequently a pretest was piloted with 12 coal mining firms to ensure the questions are clear and respondents are able to complete the questionnaire. Perceptual measures in a five-point Likert scale are used in this study. In order to avoid common method variance, the respondents of "green process innovation" are environmental managers; those of "innovation benefits" are financial managers and those of "firm image" are market managers.

We conducted our survey in six provinces in China. These provinces were Shandong, Shanxi, Shaanxi, Inner Mongolia, Xinjiang, Henan. The coal mining firms are mainly concentrated in the above provinces, so we launched our investigation in these provinces. The firm list was obtained from the local coal mine bureau. 500 mining firms were selected by random sampling method. Before the questionnaire mailing, our research team called to each sampled company to explain the objectives of the study and the questionnaire contents for heightening the valid survey response rate. The first round of the survey was in April 2016, and 109 questionnaires were returned. In order to improve the response rate of the survey, we contacted the non-respondents again and asked for assistance. The deadline of the survey was at the end of June 2016. We got a total of 284 questionnaires, including 267 valid questionnaires. The effective response rate was 53.4%, which is similar to previous studies of firms' green innovation practices (e.g., [4,45,53,61]), where response rates were 22.7%, 24.7%, 51%, and 32%, respectively.

To assess the potential non-response bias, we used independent t-test to check the mean values of firm age, firm size, and firm owner between the responses and non-responses [17,65]. The results show that there is no significant difference between them at 0.05 level. This shows that there is no non-response bias problem in our study. In order to assess the potential selection bias, the mean values of these three variables between our sample and the population are compared, which also shows no significant difference.

3.3. Measurement of Variables

The measurement of the variables in this study is with five-point Likert scale (1 = much worse, 5 = much better). The questionnaire comprises four parts. The first part consists of the descriptive data of the firms (including the numbers of the employees, firm age, etc.); the second part is the measurement of green process innovation; the third part is the measurement of innovation benefit; and the fourth part is the measurement of firm image. The items used in this survey were adopted from the literature. The questionnaire was written in Chinese initially. It was translated into English

and compared to the original English language version to confirm the accuracy. The measurements of the constructs were further defined as follows.

The measurement of green process innovation is referred to in Sharma and Henriques, Chen and Darnall [4,23,45]. It includes four items, the emission of wastes, the efficiency of energy, the efficiency of materials and recirculation. Environmental managers are asked to assess whether their firms have implemented any of the process changes during the past 3 years.

The measurement of firm image is referred to in Chen [4] and Amores-Salvadó et al. [6]. It includes four items, communication with the public, concerns for users, reputation of the firm, and the familiar degree of the firm, including a reverse item. Market managers are asked to access this construct.

To measure our dependent variable, innovation benefit, we divided it into two dimensions, "short-term benefit" and "long-term benefit". The measurement of short-term benefit focuses on financial performance relative to competitors, following the same line as other scholars [10,23,66]. It includes three items: mining cost, environmental penalty, and market share. The long-term benefit focuses on the competitive advantage accrued from the green process innovation and is measured by three items, the relationship with government, the attractiveness to its employees, and the influential power in the industry [23,66]. Thus, financial managers are asked to access their firms' innovation benefit.

Besides these key variables mentioned above, some control variables are included. Because firm size is often related to innovation and its visibility in the community [4,45], we included a variable to account for the number of employees within the firm (logged). Firm age was also used and logged [13,17]. Besides the two common control variables, firm owner and coal resource reservation were included) [2,23]. In China, firms are basically divided into two types of state-owned and non-state owned according to the nature of owners, so we set it to a dummy variable (the variable takes the value 1 if the firm is state-owned, 0 if not). Firm's coal resource reservation refers to the geological conditions of coal mining firms of the region, the number of exploitation of coal resources, which will directly affect the coal firm's technological innovation and economic performance. It is measured on a 5 point Likert scale (the resource reservation in our firm is better than our major competitors. 1 = strongly disagree, 5 = strongly agree).

The measures used in the questionnaire are shown in Appendix A.

3.4. Measurement Properties

As mentioned above, there are three measurement scales in this study, one is green process innovation (GPI), another is firm image (FI), and the third one is firm benefit (FB). Exploratory factor analysis is conducted to measure the construct validity. The results are presented in Table 1. The KMO indices of the two independent variables in this study are very close to 0.7; and the Bartlett's tests are significant at a level less than 0.05; all of the items have the loads higher than 0.6; a factor is extracted from the GPI and FI measurement scale respectively, which are consistent with the initial literature values. The KMO index of the dependent variable is 0.733; and two factors are extracted through principal component analysis, respectively corresponding to the two dimensions of firm benefit. These results show that the construct validity is acceptable [67]. Furthermore, reliabilities are tested using Cronbach's coefficients, showing values higher than 0.7 and the reliability is acceptable.

Table 1. Cronbach's coefficients and factor analysis results.

Items	Components			
	GPI	**FI**	**Short-Term**	**Long-Term**
GPI1	**0.760**			
GPI2	**0.767**			
GPI3	**0.778**			
GPI4	**0.716**			
FI1		**0.746**		
FI2		**0.782**		
FI3		**0.693**		
FI4		**0.812**		
FB1			**0.849**	
FB2			**0.890**	
FB3			**0.795**	
FB4				**0.727**
FB5				**0.887**
FB6				**0.676**
KMO	0.715	0.635	0.733	
% Explained variance	69.797	60.812	17.914	56.972
% Accumulated variance			17.914	74.886
Cronbach's	0.863	0.895	0.881	

Factor loadings are highlighted in bold.

4. Empirical Results

4.1. Correlation Analysis Results

The correlation coefficients among the variables used in this study are presented in Table 2. It can be found that green process innovation has significantly positive correlations with firm image, short- and long-term benefits. From Table 2 we also see short-term benefit and long-term benefit are highly correlated. There are two potential causal relationships between them. One is the positive effect of short-term gains on long-term gains, which is empirically verified by Jacobson [24,68]. In practice, however, there have been some situations that have shown good current financial performance but poor long-term performance [69]. In view of this contradiction, Rosenzweig [70] thought it may have been caused by the halo effect, a basic human tendency to make specific inferences on the basis of a general impression. That is to say, when a firm has a good financial performance, many people conclude that it will continue to prosper. Another causal relationship is the positive effect of long-term performance on financial performance which deserves further study.

Table 2. The descriptive analysis and correlation coefficients.

	Mean	**Standard Deviation**	**Green Process Innovation**	**Firm Image**	**Short-Term Benefit**	**Long-Term Benefit**
Green process innovation	3.8443	0.6098	1.000			
Firm image	3.2847	0.7760	0.234 ***	1.000		
Short-term benefit	3.7713	0.7091	0.240 **	0.373 ***	1.000	
Long-term benefit	3.5109	0.7462	0.510 **	0.585 ***	0.581 ***	1.000

Note: *** $p < 0.01$, ** $p < 0.05$.

4.2. Regression Results

In our model, firm image is likely to be an endogenous factor because proactive green innovators may perceive themselves with a better image. We regress firm image on green process innovation

to get residuals first. It is a common method used to correct for the endogeneity [71]. Then the Durbin-Wu-Hausman test is used to verify the endogeneity. The result indicates that endogeneity does not exist both long-term and short-term.

The results of regression analysis are presented in Table 3. The dependent variable in Model 1 is short-term benefit and the independent variable, green process innovation, shows that it has no significant effect on firm's short-term benefit ($\beta = 0.018$, $p > 0.1$). So H1a is not supported (see Model 1). As we stated in Section 2.1, the short-term benefit we use here is comparable to the term financial performance in other literature. Many previous studies, e.g., [6,13–21], focus on the relation between green innovation, including both green product innovation and green process innovation, and financial performance and provide conflicting results. Weng et al. [15] finds that green innovation can generate better financial performance while others think the positive relationship is not a realistic expectation [13,19,21]. This highlights that different innovation practices differently impact on firm benefit. When it comes to green product innovation, most of the literature confirms that it has a positive effect on financial performance [10,13,15]. In this study, we find the positive relationship between green process innovation and short-term benefit is non-significant, which is different from green product innovation. The reasons for this difference are discussed in the next subsection.

Table 3. Regression analysis results.

	Short-Term Benefit		**Long-Term Benefit**			**FI**
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 6**	**Model 5**
Firm size	0.386 ***	0.330 ***	0.208 ***	0.325 **	0.097	0.252 ***
Firm age	0.188 **	0.193 **	0.142	0.232 ***	0.213 ***	0.122 **
Firm owner	0.476 ***	0.435 ***	0.349 ***	0.332 ***	0.256 ***	0.253 **
Resource reservation	0.149 *	0.083	0.160 **	0.013	0.009	0.216 ***
Green process Innovation (GPI)	0.018		0.378 ***		0.216 ***	0.215 ***
Firm image (FI)		0.185		0.203 ***	0.273 ***	
R^2	0.319	0.341	0.445	0.332	0.549	0.348
F	10.128 ***	11.190 ***	17.353 ***	16.459 ***	22.452 ***	11.578 ***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standardized regression coefficients are reported.

The relationship between green process innovation and long-term benefit is tested in Model 3, showing a significant positive relationship between these two variables ($\beta = 0.378$, $p < 0.01$). Thus H1b is supported (see Model 3). As much literature has stated that green innovation helps firms sustain long term competitiveness [9,16,18,46], this is also applicable to green process innovation.

H2 is tested in Model 5. The dependent variable is firm image and the independent variable is green process innovation. As the result shows, green process innovation plays a significant positive effect on firm image ($\beta = 0.215$, $p < 0.01$). H2 is supported (see Model 5). To our knowledge, the research about green innovation from the angle of firm image is relative little. In earlier studies, Shrivastava [3] argued that green process practices can make firms more attractive to communities. Our result is fully in line with his statement.

H3a and H3b are tested in Models 2 and 4. The result in Model 2 shows that the relationship between firm image and short-term benefit is positive but not significant ($\beta = 0.185$, $p > 0.1$), so H3a is not supported while Model 4 shows a significant positive effect played by firm image on long-term benefit ($\beta = 0.203$, $p < 0.01$). H3b is supported in this paper. Using data from the manufacturing industry in Spanish, Amores-Salvadó [6] confirmed good firm image can bring in a better financial performance. However, our research shows a non-significant result. We will discuss this later.

In order to test the mediating effect of firm image, a three step approach is used according to Baron and Kenny [72]. First, we regress the mediator on the independent variable; second, the dependent variable on the independent variable and third the dependent variable both on the independent

variable and the mediator. Separate coefficients of these equations are estimated and tested. When the regression coefficients in all of the three equations are significant, the mediating effect can be proved.

Although green process innovation can affect firm image in step 1 ($\beta = 0.215$, $p < 0.01$; see Model 5), we can see that the regression result in step 2 is non-significant ($\beta = 0.018$, $p > 0.1$; see Model 1) when the dependent variable is short-term benefit. So the mediating effect cannot be verified. When the dependent variable is long-term benefit, the regression results in these three steps are all significant which can be seen in Models 5, 3, and 6. Additionally the coefficient of green process innovation in step 3 ($\beta = 0.216$, $p < 0.01$; see Model 6) is still significant and is less than in step 2 ($\beta = 0.378$, $p < 0.01$; see Model 3), a partial mediation played by firm image on the green process innovation and long-term benefit relationship is proved.

To access the robustness of our findings, we ran another estimation using hierarchical multiple regression [73] and obtained the same result as mentioned above.

Additionally the D-W values of these models indicate the residuals are independent. The variance inflation factors (VIF) of these models are between 1 and 2, which means we do not have to take multicollinearity problem into our consideration.

In short, the positive relationship between green process innovation and short-term benefit is non-significant (see Model 1). Green process innovation has a statistically significant positive effect on long-term benefit (see Model 3), and firm image plays a partial mediating role (see Models 3, 5 and 6).

4.3. Discussions

This study empirically explores the relationship between green process innovation and firm benefit. Unlike prior researches, firm benefit is divided into two dimensions, short- and long-term benefits; and in order to interpret their relationship, a mediating variable, firm image, is added in our model. The five hypotheses stated in this study are all supported except H1a and H3a.

As Section 3 defined, the short-term benefit in this study focuses on the firm's financial performance. Although some researches [10,13,15] show a positive relationship between green product innovation and financial performance, the relationship between green process innovation and short-term benefit is non-significant in our research. There are three possible explanations for this. First, different from green product innovation, which is pulled by customer need mainly [59,74] and can bring income from the market directly [17], green process innovation is mainly pushed by environmental policy [5,13,17] and cannot bring income from the market directly. Second, although China has established stringent environmental protection laws, they are not consistently enforced. There are still many problems in environmental policy enforcement, such as regional regulation competition and environmental information lack of transparency, which, to some extent, have affected the policy enforcement efforts [28]. Third, the pay-back period of the investment in green process innovation is very long [75]. Although green process innovation can reduce cost by improving the efficiency of energy and material and avoiding penalty, this innovation always needs large investment in equipment and R&D [2,75]. These three factors may cause firms' managers to feel that the investment in green process innovation cannot bring good returns in the short run.

Firm image has little to do with short-term earning. This may be because the samples used in this study are coal mining firms. The difference between coal products is little and the brand awareness of coal firms is relatively poor which causes the role of firm image in the product market to be small and there is no significant relationship between firm image and short-term benefit. This result is consistent with Ambec and Lanoie [36] who think consumers are less likely to be familiar with firms' green image as measured by its emissions to water or atmosphere.

The long-term benefit is reflected in the influence in the industry, the relationship with government, and the competitiveness of the employees. Green process innovation is conducive to increasing long-term benefit, and firm image plays as a mediator. Those firms who take proactive actions to implement process innovation can improve their firm images and then get long-term benefit. Unlike short-term benefit, the stakeholders involved in long-term are competitors, government, and employees

who have enough information about the innovators. In the process of continuous interaction, the firms who are actively engaged in green process innovation can improve the stakeholders' view of them, and enhance the image of the firm, thereby increasing their influence and appeal to achieve long-term development.

5. Conclusions and Policy Implications

5.1. Conclusions

This paper studies the relationship between green process innovation and firm benefit, considering the mediating effect of firm image. Although some researches have analyzed the relationship between green innovation and its economic performance, including product innovation and process innovation, this paper focuses specially on green process innovation. As mentioned above, green process innovation can help improve firm image and further improve the long-term benefit that the firm image plays as a mediator. However, the positive relationship between green process innovation and short-term benefit is non-significant.

5.2. Policy Implications

With respect to private sectors, the results can be used to improve social welfare by encouraging additional firms to voluntarily reduce their environmental impacts beyond legal requirement. Going green is not merely a way to conform with environmental policy, it improves the influence of the focal firm in the industry, which enhances its sustainable capabilities. These findings may help firm managers realize the potential benefit their firms can accrue through using green process innovation. These managers can take a more proactive stance by using the presented evidence to gain executive-level support for expanding their current innovation programs.

Besides this, firms should better understand the mediating role played by firm image. Firm image has a positive effect on long-term income, but it is not obvious for short-term income which leads to the difference between short-term gains and long-term gains of green process innovation. Because of the close contact with enterprises, the up-stream suppliers, employees and other stakeholders can timely capture information of these innovation firms and form cognition of the firm image, so green process innovation is good for the firms' long-term benefit. Additionally, the similarity of coal products results in the market users not having the ability to distinguish firms' green practices in production. Therefore, the relationship between firm image and short-term benefit is not obvious so that the green process innovation cannot make profits in the short term. Firm managers should be deeply aware that firm image is a valuable asset. What the proactive green process innovators need to do is not only put emphasis on their substantive green actions but also disseminate environmental practices to the market. A series of designs can be used purposely to give the market a good impression, e.g., environmental communication to express firms' environmental concern in relation to these processes [6]. Proactive innovation firms can discuss what they have done and what they are doing on their websites and deliver their environmental information [15].

With respect to the public policy, there are also many important implications in these findings. Regulation plays a key role in green process innovation [5,13,17]. Government can trigger firms to use clean production technology by pollution tax, abatement subsidy, and green public purchase etc. [36]. Although China has established relatively perfect environmental policies, green process innovators cannot be compensated in a short time due to the lack of strict policy enforcement and the lack of incentives of other market tools. Strict pollution control standards are necessary, and strict enforcement measures are also needed. Besides pollution charges, other flexible environmental policy instruments, such as tradable permits, government procurement, and other market-based instruments, are necessary [19,76]. A multi-level environmental performance monitoring system and information audit mechanism should be setup gradually. If consumers are armed with publicly available data and information from other independent third-parties, they will be likely to be more familiar with

the green process innovators [15]. This will help the green process innovators get better access to the product markets and increase the probability to be chosen as suppliers [19,35,36].

Due to the lack of publicly available historical data, this study uses the survey data. The possible lag between the innovation process and innovation gains has not been considered. In addition, the samples in this study are from the coal industry, which may limit the generalizability of the findings.

The existing research on green innovation can be divided into two categories, one is comprehensive research on green innovation and the other is specialized research on green product innovation. In view of the gaps in the existing research, we chose green process innovation as our theme, but there was no further division of it. Considering the complexity of green process innovation, to further distinguish a separate study is needed in the follow-up. For example, energy-saving technology innovation can save energy and raw materials for firms, which is more conducive for firms to reduce manufacturing costs; such as, compared with energy saving technology, emission reduction technology may not be conducive to the financial performance of the firm, so how can the firm get profit from the innovation of emission reduction technology?

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Appendix A

Table A1. Survey items.

Variables	Items (Relative to Your Major Competitors, Please Evaluate How Well or Poorly Your Firm Has Done during the Past 3 Years)
Green process innovation	The emission of hazardous substances is reduced in the mining process (GPI1). The energy efficiency is increased in the mining process (GPI2). The material efficiency is increased in the mining process (GPI3). The wastes are treated and re-used in the mining process (GPI4).
Firm image	The firm communicates with the public about its environmental concern and achievement (FI1). The community is not familiar with the firm (FI2, reverse question) The firm concerns for users about environmental management (FI3). The reputation of the firm in the community is good (FI4).
Short-term benefit	The mining cost is reduced (FB1). The environmental penalty is reduced (FB2). Our product sells a lot (FB3).
Long-term benefit	The relationship between government and the firm is good (FB4). The firm can attract more competent employees (FB5). The firm has influential power in the industry (FB6).

References

1. Marchi, V. Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms. *Res. Policy* **2012**, *41*, 614–623.
2. Berrone, P.; Fosfuri, A.; Gelabert, L.; Gomez-Mejia, L. Necessity as the mother of green inventions: Institutional pressures and environmental innovations. *Strateg. Manag. J.* **2013**, *34*, 891–909. [CrossRef]
3. Shrivastava, P. Environmental technologies and competitive advantage. *Strateg. Manag. J.* **1995**, *16*, 183–200. [CrossRef]

4. Chen, Y. The driver of green innovation and green image: Green core competence. *J. Bus. Ethics* **2008**, *81*, 531–543. [CrossRef]
5. Qi, G.; Zeng, S.; Tam, C.; Yin, H.; Zou, H. Stakeholers' influences on corporate green innovation strategy: A case study of manufacruting firms in China. *Corp. Soc. Responsib. Environ. Manag.* **2013**, *20*, 1–14.
6. Amores-Salvadó, J.; Castro, M.; Navas-lópez, J. Green corporate image: Moderating the connection between environmental product innovation and firm performance. *J. Clean. Prod.* **2014**, *83*, 356–365. [CrossRef]
7. Lee, K.H.; Kim, J.W. Integrating suppliers into green product innovation development: An empirical case study in the semiconductor industry. *Bus. Strateg. Environ.* **2011**, *20*, 527–538. [CrossRef]
8. Lin, R.J.; Tan, K.H.; Geng, Y. Market demand, green product innovation, and firm performance: Evidence from Vietnam motorcycle industry. *J. Clean. Prod.* **2013**, *40*, 101–107. [CrossRef]
9. Dangelico, R.M.; Pujari, D.; Pontrandolfo, P. Green Product Innovation in Manufacturing Firms: A Sustainability-Oriented Dynamic Capability Perspective. *Bus. Strateg. Environ.* **2017**, *26*, 490–506. [CrossRef]
10. Christmann, P. Effects of "best practices" of environmental management on cost advantage: The role of complementary assets. *Acad. Manag. J.* **2000**, *43*, 663–680. [CrossRef]
11. Voss, G.B.; Sirdeshmukh, D.; Voss, Z.G. The effects of slack resources and environmental threat on product exploration and exploitation. *Acad. Manag. J.* **2008**, *51*, 147–164. [CrossRef]
12. Hart, S. A natural-resource-based view of the firm. *Acad. Manag. Rev.* **1995**, *20*, 986–1014.
13. Jaggi, B.; Freedman, M. An examination of the impact of pollution performance on economic and market performance: Pulp and paper firms. *J. Bus. Financ. Account.* **1992**, *19*, 697–713. [CrossRef]
14. Mantovani, A. Complementarity between product and process innovation in a monopoly setting. *Econ. Innov. New Technol.* **2006**, *15*, 219–234. [CrossRef]
15. Weng, H.H.R.; Chen, J.S.; Chen, P.C. Effects of green innovation on environmental and corporate performance: A stakeholder perspective. *Sustainability* **2015**, *7*, 4997–5026. [CrossRef]
16. Salzmanna, O.; Ionescu-somersa, A.; Stegera, U. The business case for corporate sustainability: Literature review and research options. *Eur. Manag. J.* **2005**, *23*, 27–36. [CrossRef]
17. Walker, K.; Wan, F. The harm of symbolic actions and green-washing: Corporate actions and communications on environmental performance and their financial implications. *J. Bus. Ethics* **2012**, *109*, 227–242. [CrossRef]
18. Dangelico, R.M.; Pontrandolfo, P. Being "green and competitive": The impact of environmental actions and collaborations on firm performance. *Bus. Strateg. Environ.* **2015**, *24*, 413–430. [CrossRef]
19. Lanoie, P.; Laurent-Lucchetti, J. Environmental policy, innovation and performance: New insights on the porter hypothesis. *J. Econ. Manag. Strategy* **2011**, *20*, 803–842. [CrossRef]
20. Heras-Saizarbitoria, I.; Molina-Azorin, J. ISO 14001 certification and financial performance: Selection-effect versus treatment-effect. *J. Clean. Prod.* **2011**, *19*, 1–12. [CrossRef]
21. Rexhäuser, S.; Rammer, C. Environmental innovations and firm profitability: Unmasking the Porter hypothesis. *Environ. Resour. Econ.* **2014**, *57*, 145–167. [CrossRef]
22. Aragon-Correa, J.; Sharma, S. A contingent resource-based view of proactive corporate environmental strategy. *Acad. Manag. Rev.* **2003**, *28*, 71–89.
23. Sharma, S.; Henriques, I. Stakeholder influences on sustainability practices in the Canadian forest products industry. *Strateg. Manag. J.* **2005**, *26*, 159–180. [CrossRef]
24. Wagner, M. The role of corporate sustainability performance for economic performance: A firm level analysis of moderation effects. *Ecol. Econ.* **2010**, *69*, 1553–1560. [CrossRef]
25. Teece, D. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strateg. Manag. J.* **2007**, *28*, 1319–1350. [CrossRef]
26. Wang, Z.; Feng, C.A. Performance evaluation of the energy, environmental, and economic efficiency and productivity in China: An application of global data envelopment analysis. *Appl. Energy* **2015**, *147*, 617–626. [CrossRef]
27. Warhurst, A.; Bridge, G. Improving environmental performance through innovation: Recent trends in the mining industry. *Miner. Eng.* **1996**, *9*, 907–921. [CrossRef]
28. Marquis, C.; Zhang, J.J.; Zhou, Y.H. Regulatory uncertainty and corporate responses to environmental protection in China. *Calif. Manag. Rev.* **2012**, *55*, 39–63. [CrossRef]
29. Wang, Z.; Zhang, B.; Zeng, H. The effect of environmental regulation on external trade: Empirical evidences from Chinese economy. *J. Clean. Prod.* **2016**, *114*, 55–61. [CrossRef]

30. Cao, L.; Qi, Z.; Ren, J. China's industrial total-factor energy productivity growth at sub-industry level: A two-step stochastic metafrontier malmquist index approach. *Sustainability* **2017**, *9*, 1384. [CrossRef]
31. Sokolov, T.; Smirnov, A.; Yu, G. Resource-saving technology for underground mining of high-value quartz in Kyshtym. *J. Min. Sci.* **2015**, *51*, 1191–1202. [CrossRef]
32. Cainelli, G.; Maichi, V.; Grandinetti, R. Does the development of environmental innovation require different resources? Evidence from Spanish manufacturing firms. *J. Clean. Prod.* **2015**, *94*, 211–220. [CrossRef]
33. Nishitani, K. An empirical analysis of the effects on firm's economic performance of implementing environmental management system. *Environ. Resour. Econ.* **2011**, *48*, 569–586. [CrossRef]
34. Wagner, M. The link of environmental and economic performance: Drivers and limitations of sustainability integration. *J. Bus. Res.* **2015**, *68*, 1306–1317. [CrossRef]
35. Mitchell, R.; Agle, B.; Wood, D. Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Acad. Manag. Rev.* **1997**, *22*, 853–886.
36. Ambec, S.; Lanoie, P. Does it pay to be green? A systematic overview. *Acad. Manag. Perspect.* **2008**, *22*, 45–62.
37. Richard, P.; Devinney, T.; Yip, G. Measuring organizational performance: Towards methodological best practice. *J. Manag.* **2009**, *35*, 718–804. [CrossRef]
38. Miles, M.P.; Covin, J.G. Environmental marketing: A source of reputational, competitive, and financial advantage. *J. Bus. Ethics* **2000**, *23*, 299–311. [CrossRef]
39. Lavie, D.; Lechner, C.; Singh, H. The performance implications of timing of entry and involvement in multipartner alliances. *Acad. Manag. J.* **2007**, *50*, 578–604. [CrossRef]
40. Razan, L.; Ithai, S.; Edward, Z. When do firms change technology-sourcing vehicles? The role of poor innovative performance and financial slack. *Strateg. Manag. J.* **2016**, *37*, 855–869.
41. Steensma, H.; Tihanyi, L.; Lyles, M. The evolving value of foreign partnerships in transitioning economies. *Acad. Manag. J.* **2005**, *48*, 213–235. [CrossRef]
42. Gaur, A.; Mukherjee, D.; Gaur, S.; Schmid, F. Environmental and firm level influences on inter-organizational trust and SME performance. *J. Manag. Stud.* **2011**, *48*, 1752–1781. [CrossRef]
43. Labuschagne, C.; Brent, A.C.; van Erck, G. Assessing the sustainability performances of industries. *J. Clean. Prod.* **2005**, *13*, 373–385. [CrossRef]
44. Porter, M.; van der Linde, C. Toward a new conception of the environmental -competitiveness relationship. *J. Econ. Perspect.* **1995**, *9*, 97–118. [CrossRef]
45. Darnall, N. Regulatory stringency, green production offsets, and organization's financial performance. *Public Admin. Rev.* **2009**, *69*, 418–434. [CrossRef]
46. Wolf, J. The relationship between sustainable supply chain management, stakeholder pressure and corporate sustainability. *J. Bus. Ethics* **2014**, *119*, 317–328. [CrossRef]
47. Barla, P. ISO14001 certification and environmental performance in Quebec's pulp and paper industy. *J. Environ. Econ. Manag.* **2007**, *53*, 291–306. [CrossRef]
48. Nehrt, C. Timing and intensity of environmental investments. *Strateg. Manag. J.* **1996**, *17*, 535–547. [CrossRef]
49. Cappelli, P.; Keller, J. Classifying work in the new economy. *Acad. Manag. Rev.* **2013**, *38*, 575–596. [CrossRef]
50. Li, Y.; Peng, M.W.; Macaulay, C.D. Market–political ambidexterity during institutional transitions. *Strateg. Organ.* **2013**, *11*, 205–213. [CrossRef]
51. Sheng, S.; Zhou, K.Z.; Li, J.J. The effects of business and political ties on firm performance: Evidence from China. *J. Mark.* **2011**, *75*, 1–15. [CrossRef]
52. Cronin, J.; Smith, J.S.; Gleim, M. Green marketing strategies: An examination of stakeholders and the opportunities they present. *J. Acad. Mark. Sci.* **2011**, *39*, 158–174. [CrossRef]
53. Cordano, M.; Frieze, I. Pollution reduction preferences of U.S. environmental managers: Applying Ajzen's theory of planned behavior. *Acad. Manag. J.* **2000**, *43*, 627–641. [CrossRef]
54. Gupta, A.; Briscoe, F.; Hambrick, D.C. Red, blue, and purple firms: Organizational political ideology and corporate social responsibility. *Strateg. Manag. J.* **2017**, *38*, 1018–1040. [CrossRef]
55. Flammer, C.; Luo, J. Corporate social responsibility as an employee governance tool: Evidence from a quasi-experiment. *Strateg. Manag. J.* **2017**, *38*, 163–183. [CrossRef]
56. Barney, J.B.; Ketchen, D.J.; Wright, M. The future of resource-based theory: Revitalization or decline? *J. Manag.* **2011**, *37*, 1299–1315. [CrossRef]
57. Wan, H.; Schell, R. Reassessing corporate image: An examination of how image bridegs symbolic relationships with behavioral relationships. *J. Public Relat. Res.* **2007**, *19*, 25–45.

58. Konar, S.; Cohen, M. Does the market value environmental performance? *Rev. Econ. Stat.* **2001**, *83*, 281–289. [CrossRef]
59. Horbach, J.; Rammer, C.; Rennings, K. Determinants of eco-innovation by types of environmental impact—The role of regulatory push/pull, technology push or market pull. *Ecol. Econ.* **2012**, *78*, 112–122. [CrossRef]
60. Ghisetti, C.; Rennings, K. Environmental innovations and profitability: How does it pay to be green? An empirical analysis on the German innovation survey. *J. Clean. Prod.* **2014**, *75*, 106–117. [CrossRef]
61. Inoue, E.; Arimura, T.; Nakano, M. A new insight into environmental innovation: Does the maturity of environmental management systems matter? *Ecol. Econ.* **2013**, *94*, 156–163. [CrossRef]
62. Grilovich, T.; Griffin, D.; Kahneman, D. *Heuristics and Biases: The Psychology of Intuitive Judgment*; Cambridge University Press: New York, NY, USA, 2002.
63. Wall, T.; Michie, J.; Patterson, M. On the validity of subjective measures of company performance. *Pers. Psychol.* **2004**, *57*, 95–118. [CrossRef]
64. Winter, S. Mistaken perceptions: Cases and consequences. *Br. J. Manag.* **2003**, *14*, 39–44. [CrossRef]
65. Podsakoff, P.M.; Organ, D.W. Self-reports in organizational research: Problems and prospects. *J. Manag.* **1986**, *12*, 531–544. [CrossRef]
66. Gonzalez-Benito, J. Environmental proactivity and business performance: An empirical analysis. *Omega* **2005**, *33*, 1–15. [CrossRef]
67. Hair, J.F.; Anderson, R.E.; Tatham, R.L.; Black, W. *Multivariate Data Analysis*, 5th ed.; Prentice Hall International: New York, NY, USA, 1998.
68. Jacobson, R. The validity of ROI as a measure of business performance. *Am. Econ. Rev.* **1987**, *77*, 470–478.
69. Baker, G.P.; Kennedy, R.E. Survivorship and the economic grim reaper. *J. Law Econ. Organ.* **2002**, *18*, 324–361. [CrossRef]
70. Rosenzweig, P. Misunderstanding the nature of company performance: The halo effect and other business delusion. *Calif. Manag. Rev.* **2007**, *49*, 6–20. [CrossRef]
71. Hamilton, B.; Nickerson, J. Correcting for endogeneity in strategic management research. *Strateg. Organ.* **2003**, *1*, 51–78. [CrossRef]
72. Baron, R.M.; Kenny, D.A. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* **1986**, *51*, 1173–1182. [CrossRef] [PubMed]
73. James, L.R.; Brett, J.M. Mediators, moderators, and tests for mediation. *J. Appl. Psychol.* **1984**, *69*, 307. [CrossRef]
74. Delmas, M.A.; Toffel, M.W. Organizational responses to environmental demands: Opening the black box. *Strateg. Manag. J.* **2008**, *29*, 1027–1055. [CrossRef]
75. Kassinis, G.; Vafeas, N. Stakeholder pressures and environmental performance. *Acad. Manag. J.* **2006**, *49*, 145–159. [CrossRef]
76. Hojnik, J.; Ruzzier, M. What drives eco-innovation? A review of an emerging literature. *Environ. Innov. Soc. Transit.* **2016**, *19*, 31–41. [CrossRef]