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*Article*

# The Influence of Environmental Management Practices and Supply Chain Integration on Technological Innovation Performance—Evidence from China's Manufacturing Industry

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**Abstract:** How to effectively implement environmental management practices and supply chain integration to enhance technological innovation performance has become crucial in both research and practice. Based on resource-based view (RBV) theory, a theoretical model to determine the relationship between environmental management practices, supply chain integration, supply chain knowledge sharing, and technological innovation performance was proposed. Based on data collected from one hundred and twelve Chinese manufacturing enterprises, the empirical results show that environmental management practices have a significantly positive influence on technological innovation performance, and supply chain integration plays a moderating role on the relationship. In addition, the results indicate that supply chain integration is also a predictive variable of technological innovation performance and supply chain knowledge sharing. Our findings suggest that practitioners should couple environmental management practices with supply chain integration to improve technological innovation performance in addition to environmental performance, which has been substantiated in literature.

**Keywords:** environmental management practices; supply chain integration; technological innovation performance; supply chain knowledge sharing; resource based view

## 1. Introduction

Throughout the world, much research has been done on corporate environmental management practices. Some scholars hold negative views that given obvious externality, implementing environmental management may damage a company's economic interests or reduce its competitive power. While society may gain benefits, the company itself bears all costs of environmental management practices [1]. In practice, some companies are unwilling to implement environmental management programs, risking fines and prosecution, by ignoring or circumventing increasingly strict environmental protection regulations. Other researchers have published contradictory research demonstrating that environmental management practices could improve not only environmental but also economic performance of a company [2,3]. There are numerous cases of companies who have implemented sound environmental management practices achieving good corporate performance, especially in innovation. Corporate leaders and academia are seeking to establish the underlying linkage between corporate environment management and corporate performance. "Porter Hypothesis" provides an analytical framework; that is, environmental regulation rationally designed by the government can drive companies to adopt environmental management practices [4], and accelerate innovation, which may offset costs for environmental management and create the first-mover advantage [5].

A number of empirical studies have attempted to examine the influence of environmental management on innovation following "Porter Hypothesis" at an industrial level. (e.g., Jaffe and Palmer, 1997 [6]; Chudnovsky *et al.*, 2005 [7]; Kneller and Manderson, 2012 [8]). However, Portney (2008) pointed out that the effects of environmental regulation on firms can differ considerably and firm-level variation was an important aspect. As a consequence, some scholars analyzed the relationship between environmental management practices and technological innovation at the firm level [9], for instance the application of environmental management systems (e.g., ISO14001, EMAS), green marketing, cleaner production, and internal policies for environmental performance improvement. Environmental management practices have shown their influence on a firm's process innovation and product innovation [10,11]. The scope of current studies in this field is limited to the influence of one or two environmental management practices on technological innovation. Therefore, it is necessary to explore the mechanism of how environmental management practices promote technological innovation.

Compared with earlier environmental management practices, which focused on contaminant control during productive process and end-of-pipe treatment, current environmental management practices shifts the focus to prevention or reduction of environmental impact in all the product life-cycle stages. In each stage, the sharing of resources and operating costs and benefits of environmental management with supply chain partners could contribute to the effects of environmental management practices. According to resource-based view theory, process cooperation of supply chain partners, called supply chain integration, could create an inter-firm network for exchange of information and knowledge. The network could help to encourage resource sharing, mutual learning and joint problem solving between suppliers and customers [12,13]. Thus, it is useful to examine the interaction effects of environmental management practices and supply chain integration.

How does environmental management practices influence technological innovation performance? Does supply chain integration have any effect on this relationship? Why and how? These are the major questions that this paper will explore.

## 2. Theoretical Background

### *2.1. Resource-Based View (RBV)*

Resource-based view theory, developed by Wernerfelt (1984), suggested that a firm's competitive strategy and performance depend significantly on its valuable, rare and inimitable organizational resources [14]. Many scholars have further developed the theory by integrating RBV with relational theory, social network theory and environmental issues. There are two branches in the literatures: the natural resource-based view (NRBV) (Hart, 1995) [15], and the relational view (RV) (Dyer and Singh, 1998) [16]. NRBV proposes that there are three key strategic capabilities: pollution prevention, product stewardship, and sustainable development. Each of these has different environmental driving forces, builds upon different key resources, and has a different source of competitive advantage [17]. In this paper, we mainly focus on the first two capabilities. RV proposes that the specific inter-enterprise relationship forming through long-term organization partnership is a key resource for competitive advantage [16].

According to NRBV, pollution prevention technologies involve much tacit knowledge through skill development and "green" teams [15]. The tacit knowledge results in a resource that is difficult to be replicated. Product stewardship technologies could produce knowledge of entire "product life cycle", which can be converted into the potential for competitive advantage through strategic priority. In brief, tacit knowledge and product life cycle knowledge, which are generated by environmental management practices, are significant for corporate competitiveness and performance [17]. They are also crucial antecedent variables of another advantage resource, technological innovation [18].

According to the relational view, supply chain integration can create a network for exchange of information and knowledge. The network facilitating supply chain partners to jointly solve problems and learn about new opportunities is one type of corporate advantage resources [12,13].

### *2.2. Environmental Management Practices*

There are different understandings about environment management practices. Shrivastave and Hart (1995) [19] pointed out that environmental management could provide an overall system perspective to deal with environmental issues. Every organizational activity from raw material inputs, production process, packaging, to waste disposal, are related to environmental issues. Therefore, environmental management practices are a combination of organizational activities aiming at reducing resource consumption and improving waste disposal. Technological options, product design, manufacture and waste management are all included in environmental management practices [19]. Bergmiller and McCright (2009) [20] proposed that environmental management practices (green practices) were activities which aimed at improving environmental performance, including improving efficiency, shortening response time, cutting down energy consumption, reducing waste and toxic material usage. Hajmohammad *et al.* (2013) [21] defined environmental management practices as "the level of resources invested in activities and know-how development that lead to pollution reduction at the source", including the application of environmental management systems (e.g., ISO14001), and efforts to recycle materials and reduce waste. These management practices include environmental audits, total quality management, pollution prevention plans, environmental training for employees, total cost accounting, life-cycle analysis, hiring a designated environmental manager, R&D, environmental standards for suppliers, and employee incentive programs for environmental suggestions [22,23].

There are three motivations for enterprises to implement environment management practices. (1) Environmental regulation: A company can only be considered to be "legitimate" and avoid penalties if it meets the requirements of environmental regulation [24]. (2) Economic interests: Apart from reducing negative impact of organizational activities on the environment, environmental management practices bring economic benefits by generating recycling revenue, boosting sales, achieving first-mover advantage, enhancing social reputation, and improving product quality [5,11]. (3) Competitive advantage: According to the strategic management theory, environmental management practices are one of the strategic choices in order to gain competitive advantages. For example, using clean production technology and product re-design, optimizing production technology, improving resource utilization and reducing production costs can bring competitive advantages and business opportunities. Environment-friendly products, green marketing, and green consumption are beneficial to winning recognition from the public and customers. Establishing a green image by implementing environmental management can lessen the negative impact of competitors, which have earlier implemented environmental management [25].

Based on different motivations, enterprises execute different environmental management practices. Scholars have classified them from different perspectives. Klassen and Whybark (1999) [26], Hart and Ahuja (1996) [2] classified environmental management practices into "control" and "prevention" on the basis of reducing the environmental contamination. Roome (1992) [27] divided environmental management practices into five groups: "noncompliance", "compliance", "compliance-plus", "commercial and natural environment excellence" and "leading edge", from the perspective of motivation and corporate strategy. Zhu *et al.* (2012) [28] classified environmental management practices into internal environmental management practices and green supply chain practices.

In this paper, we assess environmental management practices from the perspective of the internal and initiative environmental control and prevention activities. These include the formulation of environmental management policies, the application of environmental management assessment tools (e.g., life cycle assessment, benchmarking, environmental auditing, ISO14001), the establishment of environmental performance targets, the public disclosure of environmental performance, and the staff training in environmental protection. Based on RBV, environmental management practices, as a kind of advantage resources, are crucial for corporate performance [17]. Environmental management practices also play a positive influence on environmental innovation and continuous improvement [11].

### *2.3. Supply Chain Integration*

In recent years, a growing body of research on supply chain integration has been published. However, there is still no uniform understanding of the definition. Flynn *et al.* (2010) [29] considered that supply chain integration was "the process cooperation between supply chain members intra-organization and inter-organizations, and by means of managing all the processes jointly on the supply chain, the goal was to control effectively the flows of products or services, information, financial affairs and decisions in order to achieve maximum value for customers with low-cost and high speed". Levary (2000) [30] suggested that supply chain integration was intra-organizational and inter-organizational process coordination and management between enterprises and supply chain partners in products, information, capital and services, which could achieve highly efficient results. Mentzer (2000) [31] believed that supply chain integration was the collaboration within node enterprise and among enterprises in the course of supply chain management, including the behavior integration of node enterprise, the process integration of entire network, information integration, sharing of risks and interests, collaboration and relationship integration. Swink *et al.* (2007) [32] divided supply chain integration into strategic integration, product/process development integration, customer integration and supplier integration from the perspective of strategic objectives and process integration. Narasimhan and Kim (2002) [33] considered that supply chain integration should be divided into internal integration and external integration, and divided external integration into supplier integration and customer integration. Frohlich and Westbrook (2001) [34] classified supply chain integration into supplier integration and customer integration, based on "arcs of integration". Supply chain integration in this study mainly refers to external supply chain integration (including supplier integration and customer integration).

Based on RV, the network resources propagated by supply chain integration are intrinsic corporate advantage resources and are contributory to corporate performance. Some studies confirmed that supply chain integration, not only could improve product quality, service level, customer satisfaction, and financial performance, but also were the key resource of business innovation (Yu *et al.*, 2013 [35]; Bellamy *et al.*, 2014 [36]).

### *2.4. Technological Innovation Performance*

Technological innovation is an important way for enterprises to obtain sustainable competitive advantage, and also a key topic of concerned for the Chinese government and enterprises. The Organization for Economic Cooperation and Development (OECD) and Eurostat defined technological innovation as "It has to be based on new technology knowledge, including product innovation and technological process innovation, which is also new to the enterprise and can be applied to the market and production (new products must come into the market or new processes must be applied to the enterprise)".

Technological innovation performance is of multidimensional construction and many scholars have studied the measurement of technological innovation, but there is no uniform measure index. Hagedoorn and Cloodt (2003) [37] put forward to the assessment of technological innovation performance from the number of patents, new products, R&D investment, patent citations. In addition, Chen and Chen (2006) [38] proposed the assessment of technological innovation performance based on the measure indexes: the sale of innovative products, the cost and speed of new product development, the sales rate of new products, the success rate of innovative projects, and leading or participation in the development of industrial standard. In this study, we used the announcement, sales rate, and development speed of new products, R&D investment, and the success rate of innovative projects as the measure indicators of technological innovation performance.

### *2.5. Supply Chain Knowledge Sharing*

Knowledge sharing can help create new ideas and facilitate the development of new business opportunities for maximizing organizational capability to generate solutions and efficiencies with competitive advantages [39,40]. Knowledge sharing occurs at the individual, organizational and inter-organizational levels, and this paper focuses on supply chain knowledge sharing at the inter-organizational levels. Argote *et al.* (2000) [41] defined supply chain knowledge sharing as social interaction between two companies, including inter-organizational exchange of employee knowledge, experience and skills. Examples included willingness to actively exchange knowledge with supply chain partners (*i.e.*, donate knowledge), consult with supply chain partners to learn from them (*i.e.*, collect knowledge) [42], and build knowledge-sharing platform such as virtual community. This paper follows the above definition. Knowledge sharing between supply chain partners can facilitate the knowledge creation process, alleviate the limited internal knowledge resources predicament, reduce development costs, and increase the speed of innovation in enterprises [43,44].

## 3. Research Model and Hypotheses

Our research model shows three antecedents of technological innovation performance from two paths (seen in Figure 1). We examine the moderating effect of supply chain integration on the relationship between environment management practices and technological innovation performance.

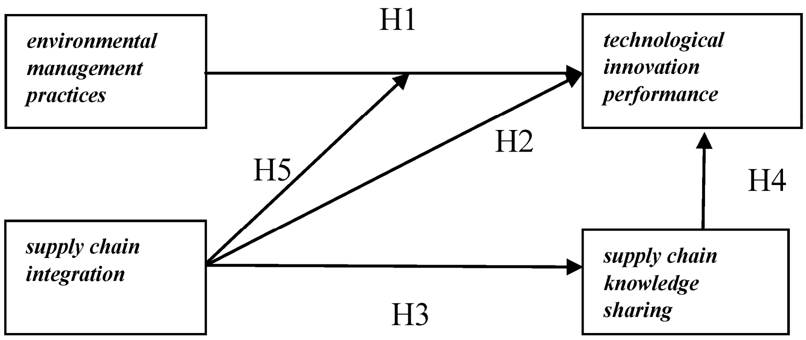


**Figure 1.** Research model.

### *3.1. Relationship between Environmental Management Practices and Technological Innovation Performance*

According to the RBV, there is much tacit knowledge and life cycle knowledge embedded in environment management, which may have an effect on technological innovation performance.

In recent years, the relationship between voluntary environmental management practices and technological innovation performance in a company has become a focus of attention. Vachon and Klassen (2008) [45] found that an enterprise could establish a dialogue with various stakeholders in the process of environmental management practices, and positive environmental management strategies could produce operational capabilities, such as the capability to easily control technological changes and the capability to make continuous improvements. On the basis of empirical research, Wanger (2008) [10] found that environmental management practices of a company could not only reduce the negative environmental impact and resource consumption, but also promote environmental process innovation and product innovation through organizational learning. Rennings *et al.* (2006) [11] proved that voluntary environmental management practices, including life cycle analysis and ISO14001 certification, had a significantly positive impact on product innovation and process innovation. Similarly, Lee *et al.* (2014) [46] found that environmental management practices, such as internal environmental management, eco-design, recycling investment, and so on, had a positive impact on technological innovation. The tacit knowledge and life cycle knowledge embedded in some environmental management practices can improve technological innovation performance.

Therefore, we propose the following hypothesis:

> *H1: Environmental management practices have a positive effect on technological innovation performance.*

### *3.2. Supply Chain Integration and Technological Innovation Performance*

Both supply chain and technological innovation focus on production methods, organizational and commercialized processes. Supply chains are committed to creating value for the end customers [8]. For enterprises, supply chain members (including customers and suppliers) are not only the primary source of technological innovation, but also an important source of ideas and knowledge. Information sharing, mutual trust and joint problem-solving among members, what supply chain integration emphasizes, could enhance direct or indirect interaction between enterprises and their supply chain partners. This could bring out a new and different perspective and help generate novel ideas and different alternatives, which are essential for innovation [46].

Many empirical studies (e.g., Gemünden, 1996) found that having suppliers involved in projects for product innovation earlier can avoid costly design changes later [47]. Suppliers' participation in technological innovation has a significantly positive effect on operational performance and innovative performance [48]. Customers' participation in new product development projects can help enterprises acquire demand information, which can improve customer satisfaction with lower costs and higher quality. Customer demand is an important antecedent of cooperative innovation and crucial to product design, so customers' engagement in innovation contributes positively to the quality performance and innovation performance [49,50].

According to RV, the network resources that are propagated by supply chain integration, rich in knowledge and information, are a kind of corporate advantage resource [12]. On one hand, the network can accelerate knowledge sharing of inter-enterprises in supply chain. On the other hand, the network can facilitate mutual learning and problem-solving of inter-enterprises in supply chain, which helps to acquire innovative resources and promote innovative performance [51].

Literature published in the recent two years show that increasingly scholars are beginning to research the effect of supply chain integration on innovation from a holistic approach of supply chain. Bellamy *et al.* (2014) [36] confirmed that the supply chain network integration and knowledge collaboration, not only could improve product quality and service level, but also were the key resource of business innovation. Lee *et al.* (2014) [46] found that supply chain integration had a significantly positive effect on innovation performance in manufacturing firms of Malaysia. Therefore, we propose the following hypothesis:

*H2: Supply chain integration has a positive effect on technological innovation performance.*

### *3.3. Relationship between Supply Chain Integration and Knowledge Sharing*

As discussed in the RV, with the transformation of business management from closed-end management to open management, supply chain network has become an important way for enterprises to share knowledge. The influence of supply chain integration on knowledge sharing is as follows: Firstly, for development, enterprises should not only rely on its own scarce resources (including knowledge) but also actively acquire new knowledge from external sources. Supply chain integration provides suitable conditions and opportunities for firms to acquire knowledge within the scope of the supply chain [52]. Secondly, the closer a firm is to supply chain partners, the more it can stimulate knowledge sharing. Tight inter-enterprise relationship networks can promote mutual knowledge sharing [53]. Thirdly, by properly using inter-organization "relationship", a firm can not only enhance the quality of resource exchange and knowledge acquisition, but can also enhance the cohesion, thus improve the transfer of each other's "tacit knowledge" and the exchange efficiency [54]. Supply chain integration provides its members friendly communication opportunities facilitating consensus building, which contributes to open sharing and effective use of tacit knowledge. Lee *et al.* (2014) [46] also found out that supply chain network was an important source of knowledge and resources for enterprises. Thus the following hypothesis is proposed:

*H3: Supply chain integration has a positive effect on supply chain knowledge sharing.*

### *3.4. Relationship between Knowledge Sharing and Technological Innovation Performance*

According to knowledge management theory, enterprise innovation stems from the re-integration and creativity of knowledge resources [52], and knowledge is the key factor to innovation. Nonaka (1991) [55] proposed knowledge sharing was the primary stage of innovation; An organization cannot create knowledge by itself, only when the knowledge wealth that its staff owned was shared, discussed and analyzed, the organization would have the ability to innovate. Knowledge sharing of inter-organization can not only alleviate the predicament of limited internal knowledge resources and reduce development costs, but also improve the implementation rate of innovation [44]. Enterprises, by sharing knowledge with supply chain partners, are able to timely grasp advanced technology and cutting-edge innovative achievements which are essential for technological innovation. Thus, we propose the following hypothesis:

*H4: Supply chain knowledge sharing has a positive influence on technological innovation performance.*

### *3.5. The Moderating Effect of Supply Chain Integration*

Supply chain integration is not only an antecedent of technological innovation performance; it also could become a condition under which environmental management practices impact on technological innovation performance. Llerena (1999) [56] and Avadikyan (2001) [57] indicated that organizational learning and inter-organizational cooperation mechanisms were obviously related to the relationship between environmental management and innovation. Cai and Zhou (2014) [58] found that supply chain integration meant good communication, trust, and cooperation among supply chain members, which had a direct impact on the establishment of supply chain collaboration network and the inter-organizational learning. According to RV of RBV theory, the network propagated by supply chain integration, as an advantage resource, could promote organizational learning and knowledge sharing and cooperation among supply chain partners [12,59]. Thus, firms with higher level supply chain integration can get more tacit knowledge and product life cycle knowledge from environmental management practices and have more inter-organizational learning and collaboration opportunity to apply this knowledge for technological innovation.

Therefore, supply chain integration, as an important supplementary factor, should not be ignored while exploring the relationship between environmental management practices and technological innovation. Therefore, we propose the following hypothesis:

> *H5: Supply chain integration positively moderates the relationship between environmental management practices and technological innovation performance.*

## 4. Research Method

### *4.1. Data Sources*

This study used the questionnaire survey method to collect data. We invited two professors, six PhD graduates and four managers of Chinese companies (two CEOs, a supply chain executive, and a technical director) to discuss the content and applicability of the scales. After the scales were determined, the survey was divided into two stages. The first stage was questionnaire test. We generated twenty-five valid questionnaires through face-to-face interviews with manufacturing executives in the provinces of Guangdong and Henan, and twenty valid questionnaires from interviews with Henan University MBA students. Then, the structure and questions of the questionnaire were modified and improved by analysis outcome.

The second stage was the formal investigation stage. We focused on manufacturing enterprises and asked for senior managers who had comprehensive understanding of enterprises to fill in the survey. Enterprise samples were distributed mainly in Shanghai, provinces of Guangdong, Hunan, Henan, and other places. A total of 375 formal questionnaires were given out, and 154 questionnaires were received with 112 valid, which represented a 29.9% response rate. Sample industries cover transportation equipment manufacturing (26%), electrical machinery and equipment manufacturing (14%), communications equipment, computers and other electronic equipment manufacturing (12%), petrochemicals (11%) and other industries including biopharmaceuticals, equipment instrument manufacturing, paper printing, and metal smelting (37%).

We assessed the nonresponse bias by comparing the firm size and the industrial distribution of the 112 responding firms with those of all non-responding firms. The result revealed no significant differences between responding and non-responding firms.

### *4.2. Variable Measurements*

All the scales used in this paper are well-known to most scholars and from respected journals (shown in Table 1).

**Table 1.** Sources of the scales.

| Variables | Sources | Cronbach α | KMO |
|---|---|---|---|
| Supply chain integration | Flynn *et al.* (2010) [29], Frohlich and Westbrook (2001) [34] | 0.915 | 0.908 |
| Environmental management practices | Xue and Gao (2004) [60] | 0.883 | 0.861 |
| Knowledge sharing | Lin (2014) [42] | 0.769 | 0.773 |
| Technological innovation performance | Hagedoom and Cloodt (2003) [37], Chen and Chen (2006) [38] | 0.823 | 0.746 |

*Technological Innovation Performance:* According to the studies of Hagedoorn and Cloodt (2003) [37] and Chen and Chen (2006) [38], we used the announcement, sales rate, and development speed of new products, R&D investment, and the success rate of innovative projects as the measurement indicators of technological innovation performance. To exclude differences among industries, each issue is limited with "compared with your peers in recent three years". We use a 5-point scale (1 = "very low" and 5 = "very high") and Cronbach α coefficient is 0.802, more than 0.7, indicating high reliability. KMO is 0.747, more than 0.7, and the factor loading of each item is greater than 0.713, indicating that the scale is very valid.

*Environmental Management Practices:* In this paper, we used the scale of Xue and Gao (2004) [60], including eight items such as "establishment of green management objectives", "improvement of staff environmental awareness", "increase in investment in environmental protection", and so on. A 5-point scale is used (1 means "no consideration"; 2 "planning to be considered"; 3 "having been considered"; 4 "being implemented to some extent" and 5 "having been implemented successfully"). Cronbach α coefficient is 0.882, more than 0.7, indicating good reliability. KMO is 0.893, which is also more than 0.7. Except one factor loading 0.570, the others are greater than 0.726, indicating that the scale is very valid.

*Supply Chain Integration:* We referenced the scales of Flynn *et al.* (2010) [29], Frohlich and Westbrook (2001) [34], and selected nine questions. A 5-point scale is used (1 = not at all; 5 = extensive). Cronbach α coefficient is 0.909, more than 0.7, meaning good reliability. KMO is 0.905, greater than 0.7, and factor loading of each item is greater than 0.682, indicating that the questionnaire has good validity.

*Supply Chain Knowledge Sharing:* In this paper, we used the scales of Lin (2014) [42], including five items. A 5-point scale is used (1—strongly disagree, 5—strongly agree). Cronbach α coefficient is 0.769, more than 0.7, meaning good reliability. KMO is 0.773, greater than 0.7. Except one factor loading 0.589, the others are greater than 0.720, indicating that the questionnaire has good validity.

*Control Variable—Enterprise Size:* Bigger companies tend to pay more attention to environmental management than smaller ones, and take up more positive attitude and behavior towards environmental management (Thoumy and Vachon, 2012) [61]. This may result in that large companies could more easily attract public attention, and have more resources in capital, technology, and labor, providing necessary conditions for the implementation of environmental management. Thus, we set enterprise size as the control variable. According to the number of employees, enterprise size is divided into four categories: 1 represents "$x \leq 50$"; 2 "$50 < x \leq 300$"; 3 "$300 < x \leq 1000$" and 4 "$x > 1000$".

### *4.3. Confirmatory Factor Analysis*

A confirmatory factor analysis (CFA) was run using Amos 22. The results showed that all the remaining items loaded significantly and highly on their assigned constructs. The overall models' fit indices were good: $\chi^2 = 329.933$, df = 226; CF1 = 0.913, IFI = 0.915; and RMSEA = 0.064, indicating that the model was acceptable.

### *4.4. Common Method Bias Analysis*

Harman's single-factor test was applied to establish whether one single-factor accounting for most of the variance in the data could be identified from the unrotated solution of a factor analysis. Here, the unrotated factor solution yields 27 factors, of which five have eigenvalues larger than unity, explaining 63.195% of total variance. The first factors explained 37.041%, which is not majority of the total variance. Then, confirmatory factor analysis (CFA) was applied to Harman's single-factor model [35]. The model fit indices of $\chi^2 = 841.527$, df = 324, CFI = 0.655 and IFI = 0.661 were unacceptable and were significantly worse than those of the measurement model. Thus the common method bias is small.

## 5. Research Results

### *5.1. Descriptive Statistics and Correlations*

Descriptive statistics is shown in Table 2, including mean, standard deviation and correlation coefficient of all the variables.

**Table 2.** Descriptive statistics and correlations.

| Variables | Mean | Standard Deviation | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Supply chain integration | 3.82 | 0.73 | 1 | 0.47 ** | 0.69 ** | 0.52 ** | 0.09 |
| Environmental management practices | 3.37 | 0.90 | 0.47 ** | 1 | 0.45 ** | 0.50 ** | 0.24 * |
| Knowledge sharing | 3.71 | 0.70 | 0.69 ** | 0.45 ** | 1 | 0.44 ** | −0.40 |
| Technological innovation performance | 3.33 | 0.71 | 0.52 ** | 0.50 ** | 0.44 ** | 1 | −0.16 |
| Enterprise size | 3.03 | 1.10 | 0.09 | 0.24 * | −0.04 | −0.16 | 1 |

* $p < 0.05$; ** $p < 0.01$.

### *5.2. Empirical Results*

Five hypotheses are verified through seven regression models, as shown in Tables 3 and 4. Model 1a verifies that the enterprise size has no significant effect on technological innovation performance. Added in the control variables, Model 1b shows that environmental management practices have a significantly positive impact on technological innovation performance (β = 0.535, $p < 0.001$), supporting H1. Model 1c shows that supply chain integration has a significantly positive effect on technological innovation performance (β = 0.532, $p < 0.001$), supporting H2. Model 2b verifies that supply chain integration has a significantly positive effect on supply chain knowledge sharing (β = 0.692, $p < 0.001$), thus H3 is verified. Model 1d shows that supply chain knowledge sharing has a significantly positive effect on technological innovation performance (β = 0.452, $p < 0.001$), supporting H4.

**Table 3.** Regression analysis.

| Variables | Technological Innovation Performance | | | |
|---|---|---|---|---|
| | **Model 1a** | **Model 1b** | **Model 1c** | **Model 1d** |
| Enterprise size | −0.016 | −0.143 | −0.065 | 0.002 |
| Environmental management practices | | 0.535 *** | | |
| Supply chain integration | | | 0.532 *** | |
| Knowledge sharing | | | | 0.452 *** |
| Supply chain integration × environmental management practices | | | | |
| $R^2$ | 0.000 | 0.270 | 0.281 | 0.204 |
| Adjusted $R^2$ | −0.009 | 0.256 | 0.267 | 0.190 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

**Table 4.** Regression analysis.

| Variables | Knowledge Sharing | | Technological Innovation Performance |
|---|---|---|---|
| | **Model 2a** | **Model 2b** | **Model 3** |
| Enterprise size | −0.040 | −0.103 | −0.147 * |
| environmental management practices | | | 0.370 *** |
| Supply chain integration | | 0.696 *** | 0.441 *** |
| Knowledge sharing | | | |
| Supply chain integration × environmental management practices | | | 0.210 ** |
| $R^2$ | 0.002 | 0.482 | 0.414 |
| Adjusted $R^2$ | −0.008 | 0.473 | 0.391 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

By using hierarchical regression, Model 3 brings the interaction term between supply chain integration and environmental management practices into the regression model. The result shows that the interaction term has a significantly positive effect on technological innovation performance (β = 0.210, $p < 0.01$). To explain the moderating effect, we plot the relationship between environmental management practices and technological innovation performance at 1SD above (high supply chain integration) and 1SD below

(low supply chain integration) the mean of supply chain integration, as shown in Figure 2. Figure 2 indicates that there is a positive correlation between environmental management practices and technological innovation performance: when the company has a higher level of supply chain integration, environmental management practices have more impact on technological innovation. The moderating effect in H5 has been verified.

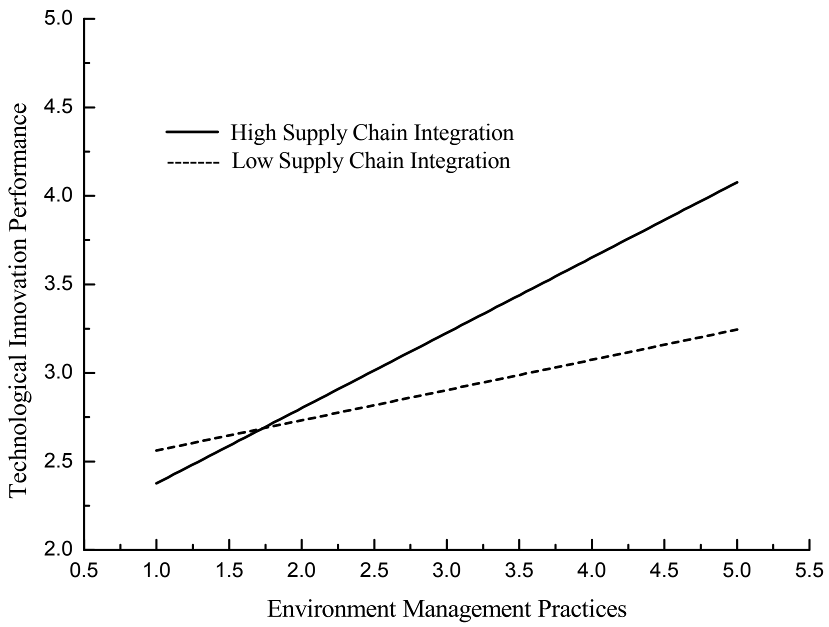


**Figure 2.** Moderating effect.

## 6. Discussions and Conclusions

The study suggests that environmental management practices are positively related to technological innovation performance. Supply chain integration is not only a predictive variable of technological innovation performance, also a positive condition under which environmental management practices exercise a great influence on technological innovation performance. Consistent with RBV, the tacit and product life cycle knowledge embedded in environmental management has a positive effect on technological innovation performance, and inter-organizational learning. Network resource created by supply chain integration can catalyze this effect.

### *6.1. Main Findings*

First, our empirical results demonstrate the positive effect of environmental management practices on technological innovation performance, which are consistent with previous studies (e.g., Rennings *et al.* (2006) [11], Wanger (2008) [10], and Lee *et al.* (2014) [46]). Compared with previous studies, which are limited to one or two environmental management practices and only environmental innovation, our findings provide a complete framework for the effect of systematical environmental management practices on technological innovation. Environmental management practices promote innovation, and create tacit knowledge and product life cycle knowledge, which are vital for all innovation activities.

The results are in accordance with the NRBV of the RBV, and are complementary to "Porter hypothesis" from the perspective of environmental management practices at the firm level.

Second, the empirical results highlight the value of supply chain integration. That is, supply chain integration not only can catalyze the influence of environmental management practices on technological innovation performance, but also has a positive effect on technological innovation performance. Supply chain integration creates a network in which knowledge exchange among supply chain partners plays a significant role. Companies with high level supply chain integration have not only advantage in implementing environmental management activities from the entire supply chain, but also access to exchange and share knowledge with supply chain partners. Apart from new technologies and ideas, they can easily capture innovation demands of customers and put innovation results into application. That ultimately leads to a high innovation performance. At the same time, enterprises with low supply chain integration have difficulty getting full knowledge of product life cycle. They are limited to end-of-pipe control and have to bear the control costs alone. Consequently, they lack the necessary knowledge and funding to support technological innovation.

Third, we observed that supply chain integration has a direct effect on supply chain knowledge sharing, and supply chain knowledge sharing has a positive influence on technological innovation. This is supported by previous findings from Constant *et al.* (1994) [53], Tsai (2002) [62], Lin (2007, 2014) [42,63], and Wang *et al.* (2008) [64]. The closer a firm is to its supply chain partners, the more it can stimulate higher knowledge sharing, which is in accordance with the RV of the RBV. Through interaction of supply chain partners, firms gain more opportunities to share their ideas and knowledge, and the network created by supply chain integration can provide channels and platforms for their knowledge sharing. Since knowledge sharing is the basis of innovation, and at present, no single firm can obtain all the knowledge that innovation needs by itself [29], so supply chain knowledge sharing has become increasingly important for innovation.

### *6.2. Managerial Implications*

The first managerial implication is that enterprise managers should realize that environmental management practices can not only lead to environmental improvement, but can also promote technological innovation which can offset costs and create the first-mover advantage. Due to worsening air quality, soil contamination, water pollution and other environmental issues, enterprises are faced with increasing pressure of environmental protection by society, governments, and supply chain members. However, many enterprises do not know how to adopt environmental management practices effectively (Kiron *et al.*, 2012) [65]. This study suggests that compared with passive and end-of-pipe treatment, proactive and preventive environmental management practices could more effectively promote technological innovation performance. Since the costs of environmental management practices must be expended now, while the benefits can only be realized in the future. A shortsighted executive will tend to postpone investments in environmental management practices. In actuality, environmental management practices such as application of environmental management assessment tools (such as life cycle assessment, environmental auditing, ISO14001), establishing environmental performance targets, publicly disclosing environmental performance and training the staff on environmental protection could provide huge gains through the first-mover advantage. Furthermore, practitioners should be mindful to collect tacit knowledge and life cycle knowledge embedded in environment management practices, and build a platform to transfer and share those knowledge to intra-organizational departments such as R&D, sales, production, and supply, and extra-organizational supply chain partners (suppliers and customers).

Second, for learning, sharing knowledge with supply chain partners, enterprises should prioritize supply chain integration. Supply chain managers can speed up supply chain integration through building a network for exchange of information, cooperating with supply chain partners in strategic decision, and sharing risks and benefits. Particularly, they should collaborate with partners in environmental management and knowledge sharing, for example, organizing meeting for experience exchange, building database of product life cycle knowledge and eco-technology, and establishing teams for collaborative innovation.

Third, for enterprises, the "Three-in-One" combining of environmental management, and supply chain integration with supply chain knowledge sharing, not only has a positive influence on innovation, but also is an advantage capability for competitive strategies and performance. The study suggests that managers could restructure functional departments on supply chain management, environmental management and knowledge management. For example, they could place the three functions in one department or empower one executive to take responsibility.

### *6.3. Limitation and Future Research*

This study acknowledges a number of limitations that need to be addressed.

First, our conclusions deserve further consideration in larger samples and wider industrial settings. If the sample size were large enough, it would be beneficial to advance the diversified statistical techniques to improve validity and reliability of the results, and increase accuracy of prediction.

Second, a potential limitation and future research is to examine the different influences of different dimensions of supply chain integration on technological innovation performance and the relationship between environmental management practices and technological innovation performance. Flynn *et al* (2010) claimed that internal integration and customer integration were more helpful to improve firms' performance than supplier integration [29]. We were subject to the limitation of the sample size and only focus on external integration.

Third, technological innovation can be divided into non-environmental innovation and environmental innovation [66,67]. Ziegler and Nogareda (2009) pointed out that the adoption of environmental programs (or specific environmental management practices) could negatively be affected by environmental innovations, and non-environmental innovation was not generally critical for the adoption of environmental programs (or specific environmental management practices) [66]. Therefore, we only examined the influence of environmental management practices on technological innovation, without detailed division of non-environmental and environmental innovation. Future research could examine this relationship thoroughly.

Finally, our theoretical model needs extensive development in the future. For example, the nomological network we conduct to improve innovation performance is an advantage capability for firms' competitive strategies and performance. Future research should look to find out how this network affects other performance (e.g., economic, environmental and social). We hope this study provides a framework for future research.

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## Author Contributions

Jiehui Yang designed and performed research at all stages with direction of Qinglan Han. Jiehui Yang collected data and wrote the paper with contributions from Juanmei Zhou， and Juanmei Zhou revised and edited English expression. Jiehui Yang interpreted the data with contributions from Chunlin Yuan.

## Conflicts of Interest

The authors declare no conflict of interest.

## Appendix: Questionnaire Items

**Environmental management practices** (adapted from Xue and Gao, 2004 [60])
(1 means "no consideration"; 2 "planning to be considered"; 3 "having been considered"; 4 "being implemented to some extent" and 5 "having been implemented successfully")
1. Establish green management objectives.
2. Increase staff awareness.
3. Increase investment in environmental protection.
4. Cleaner production.
5. Green design.
6. Green marketing.
7. Products crap and recycling management.
8. ISO14001 certification.
9. Green audit. (Not pass tests, delete)

**Supply chain integration** (adapted from Flynn *et al.*, 2010 [29]; Frohlich and Westbrook, 2001 [34])
(1 = not at all, 5= extensive)
1. The level of linkage with our major customer through information networks.
2. The level of communication with our major customer.
3. Our major customer shares demand forecast with us.
4. The level of sharing of market information from our major customer. (Not pass tests, delete)
5. The level of information exchange with our major supplier and customer through information networks.
6. The level of strategic partnership with our major supplier.
7. The participation level of our major supplier in the process of procurement and production.
8. Our major supplier shares available inventory with us.
9. We share our demand forecasts with our major supplier.
10. We help our major supplier to improve its process to better meet our needs.

**Supply chain knowledge sharing** (adapted from Lin, 2014 [42])
(1 = strongly disagree, 5 = strongly agree)

1. Our company and supply chain partners share project proposals and reports with each other
2. Our company and supply chain partners share business knowledge obtained informally (such as news stories and gossip)
3. Our company and supply chain partners share know-how from work experience with each other
4. Our company and supply chain partners share expertise obtained from education and training methods
5. Our company and supply chain partners put little effort in sharing lessons and experiences.

**Technological innovation performance** (adapted from Hagedoorn and Cloodt, 2003 [37]; Chen and Chen, 2006 [38])
(Compared with your peers in recent three years, 1 = very low, 5 = very high)
1. Our new product development speed.
2. Our new product announcement.
3. Our new product sales rate.
4. Our R&D investment.
5. Our success rate of innovative projects.

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