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Assessing the green value chain to improve environmental performance

Evidence from Taiwan's manufacturing industry

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Abstract

Purpose – The purpose of this paper is to investigate the relationship between green management and environmental performance. This was accomplished by considering each operational element, including the supply and acquisition of upstream materials, research and development, manufacturing and packaging, marketing, promotion and education, and recycling activities.

Design/methodology/approach – The paper constructs an integral model of the green value chain to reveal the extent to which Taiwanese manufacturing industries are adopting green value chain management and implementing environmentally conscious business practices. Survey data were collected from 118 Taiwanese manufacturers.

Findings – The findings indicate a positive relationship between green value chain management and environmental performance. The results suggest that when firms only implement green management in particular areas the effect is insignificant; however, a comprehensive implementation can result in an overall improvement in environmental performance.

Originality/value – This paper may serve as a reference for firms mapping out future environmental policies and provide an input of various perspectives and arguments into the discipline of green management.

Keywords Green value chain, Environmental management, Environmental performance, Competitive advantage, Taiwan

Paper type Research paper

1. Introduction

We are currently entering a new era of environmental cooperation, in which firms are inevitably subject to environmental regulations and face increasing pressure from the public with regard to environmental issues. Firms with a heightened environmental consciousness tend to consider the interests of stakeholders as a business priority, and are therefore willing to consider opinions from both sides of these contentious issues (Freeman, 1984; Hill and Jones, 1992; Henriques and Sadorsky, 1999; Ruf *et al.*, 2001; Buysse and Verbeke, 2003; Collier, 2008).

In the face of tremendous green pressure, firms wishing to take the initiative in environmental protection should embrace the concept of green management (Hopfenbeck, 1993). Lowe (1990) posited that industrial ecology illustrates the

International Journal of Development Issues
Vol. 11 No. 2, 2012
pp. 111-128

1446-8956
DOI 10.1108/14468951211241119

value of modeling industrial systems on ecosystems to achieve sustainable environmental performance. Green management is a new concept combining the ideals of environmental protection with corporate goals, product design, production development, marketing, finance, and other variables in business management (Winn and Roome, 1993). Taylor (1992) pointed out that green management refers to the implementation of comprehensive measures throughout the business process. Firms need to view environmental performance as a major component in management, adopting it as an integral part of the organization, alongside strategies, quality, staff relationships, and corporate image (Taylor, 1992). By doing so, firms can transform the pressure from environmental concerns into competitive advantage (Porter and Kramer, 2006).

A green value chain refers to the lifecycle of a product beginning with the initial sourcing, through research and development (R&D) and production, all the way to the final recycling of waste and product abandonment. Environmental control is implemented in every stage of the operation to reduce the waste of resources and curb unnecessary expenses. The resulting environmentally friendly products possess unique market value gained from a favorable image (Russo and Fouts, 1997).

Previous scholars have focused primarily on the issues of green management within western markets and only a handful of studies have conducted comprehensive analysis of the green value chain (Hartman and Stafford, 1988; Simon, 1992; Handfield *et al.*, 1997; Fullerton and Wu, 1998; Rivera-Camino, 2007). Therefore, this study constructs an integrated model of the green value chain to reveal the extent to which Taiwanese manufacturing industries are adopting green value chain management.

To meet the challenges posed by the transition from regional operations to a global front, Taiwanese manufacturers must devise new strategies to deal with more stringent environmental standards in international markets. Many Taiwanese manufacturers are convinced that the more environmentally friendly they become, the more business opportunities they will be able to create. Firms believe that by making operations sustainable and developing green products, they will not only be adhering to increasingly stringent international environmental regulations, but will also be developing a competitive advantage (Chien and Shih, 2007). This will be particularly helpful in extending markets into countries with rigorous environmental standards. This study, therefore, seeks to extend the literature and provide managerial implications to firms in Taiwan, as well as to those in other emerging economies.

Previous studies have discussed the relationship between green management and environmental performance from a broad perspective (Hopfenbeck, 1993; Garrod and Chadwick, 1996; Gadenne *et al.*, 2009). The discussions were conducted without taking into consideration the individual operational elements associated with the value chain, including the supply and acquisition of upstream materials, R&D, manufacturing and packaging, marketing, promotion and education, and recycling activities (Simon, 1992). Nor did previous discussions address how these items come into play with regard to the environmental performance. As a result, this study investigated the influence of each of these aspects on a firm's environmental performance.

The remainder of the paper is structured as follows. Section 2 reviews the literature and develops our hypotheses. Section 3 discusses research design. Section 4 presents the empirical results and provides additional analysis. Finally, conclusions are presented in Section 5.

2. Literature review

2.1 Green value chain management

Porter (1985) pointed out that the most important mission of a firm is value creation, and any series of complex activities aimed at creating value forms a value chain. Because customers must believe that the real value of a particular product or service exceeds the amount on the price tag and the price is always set beyond the cost of production, it is a firm's priority to improve the perceived value of a product or service and reduce the cost of production.

Porter (1985) divided the activities within a value chain into two major areas: primary activities and support activities. Primary activities refer to those directly contributing to end-product portfolios, whereas support activities are auxiliaries that help to create value. Consequently, the focus of a firm should be on the means to effectively integrate all activities within the value chain and transform them into a source of competitive advantage.

It is interesting to note that most value chains are linear, and the crux of this problem lies in the weak linkage between the initial purchase and the final delivery. Vandermerwe and Oliff (1991) proposed the concept of a system based on reconsumption. Such a system would recycle products and materials, with the process of recycling integrated with that of production, transforming the residue and remains into energy.

Hartman and Stafford (1988) pointed out that the traditional linear value chain is based on the assumption of closed-loop resources, whereas the green value chain emphasizes a closed-loop process in which the production of high-value products and the discarding of recyclables are avoided, thereby reducing pollutants. This process of recycle and reuse reflects the cyclical food chain in nature, and is both economical and environmentally friendly. Simon (1992) redefined the concept of green value chain, highlighting the principle of "reproduction and reconsumption," emphasizing the process of recycling and how it is treated. A green value chain links the treatment of waste with sourcing to form a circular value chain – an evolved version of the traditional linear value chain. Simon (1992) recommends that firms proactively develop eco-friendly niche markets and consider green demands in each and every stage of the green value chain.

According to Handfield et al. (1997), the optimal approach for firms embarking on green endeavors is to combine environmental management with the value chain. The concept and practice of green management are applied to every individual link in the value chain, a method that demonstrates significant positive association. This allows the organization to minimize pollution and waste during operations.

On the basis of the aforementioned propositions, we believe that every aspect of the value chain involves the concept and practices of green management for the purpose of developing eco-friendly raw materials and components, reducing waste, and minimizing pollution produced during operations. Thus, this study defines a green value chain as, "a looped series of business procedures in which green management techniques are applied throughout the entire process, with an emphasis on recycling and follow-up treatment, to minimize waste." This study adopts Simon's (1992) division of green value chain operations; however, because the manufacturing and packaging stages are inseparable, we have merged the two to form a single construct. Therefore, we propose a green value chain with six major aspects: green sourcing, green R&D, green production and manufacturing, green marketing, green promotion and education, and recycling.

2.2 Green sourcing

Green procurement ensures that all purchased components comply with environmental requirements. A green supply chain refers primarily to the responses and effects caused by initiatives in the European Union demanding environmentally friendly products. The broad definition of a green supply chain refers to environmental management applied to suppliers (Walton *et al.*, 1998; Beamon, 1999). In other words, a green supply chain incorporates environmental principles within the management of suppliers to encourage firms to sell environmentally friendly products (Sarkis, 2003).

The main purpose of a green supply chain is to ensure the effective management of all regulated and banned substances as well as other specific environmental concerns throughout the production process, from securing sustainable sources of raw materials and components from upstream suppliers, to the downstream delivery of products (Beamon, 1999). The foundation of the entire control operation lies in the incorporation of "green demands" within the existing material management system and operational processes. The firm then evaluates the new management system, production process, and technical standards, and conducts analysis on the raw materials and products to ensure that the entire supply chain meets the "Qualifications" or "Acceptance Criteria" approved by its clients.

This paper defines green sourcing as "the procurement of raw materials that comply with environmental standards showing a preference for materials that are reusable, recyclable, or previously recycled." In this case, sourcing also takes into consideration the environmental performance of upstream suppliers, thereby incorporating environmental principles into supplier management.

2.3 Green R&D

Chatterji (1995) pointed out that R&D units must establish proactive strategies and cannot afford to limit themselves to performing activities simply in compliance with regulations. R&D units need to actively develop green production processes, as it is within this function that firms alleviate the environmental impact of their actions, while simultaneously reducing the cost of input and waste disposal (Fullerton and Wu, 1998).

Porter and van der Linde (1995) proposed the concept of resource productivity, which begins by reengineering the design of products to ensure that the entire production process is energy-efficient. This includes recycling and renewing used resources to enhance the resource productivity of products.

Green design begins by conducting a life-cycle assessment and taking the environmental impact into consideration throughout the entire process, from the selection of materials, through manufacturing processes, packaging and transportation, and product usage, down to the disposal of waste. The focus of green design is "researching, developing and designing green life cycles," the key to which lies not in the means of recycling existing waste, but rather in enabling designers to foresee the potential environmental impact of the product during its conception (Billatos, 1997). In this manner, designers approach product R&D with a mind to reducing the potential environmental impact, thereby acting to ameliorate any damage the product may have on the ecosystem.

Green design stresses that R&D engineers incorporate environmental requirements into the design process. On the basis of the aforementioned literature, this paper defines green R&D as "establishing a set of principles and tests for green design, such that firms are capable of supporting designers in the development and testing of products according to an assessment of life cycle."

2.4 Green manufacturing and packaging

Sarkis (1995) introduced the concept of environmentally conscious manufacturing, involving the planning, development, and implementation of manufacturing technologies to reduce toxic waste, reduce abandonment, improve operational safety, and produce recyclable products capable of being remade and reused. Green manufacturing focuses on the means of ensuring that manufacturing processes meet environmental standards.

Sarkis (2003) described how efficiency in packaging has a direct effect on the environment and a strong relationship with other components in the green value chain. Peattie (1992) proposed that substances contained in the packaging of green products should have minimal environmental impact. The principles of green packaging include simple packaging, biodegradability, no excessive packaging, the use of paper wrappings, reduced quantity of polystyrene, sterilized wrapping materials, easy disassembly, and the use of simplified packaging materials.

This paper defines green manufacturing as "a reduction in the waste associated with energy and resources, as well as reduced pollution and waste throughout the manufacturing process." Hence, this paper defines green packaging as "the use of packaging materials with the least environmental impact."

2.5 Green marketing

Winter and Ewers (1988) viewed green marketing as a type of strategic management procedure, whose goal is to satisfy customer demand for green consumption. Peattie (1992) considered green marketing a type of management process that identifies, predicts, and meets the demands of consumers and society. This process can be profitable and sustainable. By contrast, Charter (1992) stressed that green marketing focuses on the acquisition, production, sales, consumption, and disposal of raw materials. In other words, green marketing is a means to minimize the environmental impact of every link in the chain.

Schoell and Guiltinan (1993) pointed out that green marketing involves the development and implementation of marketing projects to enhance the green image of firms. Green marketing is defined as the application of appeal, ideas, and practices associated with environmental protection to various aspects of marketing, ranging from marketing strategies to corporate culture or corporate missions. In response to a wave of green consumerism, firms have begun producing and marketing green products, adding green concepts to their operational strategies and shaping a green corporate culture through marketing (Cordano, 1993).

Green marketing also represents a set of strategies that applies the appeal, beliefs, and practices of environmental protection to products, pricing, promotion, and place to satisfy the demand of consumers and society for green initiatives. Prior studies have addressed a wide spectrum of green marketing. This paper defines green marketing as "the application of the appeal, beliefs, and practices of environmental protection as they pertain to products, pricing, and places," with promotion (the fourth "p") integrated with education.

2.6 Public relations and green education

Public relations and consumer education refer to the use of the tools of communication, including sales staff, promotions, public relations, and direct selling. These tools are meant to communicate a coherent message of green intentions to clients and

the public, as a means to boost a green corporate image (Hart, 1995). Promotion describes the implementation of a marketing campaign through four controllable channels: advertising, sales staff, public relations, and promotions. Each channel is afforded a different level of value according to the industry, firm, and product involved.

Green education is often involved in a firm's strategy to go green. Coddington (1993) suggested that providing green education for employees facilitates the communication of green messages and discussions of green issues within the firm. It also reinforces green concepts among the staff, making them aware of the environmental goals of the firm (Katzenbach, 2000; Ehnert, 2009). Employee commitment thus refers to decision making and the allocation of resources from a long-term perspective. This requires strong social and environmental awareness on the part of corporate leaders, coupled with the support of high-level managers, to encourage employees to act. Workforce engagement helps to direct the attention and behavior of employees regarding the sustainability of goals adopted by the firm (Ramus and Steger, 2000; Wirtenberg *et al.*, 2007).

Firms must also provide green education for consumers. Coddington (1993) suggested that green education can help to correct consumer misconceptions. This paper defines green promotion and education as "the transmission of a firm's environmental convictions to staff, clients, and suppliers."

2.7 Collection and post-use processing

Product disposal is based on the principle of increasing product value, focusing on recycling and reusing old products that no longer have economic value, for the purpose of lengthening product life cycle and value, eventually leading to resource circulation and sustainable development. Basically, the disposal of products refers to the "3R" principle of recycle, reuse, and renew (Balkau, 2006); however, it also requires that the government establish and enforce regulations, coupled with the full cooperation of the business sector and the active participation of the general public. In this paper, recycling refers to firms taking responsibility for the recycling of the waste they create.

2.8 Evaluating environmental performance

ISO 14031 divides environmental indicators into two major categories: Environmental Condition Indicators (ECI) and Environmental Performance Indicators (EPI). ECI provides information on the latest environmental conditions and helps organizations to better understand the actual, or potential, impact caused by environmental measures. Organizations can also use the information to map out and implement evaluations of environmental performance.

EPI can be divided into Management Performance Indicators (MPI) and Operational Performance Indicators (OPI). MPI refers to management policies (and the evaluation of these policies) that are used to improve internal operational performance and enhance managerial capacity. MPI also includes the efforts and decisions made at the managerial level that may influence the operation of the firm and contribute to its overall environmental performance. OPI represents indicators that help the managerial staff to continue improving operations. Such indicators include input materials, energy, output products, waste, and effluent. The definition of environmental performance in this paper is based on that of ISO 14031, namely MPI and OPI.

2.9 Green value chain management and environmental performance

Hutchinson (1992) suggested that taking an active role in environmental problems can generate a number of benefits, including the improvement of corporate image and enhancing popularity, attracting buyers who support green consumerism, and the introduction of positive investment screening. Through recycling and pollution control, firms are able to improve production efficiency, thereby lowering costs and by increasing energy efficiency, firms can reduce expenditures further. They can also avoid high insurance premiums and maintain positive relationships with residents in local communities. In so doing, firms benefit from producing high-value green products while enjoying a number of other potential advantages (Barney, 1991; Hafeez *et al.*, 2002; Porter and Kramer, 2006).

Taylor (1992) suggested that firms embark on green management and green innovation to improve environmental performance, and satisfy the demands of consumers to boost corporate image among regulators and the general public.

Steger (2000) pointed out that the results of environmental management can be observed in decreased costs, increased market opportunity, the efficient use of resources, pollution prevention, improved compliance, increased staff motivation, improved organizational efficiency, reduced risk, assigned liabilities of environmental problems, and the distribution of environmental information.

Porter and van der Linde (1995) studied 29 green factories that had embarked on energy-saving practices. They discovered that good environmental control measures prompted businesses to engage in skill innovation. Such measures may appear to have a negative impact in the short run; however, in the long run, businesses are able to reduce disposal costs resulting from a need to comply with waste volume regulations, with eventual improvements in resource productivity. They also believe that firms taking the lead in innovation benefit from greater added value, thanks to their green products, enabling them to open up new business opportunities and sell more products. Chin and Pun (1999) investigated printed circuit boards in Hong Kong and discovered some positive results generated from implementing ISO 14000: reduced legal liability, increased profits, improved corporate image, and better staff morale.

Florida and Davison (2001) conducted a survey of the manufacturing industry, illustrating that businesses adopting environmental management enjoy a number of benefits, such as decreased costs, improved operational performance, and decreased environmental risk.

From the perspective of corporate resources, Klassen and Whybark (1999) pointed out that pollution control technologies cannot reduce pollution or waste. Nevertheless, by investing more in pollution prevention technologies, firms should be able to reduce pollution, while improving their operational and environmental performance.

On the basis of the aforementioned studies, this paper proposes the following hypotheses (stated in alternate form):

H1. Green value chain management and environmental management performance are positively associated.

H2. Green value chain management and environmental operational performance are positively associated.

3. Research design

The data for this study were obtained from a questionnaire survey directed at manufacturers in Taiwan. This paper adopted Simon' (1992) green value chain and divided the chain into sourcing, green R&D, green manufacturing and packaging, green marketing, promotion and education, and recycling. According to Porter's (1985) value chain model, the chain can be further subdivided into primary and support activities.

This paper categorized recycling, sourcing, and R&D as support activities, while manufacturing and packaging, marketing, and promotion and education are the primary activities. Environmental performance used the ISO 14031 categorization and was divided into two types of performances: environmental management and environmental operations. In addition, the paper takes into consideration the control variables, including environmentally sensitive industries, years of establishment, corporate capital, ISO 14001 acquisition, and environmental labels.

3.1 Measures of constructs

3.1.1 Green value chain management. We used Simon's (1992) studies, along with other researchers' work (Taylor, 1992; Peattie, 1992; Porter and van der Linde, 1995), to conduct a scale for green value chain management. The scale consists of 37 items: seven on sourcing, four on green R&D, seven on green manufacturing and packaging, seven on green marketing, seven on promotion and education, and five on recycling. At the start of the survey, participants were asked whether the firm has adopted green value chain activities. If the answer was yes, then the respondent was to compare the level of adoption in his/her firm with other firms on a five-point Likert scale. The respondent was to check the box for zero if the firm has not adopted the activity. The respondents were then asked to rate their own firm on a scale of one to five, which indicated either an extremely low adoption or extremely high adoption, respectively, as compared with other firms.

3.1.2 Environmental performance. The environmental performance scale was created according to the framework of the ISO 14031 that references the questionnaires presented in Melnyk *et al.* (2003) and Wagner and Schaltegger (2004). The scale consisted of 17 items: nine on how the firm performs in terms of environmental management and eight on environmental operations. The questions adopted the five-point Likert scale. As a result, the respondents were asked to rate, on a scale of one to five, the performance of their firm after implementing green management. The numbers stand for little improvement and huge improvement, respectively.

3.2 Sample and data collection

Samples were selected from the top 1,000 manufacturers listed in the 2006 June issue of the *CommonWealth Magazine*. Manufacturers were ranked according to their operating revenue. The potential respondents were the directors of the environment and safety and individuals related to the firms in question. These individuals were instructed to either complete the survey themselves, or refer it to the most appropriate person in the firm for completion.

To ensure the content validity of the measurement instrument, the questionnaire was developed in two-stages. First, an initial questionnaire was designed on the basis of a review of the literature followed by a discussion with managers of manufacturers

regarding the wording, logic, and content appropriateness of the draft. Second, the revised version was then modified by accommodating the comments and suggestions of seven managers to ensure that each item was suited to the manufacturing industry and was interpreted as expected.

All responses are anonymous and no information will be disclosed. A total of 1,000 questionnaires were mailed out, and 135 were collected. After deleting 17 invalid questionnaires, there were a total of 118 valid questionnaires with a return rate of 11.8 per cent. The highest response rate was obtained from respondents in the electronic industry (31 per cent), followed by the chemistry industry (9 per cent). On the basis of the categorization mentioned in previous studies, we divided the industries into highly environmentally sensitive, medium environmentally sensitive, and low environmentally sensitive groups. The environmentally sensitive group distribution are detailed in Table I.

A majority of the firms surveyed were established over 31 years ago. The second majority were firms that were established between 11 and 15 years ago. As for registered capital, the highest amount (in NT dollars) was between one billion to five billion annually, followed by 500 thousand to one billion annually. In regard to ISO 14000 acquisitions: 31.7 per cent (a majority) of the firms in question were yet to acquire ISO 14000 acquisitions, fewer firms had acquired it for six to eight years, and only a few had acquired it for nine to ten years. In terms of environmental labels, 49.5 per cent of the firms had obtained environmental labels.

3.3 Respondent characteristics

A summary of the profile of the respondents is as follows: an overwhelming majority of respondents (84.7 per cent) were male. The vast majority of respondents held a college degree (73.7 per cent) and were between 31 and 50 years of age (64.3 per cent). In addition, 61.1 per cent of respondents said they had worked in environmental protection related fields for over three years. Of those, 52.9 per cent had served in related responsibilities for over six years.

Because we used a questionnaire survey, one limitation of this study was the fact that the results may have suffered from respondent bias. Participants may have modified their responses to make them socially acceptable or to appear rational. Moreover, the study was unable to maintain complete control over the collection of questionnaires. As a result, the data collected might have centered on particular samples with similar characteristics, thereby leading to erroneous results. Moreover, green value chain management, in this case, involved different sectors and units in a firm. The definition of

Environmentally sensitive group[a]	Industries	Number
High sensitivity	Cement, plastic, chemical, rubber, mineral oil	23
Median sensitivity	Textile, electric machinery, glass ceramic, iron and steel, automobile, bicycle, sewing machine	39
Low sensitivity	Electrical and cable, computer and peripheral, information	56

Notes: [a]The environmental sensitive groups are classified by the percentage of capital investment in pollution control equipment to total fixed assets; *Industrial Census Report*, Department of Statistics, Ministry of Economic Affairs

Table I. Environmentally sensitive group distribution

the responsibilities for the environmental unit directors may vary between firms. In some firms, the directors were primarily responsible for environmental performance, while in other firms, their responsibility may have been focused more on ensuring the legal compliances of the firm. It is therefore anticipated that such differences may have affected the results of the study.

3.4 Reliability and validity

This study used Cronbach's α to test the internal consistency reliability between indicators in the questionnaire. Table II presents Cronbach's α for the variables. The items regarding overall green value chain management was 0.95, while support and primary activities were 0.9 and 0.94, respectively. The items on evaluating environmental performance, namely, environmental management and environmental operations, have alphas of 0.91 and 0.93, respectively. The alphas for these items are all greater than the 0.7 suggested by Nunnally (1978), indicating good internal consistencies.

The questionnaire design was based on an extensive literature review. The content and language of the questionnaire were modified after a pretest, so as to provide the items with greater face validity.

A factor analysis was conducted. The results revealed that sourcing, green manufacturing, and green packaging contained two factors each. All other aspects contained only one factor. This result demonstrates adequate construct validity.

4. Results

4.1 Descriptive statistics

Table III presents the descriptive statistics of the variables. The mean scores for the performance of environmental management and environmental operations were 3.432 and 3.429, respectively. Judging by the scores illustrated in Table III, the firms surveyed were above average in terms of their environmental performance. On the contrary, the scores for green R&D were relatively lower. One reason may be because Taiwanese manufacturers were only beginning to take in the idea of green R&D. It might also have been the result of operational difficulties, since green design involves the integration of various technical skills and knowledge, be it management, design, or the coordination between corporate sectors.

Table II.
Cronbach's α coefficients for each variable

Variable	Cronbach's α	Cumulative variance (%)
Sourcing	0.810	63.88
R&D	0.901	77.17
Manufacturing & packaging	0.814	68.04
Green marketing	0.919	67.86
Promotion & education	0.884	59.48
Recycling	0.806	56.42
Green value chain	0.959	
Support activities	0.904	
Primary activities	0.945	
Management performance	0.919	62.05
Operational performance	0.933	68.40

Variables	Mean	SD	Minimum	Maximum
Environmental performance				
Env. management performance	3.432	0.868	1	5
Env. operational performance	3.429	0.957	1	5
Green value chain management				
Sourcing	2.821	1.110	0	5
R&D	2.071	1.611	0	5
Manufacturing & packaging	2.859	1.002	0	5
Marketing	2.478	1.417	0	5
Promotion & education	2.385	1.360	0	5
Recycling	2.222	1.329	0	5
Green value chain	2.470	1.087	0.38	4.97
Control variables				
ISO 14001	3.490	3.193	0	10
Environmental labels	0.495	0.502	0	1
Registered capital	3.813	1.314	1	7
Establishment	5.001	1.941	1	7
High environmentally sensitive group	0.194	0.398	0	1
Low environmentally sensitive groups	0.474	0.501	0	1

Table III.
Descriptive statistics for variables

Green manufacturing and packaging scores were relatively high. This may be because manufacturing and packaging can be more easily implemented, for example, improving environmental protection in the manufacturing and packaging sectors. It could also be that government subsidizing enables firms to purchase pollution-preventive devices, or that more governmental legislation was established by the environmental units within the public sector.

The control variables illustrated a maximum value of 10 and a mean value of 3.49 for ISO 14001 acquisitions. Therefore, the firms that acquired it the earliest did so approximately ten years ago. The average years of acquisition were between three and four years. The mean value for the possessions of environmental labels was 0.495. Since the labels are dummy variables, the possession and non-possession of the labels were fifty-fifty.

The mean value for highly environmentally sensitive groups was 0.194. Since high environmental sensitivity was a dummy variable, the highly sensitive groups were lower than their mid and low counterparts. The mean value for low environmentally sensitive groups was 0.474, with the groups themselves being dummy variables as well. The mean value for years of establishment was 5.001, meaning that the firms surveyed were established, on average, 21-30 years ago. Registered capital had a mean value of 3.813, which illustrates that the average capital ranged from 500 million to five billion NT dollars.

Table IV presents the correlations among the variables, revealing a high correlation between environmental management and environmental operations. The performance of environmental management and the green value chain management demonstrated a significantly positive correlation. Among which, the coefficient for promotion and education was the highest at 0.53, followed by green R&D and design, with a coefficient of 0.52. Environmental operations and the different aspects of green value chain management also demonstrated a significantly positive correlation. Among which, the coefficient with green manufacturing and packaging had the highest coefficient of 0.54,

Table IV.
Pearson correlations among variables

Variables	Correlation coefficient Y1	Y2	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Y1 Env. management performance	1													
Y2 Env. operational performance	0.832**	1												
X1 Sourcing	0.430**	0.382**	1											
X2 R&D	0.522**	0.442**	0.609**	1										
X3 Manufacturing & packaging	0.467**	0.544**	0.600**	0.542**	1									
X4 Marketing	0.478**	0.461**	0.648**	0.713**	0.686**	1								
X5 Promotion & education	0.525**	0.539**	0.578**	0.621**	0.671**	0.752**	1							
X6 Recycling	0.358**	0.382**	0.545**	0.504**	0.628**	0.590**	0.715**	1						
X7 ISO14001	0.356**	0.296**	0.299**	0.270**	0.355	0.191	0.304**	0.231*	1					
X8 Env. labels	0.264**	0.275**	0.117	0.181	0.111	0.126	0.105	0.254**	−0.057	1				
X9 High sensitive	0.000	0.006	−0.053	−0.017	0.019	0.005	0.048	0.043	0.081	−0.151	1			
X10 Low sensitive	0.136	0.073	0.289**	0.289**	0.050	0.195*	0.068	0.095	0.140	−0.064	−0.468**	1		
X11 Establishment	0.063	0.054	−0.100	−0.016	0.114	−0.023	−0.058	−0.032	0.125	0.140	0.230	−0.461**	1	
X12 Registered capital	0.161	0.148	−0.017	0.156	0.073	0.098	0.127	0.025	0.227**	−0.112	0.005	0.187*	0.041	1

Note: Significant at the *0.05 and **0.01 levels (two-tailed), respectively

followed by promotion and education, with a coefficient of 0.53. Significantly positive correlations were also seen among the different aspects of the green value chain. Among which, green marketing and promotion and education exhibited the highest correlation coefficient of 0.75, followed by a 0.72 coefficient between promotion, education, and recycling. The results presented in Table IV indicated that six aspects of the green value chain management were correlated.

4.2 Path analysis

With an exception of green R&D having no significant effect on recycling, the analysis of the green value chain management model illustrated a statistical significance in the coefficients for all path coefficients. Figure 1 shows that promotion and education had a direct effect on green R&D, sourcing, green manufacturing and packaging, and green marketing and recycling. Furthermore, promotion and education had an indirect effect on sourcing, green manufacturing and packaging, and green marketing.

Figure 1 shows the direct effect (0.26) that promotion and education had on sourcing, while the indirect effect was 0.21 (0.74*0.28), creating a total effect of 0.47. Promotion and education had a 0.74 direct effect on green R&D. It had a 0.40 direct effect and a 0.10 indirect effect on green manufacturing and packaging. Therefore, the total effect was 0.5. Promotion and education also had a direct effect of 0.53 and an indirect effect of 0.27 on green marketing, creating a total effect of 0.8. Promotion and education had a direct effect of 0.64 on recycling, but no indirect effect. Figure 1 also shows that green R&D had a 0.28, 0.13, and 0.36 direct effect on sourcing, green manufacturing and packaging, and green marketing, respectively.

Model fit analysis reflects the level of fitness between hypothesis models and the actual measurement models. The analysis illustrates that the model had a GFI of 0.88,

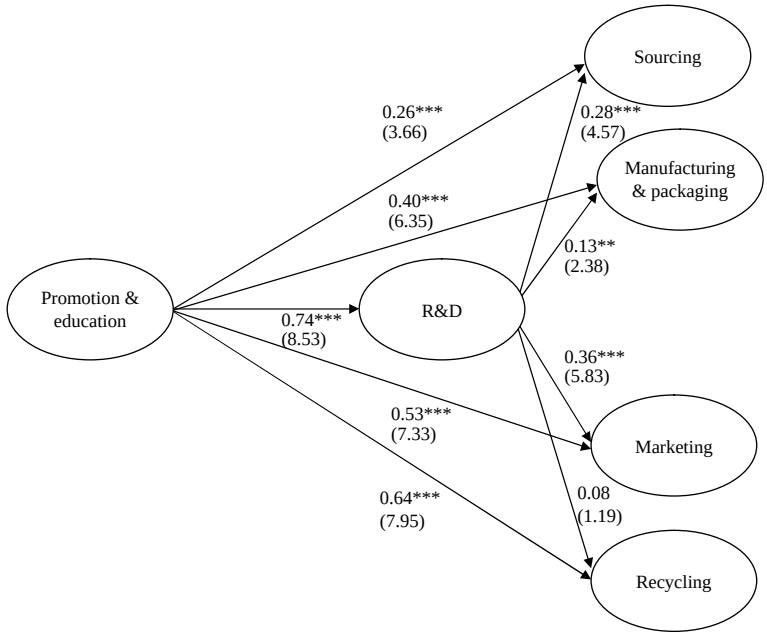

Figure 1.
Path coefficients between all variables in green value chain management

CFI of 0.95, NFI of 0.95, NNFI of 0.88, and an RMSEA of 0.05 (the standard threshold was < 0.05). However, recent studies revealed that the RMSEA can be overestimated in small study samples. Since this study used small samples, the evaluation of the model fitness will rely upon the interpretation of the CFI and NNFI indices.

4.3 Multiple regression results

Table V presents a detailed result of the regression analysis. In terms of environmental management performance and operational performance, Model 1 indicates that green value chain management exhibited a statistical significance (0.487; $p < 0.001$). This supports *H1* and *H2* mentioned previously in this paper.

This paper considers the length of ISO 14001 acquisitions, the attainment of environmental labels, the years of establishment, corporate capital, and different levels of environmental sensitivity, as control variables. In regard to environmental management performance, Model 1 demonstrates that the ISO 14001 acquisitions and attainment of environmental labels have both achieved statistical significance

	Environmental management performance		Environmental operational performance	
	Model 1	Model 2	Model 1	Model 2
Green value chain management				
Sourcing	0.487***	0.094	0.539***	−0.047
	(5.363)	(0.745)	(5.875)	(−0.377)
R&D		0.080		−0.010
		(0.599)		(−0.076)
Manufacturing & packaging		0.038		0.345**
		(0.279)		(2.572)
Marketing		0.049		0.086
		(0.278)		(0.495)
Promotion & education		0.441***		0.359
		(2.707)		(2.237)**
Recycling		−0.164		−0.153
		(−1.261)		(−1.189)
ISO14001	0.236**	0.228**	0.163*	0.133
	(2.617)	(2.420)	(1.786)	(1.434)
Environmental labels	0.166*	0.210**	0.136	0.222**
	(1.869)	(2.234)	(1.567)	(2.387)
Establishment	0.028	0.012	0.040	−0.006
	(0.296)	(−0.186)	(0.424)	(−0.067)
Registered capital	0.020	0.013	0.012	0.011
	(0.768)	(−0.323)	(0.141)	(0.123)
High sensitive group	−0.032	−0.019	−0.067	0.003
	(−0.332)	(0.126)	(−0.678)	(0.033)
Low sensitive group	−0.055	−0.037	−0.171	−0.074
	(−0.515)	(0.146)	(−0.574)	(−0.662)
F	8.854	5.774	8.842	6.123
Adj. R^2	0.364	0.374	0.365	0.390
Durbin-Watson	1.842	1.817	1.765	1.801

Notes: Significant at the *0.10, **0.05 and ***0.01 levels (one-tailed where sign is predicted; two-tailed otherwise), respectively

Table V.
Regression analysis: green value chain management and environmental performance

(0.236; $p < 0.01$ and 0.166; $p < 0.65$). As for operational performance, ISO 14001 acquisitions have achieved statistical significance (0.539; $p < 0.001$).

Different aspects of the value chain in Model 2 illustrated that environmental management performance only achieved statistical significance with promotion and education (0.441; $p < 0.008$). A positive relationship was evident between environmental operations, green manufacturing and packaging (0.345; $p < 0.012$), and promotion and education (0.359; $p < 0.028$).

This paper takes this process one step further to examine the presence of autocorrelation among the variables by referring to the Durbin-Watson statistics, where values between 1.72 and 2.28 indicate no autocorrelation. The paper also inspected the collinearity of each variable by observing the values of the VIF. In Model 1, the VIF values fell between 1 and 2. In Model 2, the largest VIF for manufacturing and packaging was 4.72. All of these values were below 10. Therefore, no collinearity was found.

5. Discussions and conclusions

Previous studies have discussed green management from a broad perspective. Based on Simon's (1992) circular green value chain, this paper focuses on the extent to which green value chain management has been adopted. We then examined the relationship between environmental performance and various aspects of the green value chain. Among these aspects, green R&D scored the lowest in terms of its association with environmental performance, while green manufacturing and packaging scored the highest. In addition, positive relationships were observed among the performance of environmental management and the overall green value chain management, and promotion and education. Positive relationships were also observed between environmental operational performance, overall green value chain management, green manufacturing, packaging, and promotion and education. As for the control variables, the adoption of ISO 14001 standards and the attainment of environmental labels were positively associated with environmental performance.

This paper revealed that the implementation of green management in specific areas, such as sourcing, green R&D, green marketing or recycling had an insignificant effect on the environmental performance; however, comprehensive implementation of green value chain management could improve the overall environmental performance of a firm. On the basis of that discovery, we recommend that firms implement green management thoroughly to maximize their environmental performance.

This paper also found that the performance of both environmental management and environmental operations was positively associated with extended education. On the basis of this finding, we recommend that firms facing difficulties implementing complete green value chain management should begin with promotion and education, or the assembly of end-products, such as green manufacturing and packaging.

Among the various aspects of corporate green management, green R&D scored the lowest, while green manufacturing and packaging scored the highest. This discovery may be a starting point for future studies to discover why manufacturing and packaging receives greater attention in green management than R&D.

This paper provides a number of suggestions for firms in general, and specifically for those in Taiwan. Conducting green management in every aspect of the green value chain enhances positive environmental performance. Firms need to recognize the importance of providing green education to consumers and establish long-term development plans,

which include the formation of strategic alliances with environmental groups, recycling businesses, and government agencies. Such actions will have a considerable impact on the greening of the product life cycle and help to maintain healthy ecosystems for the future.

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