Do green supply chains lead to competitiveness and economic performance?

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Abstract

Purpose – Green supply chain management is a concept that is gaining popularity in the South East Asian region. For many organizations in this region it is a way to demonstrate their sincere commitment to sustainability. However, if green supply chain management practices are to be fully adopted by all organizations in South East Asia, a demonstrable link between such measures and improving economic performance and competitiveness is necessary. This paper endeavors to identify potential linkages between green supply chain management, as an initiative for environmental enhancement, economic performance and competitiveness amongst a sample of companies in South East Asia.

Design/methodology/approach – For this purpose a conceptual model was developed from literature sources and data collected using a structured questionnaire mailed to a sample of leading edge ISO14001 certified companies in South East Asia followed by structural equation modelling.

Findings – The analysis identified that greening the different phases of the supply chain leads to an integrated green supply chain, which ultimately leads to competitiveness and economic performance. Future research should empirically test the relationships suggested in this paper in different countries, to enable comparative studies. A larger sample would also allow detailed cross-sectoral comparisons which are not possible in the context of this study.

Originality/value – This paper presents the first empirical evaluation of the link between green supply chain management practices and increased competitiveness and improved economic performance amongst a sample of organizations in South East Asia.

Keywords Supply chain management, Linear structure equation modelling, Economic performance, South East Asia

Paper type Research paper

Introduction

Organizations worldwide are continuously trying to develop new and innovative ways to enhance their competitiveness. Bacallan (2000) suggests that some of these organizations are enhancing their competitiveness through improvements in their environmental performance to comply with mounting environmental regulations, to address the environmental concerns of their customers, and to mitigate the environmental impact of their production and service activities. Green supply chain management as a form of environmental improvement is an operational initiative that many organizations are adopting to address such environmental issues, including corporations in the South East Asian region.

In this paper, the concept of green supply chain management encompasses environmental initiatives in:

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(1) inbound logistics;
(2) production or the internal supply chain;
(3) outbound logistics; and in some cases
(4) reverse logistics, including and involving materials suppliers, service contractors, vendors, distributors and end users working together to reduce or eliminate adverse environmental impacts of their activities.

Green supply chain management is a concept that is gaining popularity in the South East Asian region. For many organizations in this region it is a way to demonstrate their sincere commitment to sustainability (Bacallan, 2000). Furthermore, many realize that customers and other stakeholders do not always distinguish between a company and its suppliers. If an organization has environmental liabilities, stakeholders may often hold the lead company in a particular supply chain responsible for the adverse environmental impacts of all organizations within a specific supply chain for a particular product.

Many authors are exploring environmental initiatives within each of the major phases of the supply chain. However, much of this research, as observed by Sarkis (1999), is focused predominantly on only one functional area. Yet, Handfield and Nichols (1999) define supply chain management as all the activities associated with the flow and transformation of materials from raw extraction phase through to the consumption of goods and services by an end user, along with associated information flows, both up and down the supply chain. Thus, there is arguably a need to focus green supply chain management research on the totality of the supply chain in both an upstream and downstream direction.

It is generally perceived that green supply chain management promotes efficiency and synergy among business partners and their lead corporations, and helps to enhance environmental performance, minimize waste and achieve cost savings. This synergy is expected to enhance the corporate image, competitive advantage and marketing exposure. However, if green supply chain management practices are to be fully adopted by all organizations in South East Asia, a demonstrable link between such measures and improving economic performance and competitiveness is necessary. Bowen *et al.* (2001) state that organizations will adopt green supply chain management practices if they identify that this will result in specific financial and operational benefits. Thus, there is a clear research need to establish the potential link between green supply chain initiatives and increased competitiveness and enhanced economic performance, to provide an impetus for organizations to green their supply chains.

In the South East Asian region there are many organizations that have undertaken significant efforts towards establishing green supply chain management initiatives. Whilst the motivation and driving forces for these initiatives have been examined for organizations in this region (Bacallan, 2000; Rao, 2004), no previous research has tested an empirical link between such efforts and subsequent improvements in competitiveness and economic performance. Therefore, this paper presents the results of a survey of organizations in the South East Asian region to investigate the proposition that there is a significant correlation between greening certain phases of the supply chain and the competitiveness and economic performance of the organizations involved.

This paper begins by exploring previous "functional" specific research on aspects of green supply chain management, to develop a conceptual model of green supply chain management, competitiveness and economic performance. This paper then outlines the specific methodology employed in this study to test this conceptual model. The conceptual model is then tested using structural equation modeling (SEM) techniques based on the findings from a study of South East Asian organizations to establish any causal links between the constructs within this model. The paper concludes with an examination of the significant relationships identified in this model to examine the link between green supply chain management, economic performance and competitiveness.

Developing the conceptual model

The conceptual model examined in this paper and tested through SEM techniques, has been developed through an examination of literature on all aspects of the totality of the supply chain. This "totality" is encapsulated using five latent constructs, measured using indicator variables developed from the responses obtained from the survey of organizations in the South East Asia region. These constructs are: greening the inbound function of the supply chain; greening production; greening the outbound function; competitiveness; and economic performance.

Inbound function

From the "inbound" perspective of the supply chain it is argued that greening the supply chain has numerous benefits to an organization, ranging from cost reduction, to integrating suppliers in a participative decision-making process that promotes environmental innovation (Bowen *et al.*, 2001; Hall, 1993; Rao, 2002). A large part of the inbound function essentially comprises of green purchasing strategies adopted by organizations in response to the increasing global concerns of environmental sustainability. Green purchasing can address issues such as reduction of waste produced, material substitution through environmental sourcing of raw materials, and waste minimization of hazardous materials. The involvement and support of suppliers' is crucial to achieving such goals. Therefore, companies are increasingly managing their suppliers' environmental performance to ensure that the materials and equipments supplied by them are environmentally-friendly in nature and are produced using environmentally-friendly processes.

Min and Galle (1997) explore "green purchasing" to determine the key factors affecting a buying firm's choice of suppliers, the key barriers and the obstacles to green purchasing initiatives. They also investigated the impact of green purchasing on a corporation's environmental goals. Sroufe (2003) presents a framework involving performance indicators and supplier assessment metrics that argues that environmental initiatives such as strategic environmental sourcing improve an organization's competitive position and reduce risks.

In exploring green purchasing strategies as part of greening the inbound phase, Min and Galle (1997) consider selected industry groups (heavy producers of scrap and waste materials) and identify that green purchasing contributes significantly towards source reduction of pollution in terms of recycling, re-use and low-density packaging, and towards waste elimination in terms of scrapping or dumping, recycling and sorting for non-toxic incineration and bio-degradable packaging. They also identify that the high cost of environmental programs, uneconomical recycling and

uneconomical re-use are the three most important barriers and obstacles to green purchasing. Lack of management commitment, lack of buyer awareness, lack of supplier awareness, deficient company-wide environmental standards or auditing programs and lack of state and federal regulations are also important issues.

Walton *et al.* (1998) examine the integration of suppliers into environmental management processes, and observe two evolving trends. They firstly suggest that environmental issues are becoming an intrinsic part of strategic planning in organizations due to stricter regulations and the demands of environmental accountability. They also identify a second trend amongst their case examples, that organizations are integrating their supply chains to reduce operating costs and improve their customer service. This suggests that organizations need to involve suppliers and purchasers in improving the environmental performance of the whole supply chain, and thus addressing the purchasing function's impact on the environment. They also establish that some of the organizations examined are working with suppliers to reduce emissions, monitor the waste streams from suppliers, helping to set up their suppliers' environmental programs and even extending technical support to suppliers to help them with conservation of natural resources. From a monitoring perspective their study also identifies environmental supplier evaluation criteria in use in the organizations examined, including: the level of public disclosure of the supplier's environmental record; the management of waste and pollution; accreditation to an environmental management standard such as ISO 14000; and involvement in reverse logistics programs.

Green purchasing strategies arguably revolve around two key components, the evaluation of suppliers' environmental performance and mentoring to assist suppliers improve this performance. Green purchasing research has traditionally focused upon this evaluative element, with authors such as Noci (2000) detailing the range of tools and techniques in place to assess the environmental behavior of suppliers to aid in supplier selection. Often organizations urge suppliers to develop their own in-house environmental management systems, and may request that a supplier accredits to an environmental management standard such as ISO 14001. This external certification may be especially important when suppliers are located at a distance geographically from the "customer" organization, for instance western companies purchasing from suppliers in the South East Asia region.

Hines and Johns (2001) identify the mentoring role within green supply chain management as an emerging concept that promotes a more significant relationship between the customer and the supplier. This mentoring culture goes beyond monitoring and evaluation, towards guiding and supporting suppliers and requires a substantial change in the attitude of the lead corporations in a supply chain. Specific operational initiatives involved in the mentoring process might include holding environmental awareness seminars for suppliers and vendors, undertaking educational program to explain the benefits and relevance of green supply chain management initiatives, setting up environmental teams to guide suppliers in their development of environmental programs, visiting supplier premises to provide on-site recommendations and assisting in the set up of their environmental programs.

Hines and Johns (2001) also examine the strengths and weaknesses of the mentoring and partnering approach within green supply chain management. From a positive perspective, supplier mentoring is proactive, non-threatening, shares potential benefits,

and builds teamwork. However, they also identify the critical weaknesses of this approach as resource and cost implications, lack of physical facilities, lack of mentoring skills, and trained personal to deliver such mentoring initiatives.

The research presented in this paper uses six factors to capture information on greening the inbound phase of a green supply chain:

(1) holding awareness seminars for suppliers and contractors;

(2) guiding suppliers to set up their own environmental programs;

(3) bringing together suppliers in the same industry to share their know-how and problems;

(4) informing suppliers about the benefits of cleaner production and technologies;

(5) urging/pressuring suppliers to take environmental actions; and

(6) choice of suppliers by environmental criteria.

Greening the production phase or the internal supply chain

Much of the previous research on environmental issues in business has focused on the internal operational practices an organization may adopt, such as waste management and eco-efficiency. However, this is also an important stage within a green supply chain management program. For instance, over 75 percent of respondents to a survey of 212 US manufacturing firms identified pollution prevention as important to their overall corporate performance, with 49.1 percent of the firms' identifying suppliers as a key component in pollution prevention efforts, and 37.7 percent identifying customers as the key players in pollution prevention efforts (Florida, 1996). Several of these respondents noted that they pursued specific initiatives with suppliers to reduce wastes, prevent pollution, develop new products and specifications and held regular meetings with their suppliers to discuss their pollution prevention strategies.

In the production phase of a green supply chain, there are a number of concepts that can be explored, such as cleaner production, design for environment, remanufacturing and lean production. Florida and Davison (2001) surveyed 580 manufacturing plants in the US adopting cleaner production techniques. Their research reveals that green corporations are innovative in their environmental practices, and these strategies emerge from a real commitment towards reducing waste and pollution. Lean production/manufacturing is also an important consideration in reducing the environmental impact of the production phase. A study by Lewis (2000) identified a twofold improvement in productivity in Japanese automotive firms when compared to those in the West, and attributes the key differences to lean production systems in the Japanese organizations reducing lead times, material and staff costs and yet simultaneously increasing production activity and enhancing quality. Sanches and Perez (2001) also investigate the link between lean production practices in manufacturing organizations and resultant enhanced competitiveness. Lean production is also expected to improve environmental performance of the firms through good housekeeping practices, such as general waste reduction and minimizing hazardous wastes. King and Lenox (2001) investigate the hypothesis that lean production reduces the marginal cost of environmental management and, consequently results in enhanced environmental performance. Their research concludes that lean production is complementary to improvements in environmental performance and it

often lowers the marginal cost of pollution reduction thus enhancing competitiveness. The success of lean production emanates from three major factors: minimization of non-value adding activities, efficient work systems, and applicable human resource management. Rothenberg *et al.* (2001) identify that lean plants aim to minimize waste and buffers, leading not only to reduce buffers in environmental technology and management, but also in an overall approach to manufacturing that minimizes waste products.

Over the last decade, supply chain management has undergone a remarkable transformation in terms of playing a key role in influencing manufacturing organizations. This has happened as a result of globalization pressures, advances in information technology and increasing competitiveness leading to a shortening of product life cycles. Along with these developments, some organizations in South East Asia are integrating environmental management considerations into their production phase operational activities and even taking back the products after use through reverse logistics.

Occasionally, certain manufacturing modules are outsourced to subcontract manufacturers. These subcontractors are viewed as "high risk" because their environmental performance could impact upon the perception of the environmental credentials of that organization's products. In Southeast Asia, much of the manufacturing business is quality driven, and the integration of these suppliers into the manufacturing process is crucial in this quality process (Trowbridge, 2003). Whilst the management of suppliers is discussed in the previous section, the outcome of such interaction often affects the quality of the production process and any proposed environmental improvements.

Thus the production phase has a critical role in ensuring that: products/services produced by an organization are environmentally-friendly in nature; prevention of pollution at source is achieved through the production process; cleaner production practices are adopted; closed loop manufacturing (reverse logistics) is incorporated to the fullest extent possible, so that wastes generated are processed and recycled back into the production phase; re-use and recycling of materials is maximized; material usage is reduced; the recyclable content of a product is increased; the production processes are optimized so that generation of waste, both hazardous or otherwise, is minimized; and products are redesigned (design for the environment) so that the adverse environmental impacts of a particular product are minimized.

In this study all of these considerations are encapsulated in eight variables that measure the greening of the production phase:

(1) environmentally-friendly raw materials;

(2) substitution of environmentally questionable materials;

(3) taking environmental criteria into consideration;

(4) environmental design considerations;

(5) optimization of process to reduce solid waste and emissions;

(6) use of cleaner technology processes to make savings in energy, water, and waste;

(7) internal recycling of materials within the production phase; and

(8) incorporating environmental total quality management principles such as worker empowerment.

Greening the outbound function

On the outbound side of the green supply chain, green marketing, environment-friendly packaging, and environment-friendly distribution, are all initiatives that might improve the environmental performance of an organization and its supply chain (Rao, 2003; Sarkis, 1999). Management of wastes in the outbound function such as reverse logistics and waste exchange can lead to cost savings and enhanced competitiveness (Rao, 2003). Many of these initiatives involve compromises between various logistics functions and environmental consideration in order to improve the environmental performance of an organization (Wu and Dunn, 1995).

Currently, most products in the market come in a form of packaging that prevents the product from damage and makes the product easy to handle. The use of packaging whether, it is made of glass, metal, paper or plastic, contributes heavily to the solid waste stream. In order to address these environmental impacts of packaging, many countries now have programs and legislation that aims to minimize the amount of packaging that enters the waste stream, such as the Packaging Directive in the EU. Recycling and re-use are key strategies that are adopted and several organizations in South East Asia actively participate in packaging reduction programs. For instance, Amway (Thailand) delivers its detergent and other house cleaning products to customers in plastic containers. After their use, these plastic containers are collected by the Amway sales force, brought back to the company and recycled. The empty paper cartons in which the suppliers deliver the raw materials to the company are given back to the suppliers for re-use (Rao, 2001).

In South East Asia, like other developing regions, many organizations face the problem of how to dispose of the waste from their production process; and the way they address this concern is varied and fragmented. Lack of stringent waste management legislation can lead to unregulated and ad hoc dispersal. However, more environmentally engaged organizations are adopting on-site waste management treatment facilities and waste exchange networks. To address the problem of industrial waste management in the South East Asia region, many government agencies and NGOs in this region are trying to promote the concept of industrial ecology for corporations, where a "closed loop" approach (Frios, 1999) utilizes all waste through the recycling and reuse of energy and materials.

As part of outbound logistics, green marketing has an important part to play in the link between environmental innovation and competitive advantage (Menon and Menon, 1997). The impact of green marketing on customer relationships, and the impact of corporate customers on suppliers, had also been widely investigated (Lamming and Hampson, 1996; Karna and Heiskanen, 1998). Encouraging suppliers to take back packaging is a form of reverse logistics that can be an important consideration in greening the outbound function, with a study by Dorn (1996) identifying an increase in market share amongst companies that implemented an environmentally-friendly packaging scheme. Wu and Dunn (1995) identify warehousing and packaging design as the two most important issues in outbound logistics and distribution. They argue that standardized reusable containers, good warehousing layouts, and easy information access reduce storage and retrieval delays

which leads to savings in operating costs whilst being environmentally sound. They also identify the specific design of logistics networks and its implementation as two of the most important strategic issues facing outbound logistics.

In an environmentally-friendly transportation system, essential elements of a transportation system such as type of transport, fuel sources, infrastructure, operational practices and organization, can be considered. These elements and the dynamics that connect them, determine the environmental impact generated in the transportation logistics phase of the supply chain (Kam *et al.*, 2003).

The components of the latent construct that investigates this element of green supply chain management comprise of the identification of packaging, waste disposal and transportation and green marketing strategies, Thus, the latent construct for this function includes manifest variables for:

(1) environment-friendly waste management;

(2) environmental improvement of packaging;

(3) taking back packaging;

(4) eco-labeling;

(5) recovery of company's end-of-life products;

(6) providing consumers with information on environmental friendly products and/or production methods; and

(7) use of environmentally-friendly transportation.

The link between the green supply chain and competitive advantage and economic performance

Whilst there have been credible research efforts to explore green supply chain management initiatives, little research has been undertaken on the impact of these on economic performance and competitive advantage. Perhaps it would be encouraging for industry to adopt green supply chain management if there is a demonstration of a clear, significant and observable correlation between these efforts, competitive advantage and economic performance.

The study by Rao (2003) does identify that organizations in South East Asia believe that greening the inbound logistics function has led to using environmentally-friendly raw materials, greening of production to cleaner production, prevention of pollution as well as waste at the source; whereas greening outbound logistics led to environmentally-friendly waste disposal and mitigation of the effects of pollution through waste water treatment and abatement of emissions (Rao, 2003). Such initiatives lead to improvements in environmental performance, and reduce the risk of non-compliance, penalty and threat of closure. At the same time, the link between green supply chain initiatives and improvements in competitiveness and economic performance for organizations in this region remains unclear.

This observation holds true not only for corporations in South East Asia but also, to a certain extent in the US and Europe, as shown by the lack of research considering the economic impact of green supply chain management generally. There are many research initiatives, as mentioned above, exemplifying greening initiatives in the supply chain and others investigating the economic and business impacts of environmental performance of the firm (Klassen, 1996). However, this study has not identified literature that empirically tests the relationship between green supply chain

management, competitiveness and economic performance. This lack of research makes this study exploratory and pioneering in nature, especially in the South East Asian context for which practically no field-based or empirical research is available. However, there are many leading-edge corporations in this region who are taking path-breaking initiatives: for example, Nestle Philippines is greening every phase of their supply chain; PT Aryabhatta (name disguised) in Indonesia has a well structured framework for supplier evaluation; Philip DAP in Singapore is organizing a "greening of suppliers program"; Nestle Jakarta and Seagate Thailand are using green purchasing and cleaner production; Purechem Onyx is implementing an environment-friendly disposal of hazardous and non-hazardous waste (Rao, 2003).

To investigate the possible empirical link between green supply chain management initiatives, economic performance and competitiveness, two constructs are presented in this study to encapsulate these, as discussed below.

Competitiveness

Frameworks for attaining competitive advantage through the managerial principles of customer satisfaction, employee empowerment, quality cost systems, lean manufacturing, continuous improvement and productivity enhancement have been developed according to Deming's 14 points and Juran's trilogy by Gevirtz (1994). However, these measures do not reflect the impact of environmental management or green supply chain management towards the overall competitiveness of the firm. This is not really surprising since competitiveness primarily interfaces between the firm and the market, and as long as the market does not seek environmental value-drivers in the products and services it purchases, environmental issues are not necessarily considered by organizations and consumers. However, over the last few years there has been an upsurge in environmental awareness of consumers in general. Clearly a growing number of corporations are developing company-wide environmental programs and "green" products sourced from markets around the world (Min and Galle, 1997).

Arguably, environmental issues are becoming a source of competitiveness. Anecdotally, it is apparent that many of the leading companies in the South East Asia region are realizing a competitive dimension to having a green supply chain. However, the lack of empirical research on this link is a key research gap and is addressed through the research presented in this paper. Hence, the manifest variables considered in this study to investigate competitiveness are:

(1) improved efficiency;

(2) quality improvement;

(3) productivity improvement; and

(4) cost savings.

Economic performance

Environmental management encompasses diverse initiatives to reduce or minimize the adverse environmental impacts of an organization's operations. These efforts aim to improve environmental performance, reduce costs, enhance corporate image, reduce risks of non-compliance and improve marketing advantage. Nevertheless, many organizations still look upon green initiatives as involving trade-offs between environmental performance and economic performance (Klassen and McLaughlin,

1996). The financial performance of firms is affected by environmental performance in a variety of ways. When waste, both hazardous and non-hazardous, is minimized as part of environmental management, it results in better utilization of natural resources, improved efficiency and higher productivity and reduces operating costs. Again, when the environmental performance of the firm improves, it ushers in tremendous marketing advantage, and this leads to improved revenue, increased market share, and new market opportunities. Organizations that minimize the negative environmental impacts of their products and processes, recycle post-consumer waste and establish environmental management systems, are poised to expand their markets or displace competitors that fail to promote strong environmental performance (Klassen and Mclaughlin, 1996).

Since many believe that green supply chain management does lead to improved environmental performance, it implies that greening different phases of the supply chain should directly, or indirectly, translate into enhancement of economic or financial performance. At the same time it is not necessarily true that greening all the phases of the supply chain should directly lead to financial performance. For instance, greening the inbound phase certainly should lead to reduction of pollution at the source and minimization of wastes. However, whether these initiatives have a direct impact on financial performance is yet to be explored. Similarly, greening of the outbound phase, involving green logistics, would intuitively be expected to lead to competitiveness, but again, whether it would render improved financial performance needs to be investigated.

To investigate the link between green supply chain management and economic performance a number of manifest variables constitute the construct measuring economic performance:

(1) new market opportunities;

(2) product price increase;

(3) profit margin;

(4) sales; and

(5) market share.

Methodology

To validate the framework presented in the preceding section, a linear SEM approach is used (Jöreskog and Sörbom, 1993) to validate the causal relationships between the different latent constructs of: greening the inbound function; greening production; greening the outbound function; competitiveness and; economic performance. The significance of the overall models is determined by the chi-square value, the corresponding degrees of freedom and the associated p-value > 0.05. The individual linkages between any two variables are tested using the critical ratio, which is an observation on a random variable that has an approximate standard normal distribution. Thus, using a significance level of 0.05, any critical ratio that exceeds 1.96 in magnitude would be significant. The conventional t-test is exact under the assumptions of normality and independence of observations, no matter what the sample size. The test based on critical ratio, depends on the same assumptions, but with a finite sample size, the test is only approximate. All the same, the critical ratio is interpreted as: if there were a significant link between, say, greening the inbound function and economic performance, it would imply that the former latent construct

directly influences the latter. In our analysis, the study has considered different structural models, which are essentially causal in nature. For instance, in addition to the final model encompassing five latent constructs as explained above, we also consider another model encompassing the three latent constructs such as greening inbound, greening production and greening outbound, and examined the relationship in terms of significant linkages between them. We did not present a detailed analysis of such models because their significance levels were not as good as the final model, which we present below. The latent variables in each of the model are measured by the manifest or indicator variables used in the research instrument. One limitation of the model was that multivariate normality was assumed. However, we did conduct tests for testing the univariate normality by plotting normal probability plots and several variables conformed to having a normal distribution.

For the confirmatory analysis, the conceptual model involving the five constructs was run using AMOS Graphics for Windows Version 3.6, estimating the regression weight of each link (arrow) and the associated significance. The estimation procedure used was under the maximum likelihood estimation (MLE) procedure, which was known to provide valid results with sample sizes as small as 50. In addition to p-value, we use chi-square/degrees of freedom < 2. Goodness of fit index (GFI), adjusted goodness of fit index (AGFI), and root mean square residual (RMSR) were additional indicators used to evaluate the validity of the model. Several sets of analyses were conducted with the input being the descriptive statistics of the indicator variables and their correlation matrix. Also, iterations of sets of structural equation models were run to test variations of the model with alternate paths deleted to assess the importance of aspects of the conceptual model.

SEM estimates a series of separate but interdependent multiple regression equations simultaneously. We have drawn upon the theory and the research objectives to determine which independent variable will predict which dependent variable. The proposed relationships are then translated into a series of structural equations for each dependent variable. The structural model expresses these relationships among independent and dependent variables.

The definition of latent constructs described earlier comprises of more items from the questionnaire than used in the final analysis (as summarized in Table I). However, reliability analysis of the internal consistency of the different manifest variables within each latent construct identified certain items that should be excluded from the final analysis.

An empirical, survey-based research approach was adopted, comprising of 64 items as described in the Appendix. This questionnaire was distributed to the environmental management representative (EMR) or the chief executive of ISO 14001 certified organizations in the Philippines, Indonesia, Malaysia, Thailand, and Singapore. Responses for each item in the SEM analysis were collected on a four-point Likert scale (ranging from strongly disagree = 1 to strongly agree = 4). The justification for using a four-point Likert scale was that if we had used the more popular five-point scale or any other odd number of points in the scale, there might have been a tendency of having most negative responses loading heavily on the median level, the center point of the scale. The four-point scale served to force the respondents to check either on the negative side or on the positive side.

Inbound	Production	Outbound	Competitiveness	Economic performance
9.1 Holding awareness seminars for suppliers/ contractors	7.1 Environment-friendly raw materials	7.17 Eco labeling	8.1 Improved efficiency	8.4 New market opportunities
9.2 Guiding suppliers to establish their own environmental programs	7.2 Substitution of environmentally questionable materials	7.18 Environmental Improvement in Packaging	8.2 Quality improvement	8.11 Product price increase
9.4 Informing suppliers about the benefits of cleaner production and technologies	7.5 Taking environment criteria into consideration	7.19 Taking back packaging	8.3 Productivity improvement	8.12 Profit margin
9.5 Urging/ pressuring suppliers to take environmental actions	7.7 Optimization of process to reduce solid waste	7.20 Providing information to consumers on environment-friendly products and/or production methods	8.5 cost saving	8.14 Sales
9.6 Choice of suppliers by environmental criteria	7.9 Optimization of process to reduce air emissions	7.21 Change for more environmentally-friendly transportation		8.15 Market share
	7.10 Optimization of process to reduce noise			
	7.11 Use of cleaner technology processes to make saving			
	7.12 Recycling of materials internal to the company			

Table I.
Variables used from the questionnaire to develop the latent constructs used to test the conceptual model

The research instrument was distributed to all ISO 14001 certified corporations in the Philippines, Indonesia, Malaysia, Thailand, and Singapore, mailed using the modified Dillman method, in which after a few months of sending out the first wave (late 2000), the questionnaire was mailed out again to the remaining organizations that had not responded (early 2001). It would have been better from the research point of view to mail the second round of questionnaires after a few weeks instead of months. However, from the practical point of view we did wait for a few months for the complete questionnaires to come back before mailing the second round.

Fifty-two valid responses were received (a 10 percent response rate), comprising of 14 Filipino corporations, 6 Indonesian, 17 Malaysian, 5 Thai, and 10 Singaporean companies. This sample size meets the absolute minimum requirement

of 50 respondents, for the MLE to provide valid results, as prescribed by Hair *et al.* (1992, p. 444), although they recommend a size of 100 and above.

Results and data analysis

The overall convergence of the SEM model was significant, as indicated by the statistics detailed in Table II.

The chi-square values and associated p-value are highly acceptable indicating a good fit for the model. However, GFI and AGFI, both of which are measures that represent overall degree of fit (squared residuals from prediction compared to the actual data) are on the low side. For both of these, higher values would indicate better fit but no absolute threshold levels have been established for GFI (Hair *et al.*, 1992). This might be expected given the sample size, which makes estimation of maximum likelihood parameters not significant. Conversely, the measure of chi-square/degrees of freedom = 1.03, which falls within the recommended levels of 1.0-2.0, and indicates a significant model. One should also consider the value of CFI equal to 0.967, which is acceptable. Thus, given the limitation of a small sample size, we accept the validity of the model. Of course the structural model does require a multivariate normality assumption of the variables included in the model. We tried to test the univariate normality by plotting the normal probability plots and the corresponding univariate distributions and more than 60 percent of the variables conformed to univariate normal distributions. However, the multivariate normality had to be assumed and this did become a limitation of the model.

Figure 1 gives the finalized model with the associated statistics as presented above.

From the statistics presented above, the evidence suggests that greening the different phases of the supply chain does lead to an integrated green supply chain where the green inbound function of the supply chain, as well as a green production stage leads to a green outbound phase.

Whilst it might be expected that the greening of the inbound function leads to green production, the critical ratio for this link (1.78), is lower than the required 1.96. For this reason, we acknowledge that there is still not enough evidence to establish the significance of this link. However, the green supply chain comprising all three phases clearly leads to significant values for competitiveness and economic performance. This establishes the linkage between the green supply chain and competitiveness for which many anecdotal examples exist, but empirically tested evidence is lacking (Sarkis, 1999; Klassen and McLaughlin, 1996).

Regression weights	Estimate	Critical ratio
The maximum likelihood estimates		
Greening inbound – greening outbound	0.226	2.244
Greening inbound – economic performance	0.645	3.141
Greening production – greening outbound	0.886	3.406
Greening outbound – competitiveness	0.780	3.002
Competitiveness – economic performance	0.676	4.097

Notes: Chi-square = 324.958; degrees of freedom = 313; probability level = 0.309; GFI = 0.733; AGFI = 0.654; CFI = 0.967; RMSEA = 0.047

Table II.

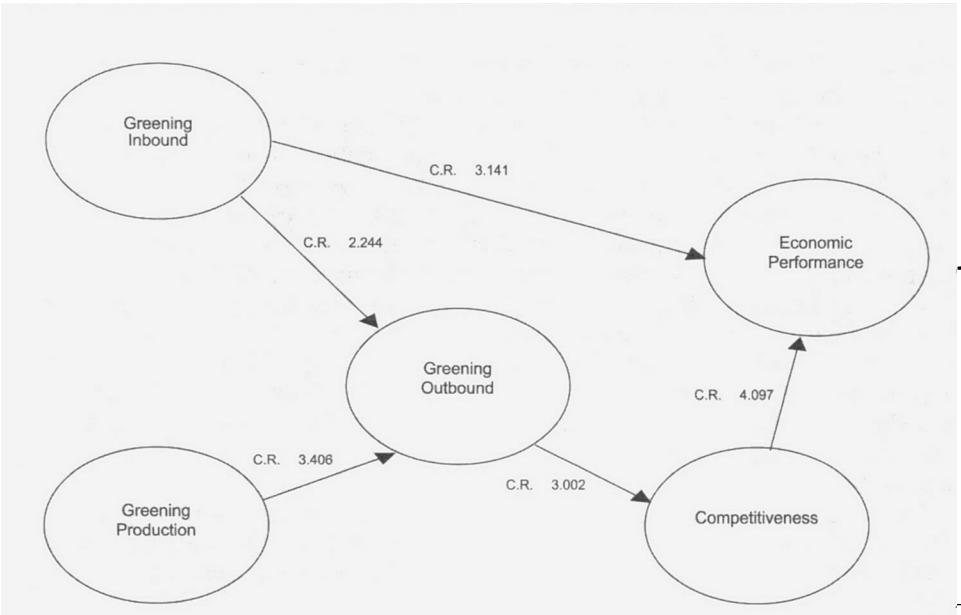

Figure 1.
The final model of the relationship between green supply chain management, competitiveness and economic performance

Hence, this research provides a number of contributions to the theoretical debate in this field. The first contribution is that it considers the green supply chain not in sections but in its entirety, and we consider the distinct environmental initiatives in each phase as different indicator variables. The second contribution is that it establishes with a sound theoretical foundation and prior empirical analysis that the green supply chain does lead to increased competitiveness and better economic performance. The third contribution is that, as opposed to much of the available anecdotal literature on green supply chain management, this research has a theoretical basis and an empirical analysis where the model converged statistically with acceptable chi-square and *p*-values.

The aforementioned results demonstrate that greening the inbound function, as well as greening production, significantly lead to greening outbound, as well as to competitiveness and economic performance of the firm. Greening the inbound function involves the integration of suppliers into a green supply chain. Getting the suppliers to have their own EMS and greening their operations helps tremendously to cut down production of waste at source. Hence, the company gains in terms of less or minimal environmentally hazardous waste, even non-hazardous solid/liquid waste and air emissions leading to reduced costs for waste disposal, compliance with regulation, reduced pollution, improved resource utilization and enhancement in economic performance.

Similarly, greening of production results in the minimization of pollution, a form of inefficiency (after Porter and van der Linde, 1995), re-use of materials and recycling initiatives. This leads to savings in raw materials, water and energy usage and thus leads to competitiveness and economic performance. From previous research by Klassen and McLaughlin (1996) environmental management is identified as a potential factor in the enhancement of financial performance and competitiveness of the firm.

This research concludes that greening the supply chain also has the same potential to lead to competitiveness and economic performance.

From an industry perspective, in particular for this region, firms are continuously striving to achieve competitiveness in their business activities in both the domestic and the global arena. These research findings suggest that if they green their supply chains not only would firms achieve substantial cost savings, but they would also enhance sales, market share, and exploit new market opportunities to lead to greater profit margins, all of which contribute to the economic performance of the firm.

The main limitation of this research is the focus on a small sample of organizations in South East Asia, but the lack of empirical research in this region is also one of the main strengths of this paper. The focus on "leading edge" ISO14001 accredited organizations also excludes those without formal environmental management accreditation, but may have well developed non-accredited environmental programs. Therefore, the findings cannot be generalized to all organizations in this region or around the world.

Future research should empirically test the relationships suggested in this paper in different countries, to enable comparative studies. A large sample would also allow detailed cross-sectoral comparisons, which are not possible in the context of this study.

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Appendix. Green supply chain management, competitiveness and economic performance in the South East Asian context

1. What is the company's main manufacturing activity?
   - ☐ Food products, beverages and tobacco
   - ☐ Textiles and textile products
   - ☐ Leather and leather products
   - ☐ Wood and wood products
   - ☐ Pulp, paper and paper products, publishing, and printing
   - ☐ Coke, refined petroleum products and nuclear fuel
   - ☐ Chemicals, chemical products, and man-made fibers
   - ☐ Rubber and plastic products
   - ☐ Other non-metallic mineral products
   - ☐ Basic metals and fabricated metal products
   - ☐ Machinery and optical equipment
   - ☐ Transport equipment
   - ☐ Others, please specify:_____
2. How many employees does the company have?

   Number:_____
3. Does your company belong to a Multinational National Corporation (MNC) category?
4. Does your company have ISO 9000 Certification?
5. Does your company have ISO 14000 Certification?
6. Does your company have Environmental Management System?
7. In the last two years, the company has taken environmental actions in the following areas (on a four point scale of strongly disagree, disagree, agree, strongly agree)

   (7.1) Environment-friendly raw materials

   (7.2) Substitution of environmental questionable materials

(7.3) Choice of suppliers by environmental criteria

(7.4) Urging/pressuring supplier(s) to take environmental actions

(7.5) Taking environmental criteria into consideration

(7.6) Design considerations

(7.7) Optimization of processes to reduce solid wastes

(7.8) Optimization of processes to reduce water use

(7.9) Optimization of processes to reduce air emissions

(7.10) Optimization of processes to reduce noise

(7.11) Use of cleaner technology processes to make savings (energy, water, wastes)

(7.12) Recycling of materials internal to the company

(7.13) Use of waste of other companies

(7.14) Use of alternative sources of energy

(7.15) Helping suppliers to establish their own EMS

(7.16) Recovery of the company's end-of-life products

(7.17) Eco-labeling

(7.18) Environmental improvement of packaging

(7.19) Taking back packaging

(7.20) Providing consumers with information on environmental friendly products and/or production methods

(7.21) Change for more environmental-friendly transportation

8. In the last two years because of implementing better management practices there has been specific benefits achieved in each of the following categories (on a four point scale of strongly disagree, disagree, agree, strongly agree).

(8.1) Increased efficiency

(8.2) Quality improvement

(8.3) Productivity improvement

(8.4) New market opportunities

(8.5) Cost saving

(8.6) Improved corporate image

(8.7) Reduction of solid/liquid waste

(8.8) Reduction of emissions

(8.9) Recycling

(8.10) Environmental compliance improvement

(8.11) Product price increase

(8.12) Profit margin

(8.13) Social commitment

(8.14) Sales

(8.15) Market share

(8.16) Preserve environment.

9. In the process of Greening the suppliers, the company has taken actions in the following areas with regard to the suppliers (on a four point scale of strongly disagree, disagree, agree, strongly agree).

   (9.1) Holding awareness seminars for suppliers/contractors

   (9.2) Guiding suppliers to establish their own environmental programs

   (9.3) Bringing together suppliers in the same industry to share their know how and problems

   (9.4) Informing suppliers about the benefits of cleaner production and technologies

   (9.5) Urging/pressuring suppliers to take environmental actions

   (9.6) Choice of suppliers by environment criteria

   (9.7) Arranging for funds to help suppliers to purchase equipment for pollution prevention, waste water recycling, etc.

   (9.8) Sending in-house company auditors to appraise environmental performance of suppliers