Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Operations Management 22 (2004) 265–289
JOURNAL OF OPERATIONS MANAGEMENT
www.elsevier.com/locate/dsw

Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises

Qinghua Zhu [a,*], Joseph Sarkis [b,1]

[a] *School of Management, Dalian University of Technology, Dalian, Liaoning Province 116024, PR China*
[b] *Graduate School of Management, Clark University, 950 Main Street, Worcester, MA 01610-1477, USA*

Received 13 May 2003; received in revised form 1 January 2004; accepted 2 January 2004

Available online 20 April 2004

Abstract

Globalization results in both pressure and drivers for Chinese enterprises to improve their environmental performance. As a developing country, China has to balance economic and environmental performance. Green supply chain management (GSCM) is emerging to be an important approach for Chinese enterprises to improve performance, possibly on both these dimensions. Using empirical results from 186 respondents on GSCM practice in Chinese manufacturing enterprises, we examine the relationships between GSCM practice and environmental and economic performance. Using moderated hierarchical regression analysis, we evaluate the general relationships between specific GSCM practices and performance. We then investigate how two primary types of management operations philosophies, quality management and just-in-time (or lean) manufacturing principles, influence the relationship between GSCM practices and performance. Significant findings were determined for a number of relationships. Managerial implications are also identified.

Keywords: International management; Green supply chain management; Moderated hierarchical regression; Empirical study

1. Introduction

Globalization, especially after China's entry into the World Trade Organization (WTO), may result in higher pressure and drivers for Chinese enterprises to improve environmental performance. Christmann and Taylor (2001) suggested that export and sales to foreign customers are two major drivers for improving the environmental performance of Chinese enterprises. Increasingly, multinational enterprises have established global networks of suppliers (Dunning, 1993). These linkages and growth in globalization provide opportunities for Chinese manufacturers to export products. However, exporting products also requires Chinese enterprises to address and overcome 'green barriers' and increase their international competitive ability (Deng and Wang, 1998). For example, Bristol-Myers Squibb, IBM and Xerox have encouraged their Chinese suppliers to develop environmental management systems consistent with ISO 14001, while Ford, GM and Toyota have required their Chinese suppliers to obtain the ISO 14001 certification (GEMI, 2001).

* Corresponding author. Tel.: +86-411-4709412; fax: +86-411-4708342.
E-mail addresses: zhuqh@dlut.edu.cn (Q. Zhu), jsarkis@clarku.edu (J. Sarkis).
[1] Tel.: +1-508-793-7659; fax: +1-508-793-8822.

0272-6963/$ – see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jom.2004.01.005

Practices of multinational enterprises in China saw foreign enterprises located in China purchasing materials and components mainly from their home countries, or other foreign enterprises already in China, leaving Chinese enterprises with relatively few customer–supplier relationships with these foreign enterprises based in China. One of the main reasons for this occurrence is that products from Chinese enterprises could not meet both quality and environmental requirements of these foreign enterprises (Zhu and Geng, 2001).

This issue is also significant because recent studies have shown that a majority of the world's manufacturing will be carried out in Asia in the next couple of decades (US-AEP, 1999). This growth is expected to create many opportunities in this part of the world, but it will also bring about substantial environmental burden (Rao, 2002).

As a developing country, China highlights economic development as a priority. The demands of economic modernization place competing demands upon Chinese manufacturing managers who are also required to act responsibly towards the environment (Liu et al., 2001). Rapid industrial modernization and economic reform have been features of the Chinese economy since the 1980s, and have brought with it substantial environmental problems. Under competitive, regulatory, and community pressures, it has become increasingly important for organizations to balance economic and environmental performance (Shultz and Holbrook, 1999). In response to these problems the Chinese government has been developing approaches to environmental management, such as establishing more strict environmental regulations, promoting cleaner production and encouraging ISO 14001 certification (Zhu and Geng, 2002a, 2003). The current corporate focus in China seeks to develop systematic and integrated approaches to environmental management such as industrial ecology (Zhu and Cote, 2004; Geng and Cote, 2003) and green supply chain management (GSCM[2]) for moving towards a closed-loop or cyclical industrial systems (Zhu and Geng, 2002b).

An empirical study to determine the economic and environmental relationships of these GSCM practices is presented in this paper. This study will help determine whether adopting these environmental measures is worth the effort of these organizations in terms of economic and environmental performance. It will also help us identify what relationships seem to be significant, providing guidance to organizations in what practices may be worthwhile to adopt. In addition, the relationship between GSCM practice and performance may be moderated by other organizational practices. Specifically, we will determine whether two operational principles, quality management (QM) programs and just-in-time (JIT) practices, would serve as moderators that influence the relationship between GSCM practices and performance. These core operational practices may act as moderators for the relationships since their existence or non-existence may help or hinder the performance implications of the GSCM practices. QM type philosophies have been tied to, and serve as the foundation, for many environmental programs. It will be expected that their existence will enhance the GSCM practices and thus provide greater opportunities for increased performance. Their non-existence may mean that more effort will be required for initial implementation and introduction of GSCM practices. The JIT moderator influence is a little more complicated since there are internal and external practices that provide diverging environmental consequences. The 'lean manufacturing' aspect of JIT which is more focused on internal operations can contribute to improved environmental/financial performance with GSCM practices. External, company to company relationships aspects of JIT and its focus on movement of materials may cause more detriment in terms of a moderating effect on the relationships between practices where an existence of such programs may supersede finding environmental efficiencies for the sake of improved operational performance (e.g. more frequent deliveries using more energy).

To complete this investigation, this paper introduces the some background on GSCM practice in general and in China. We begin this discussion by presenting the research framework and establishing hypotheses in Section 2. Section 3 describes the data collection methods and measures for this study. The methodology and results are presented in Section 4. Section 5 discusses the results with some practical implications identified, and Section 6 concludes the paper summarizing the issues and potentials for future research.

[2] In some research GSCM represents Global Supply Chain Management. In the context of this paper GSCM stands for environmental (green) supply chain management.

2. Research framework and hypotheses

We begin this section by further defining GSCM and framing the research question.

A recent textbook on supply chain management (Handfield and Nichols, 1999) has provided the following definition for a supply chain:

> The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials (extraction), through the end user, as well as associated information flows. Material and information flow both up and down the supply chain. (p. 2)

In this description, the supply chain is considered to be a linear process. The circular and systemic philosophy of "ecosystem" thinking (Shrivastava, 1995) is not explicitly included. Thus, from this textbook perspective, the integration of the full cyclical supply chain is not considered central to its definition. Few textbooks (and the supply chain literature in general) seem to diverge from this definition. This small example is exemplary of common wisdom among this relatively new field. Developments in greening supply chains have yet to diffuse through the general operations literature.

A number of possible definitions of GSCM have been put forth over the past decade including:

> Green supply refers to the way in which innovations in supply chain management and industrial purchasing may be considered in the context of the environment. (Green et al., 1996, p. 188)

> Environmental supply chain management consists of the purchasing function's involvement in activities that include reduction, recycling, reuse and the substitution of materials. (Narasimhan and Carter, 1998, p. 6)

> The practice of monitoring and improving environmental performance in the supply chain ... (Godfrey, 1998, p. 244).

> The term 'supply chain' describes the network of suppliers, distributors and consumers. It also includes transportation between the supplier and the consumer, as well as the final consumer ... the environmental effects of the researching developing, manufacturing, storing, transporting, and using a product, as well as disposing of the product waste, must be considered. (Messelbeck and Whaley, 1999, p. 42)

From these four definitions we see that there is a range of author focus and purpose of GSCM. The research or practitioner field (i.e. purchasing, operations, marketing or logistics) also influences the definition. The definition of the purpose of green supply chains, which range from reactive monitoring of general environmental management programs to more proactive practices such as the Re's (e.g. recycling, reclamation, remanufacturing, reverse logistics) of environmental management and incorporating "innovations," also seem to differ. This lack of consensus in practice and definition of GSCM is not surprising, since it lies at the confluence of elements of corporate environmental management and supply chain management which are both relatively new areas of study and practice, if not new terminologies to explain older practices. In this paper we consider the literature and develop four factors for GSCM practice, as defined in Table 1. As can be seen in this table we take a broad perspective of GSCM and include internal and external practices that play a role in greening the supply chain.

The research framework, shown in Fig. 1, is developed to investigate the relationships between four GSCM practices (internal environmental management, external GSCM, investment recovery, and eco-design or design for environment practices) that Chinese enterprises may implement to improve their performance. GSCM practices dimensions and items were based on previous literature that addressed various elements of GSCM (e.g. see Carter et al., 1998; Zsidisin and Hendrick, 1998; Walton et al., 1998; Zhu and Cote, 2002) as well as input from expert opinion.

Performance items were developed by the authors after consultation with academic experts, officials and enterprises on environmental management, and are presented in Table 2. All four major GSCM practices are integrative and need cross-functional cooperation rather than oriented towards a single function or department. Internal environmental management is a key to improving enterprises' performance (Carter et al., 1998). External GSCM relationships (e.g. supplier certification) and eco-design (also defined as design

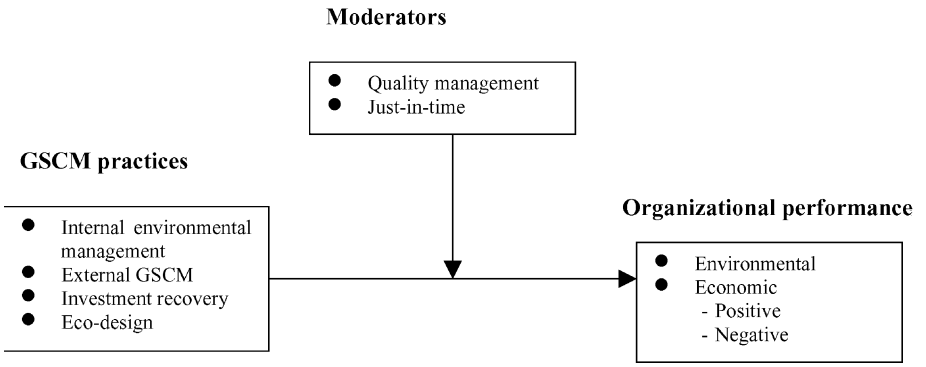

Fig. 1. Research framework for investigation of relationship between GSCM practices and performance in Chinese manufacturing enterprises.

for the environment) are two emerging approaches in evidence in Chinese enterprises (Zhu and Cote, 2002). United States and European enterprises have also considered investment recovery as a critical aspect for green purchasing and GSCM (Zsidisin and Hendrick, 1998). Investment recovery is a traditional business practice, but it can also be considered a green practice since it can reduce waste that may have otherwise been disposed. Even though investment recovery may not be the most sustainable practice, it does lengthen the life of the product or material where it can be recycled into other products or materials. In China, the government switched from resource subsidies to levying taxes for some resources such as coal and natural gas (Zhu and Cote, 2002). However, investment recovery has received much less attention in China when compared to

Table 1
Categories of green supply chain management from literature

Internal environmental management
Commitment of GSCM from senior managers
Support for GSCM from mid-level managers
Cross-functional cooperation for environmental improvements
Total quality environmental management
Environmental compliance and auditing programs
ISO 14001 certification
Environmental management systems exist
External GSCM practices
Providing design specification to suppliers that include environmental requirements for purchased item
Cooperation with suppliers for environmental objectives
Environmental audit for suppliers' internal management
Suppliers' ISO14000 certification
Second-tier supplier environmentally friendly practice evaluation
Cooperation with customer for eco-design
Cooperation with customers for cleaner production
Cooperation with customers for green packaging
Investment recovery
Investment recovery (sale) of excess inventories/materials
Sale of scrap and used materials
Sale of excess capital equipment
Eco-design
Design of products for reduced consumption of material/energy
Design of products for reuse, recycle, recovery of material, component parts
Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process

Table 2
Distribution of survey respondent enterprises by industry and size

	Total	Percentage
Industry		
Automobile	55	29.6
Power generating	34	18.3
Electrical and electronic	25	13.4
Chemical	17	9.1
Steel	9	4.8
Petroleum	8	4.3
Pharmaceutical	5	2.7
Other	33	17.8
Total	186	100
Size (employees)		
>8000	13	7.0
3000–8000	39	21.0
1000–3000	44	23.6
500–1000	58	31.2
<500	32	17.2
<100	6	
Total	186	100

more developed countries such as the USA and Germany, primarily due to waste management policies and lack of recycling systems and infrastructure. In this general framework, we will posit that the four GSCM practice factors have a positive, direct relationship with enterprises' performance improvements. We also posit that the degree of QM and JIT manufacturing influences the relationships between GSCM practice and performance; i.e. QM and JIT have a moderating effect. We now discuss these specific relationships.

2.1. GSCM practices and enterprises' environmental performance

Environmental performance is a concern of managers due to reasons ranging from regulatory and contractual compliance, to public perception and competitive advantage (Theyel, 2001). Recent literature (Florida, 1996a; Florida and Davison, 2001; Geffen and Rothenberg, 2000; Green et al., 1996; Handfield et al., 2002; Sarkis, 1995) offers insight on potential patterns of supply chain relations for improving environmental performance. Investment in these programs can be great and pressures to perform environmentally are great, improved environmental performance from these practices may not be guaranteed. Thus, further understanding of the relationship between GSCM practices and environmental performance is needed, especially for enterprises in countries that need to balance a growing economy and environmental protection such as China.

The raison d'être for GSCM practices is that they will actually improve environmental performance. The literature for supporting this idea is relatively strong. For example, Frosch (1994) argued that an inter-firm linkage facilitated by proximity could lead to improvement in environmental performance. Florida (1996a) stated that closer bonds between suppliers and customers, which can facilitate cleaner production, are the trend in manufacturing as leading enterprises need such close relationships with suppliers to incorporate management strategies such as JIT, continuous improvement and total quality management. Geffen and Rothenberg (2000) suggested that relations with suppliers aid the adoption and development of innovative environmental technologies. In addition, the interaction of customer and supplier staff, partnership agreements and joint research and development lead to improvements in environmental performance. Thus, the first hypothesis is chosen to determine if the intuition, at least for Chinese manufacturing enterprises, is accurate.

Hypothesis 1. Enterprises having higher levels of adoption of GSCM practices will have better environmental performance improvements.

2.2. GSCM practices and enterprises' economic performance

Economic performance is typically the most important driver for enterprises that wish to implement environmental management practices, especially for enterprises in developing countries such as China. It has been argued that success in addressing environmental issues may provide new opportunities for competition, and new ways to add value to core business programs (Hansmann and Kroger, 2001). Dodgson (2000), Dyer and Singh (1998), Von Hippel (1998), and others argue that inter-firm relations provide formal and informal mechanisms that promote trust, reduce risk and in turn increase innovation and profitability. Through examination, Bowen et al. (2001a) suggest economic performance is clearly not being reaped in short-term profitability and sales performance. Despite this, there is evidence to suggest that proactive GSCM approaches can prepare enterprises for superior longer term performance through improved management of environmental risks and the development of capabilities for continuous environmental improvement. Alvarez Gil et al. (2001) indicated that environmental management such as GSCM has a positive relationship with an organization's economic performance.

Environmental protection activities are embedded in business operations and, thus, may also bring about some benefits for firms (e.g. improvement in organizational reputation; Welford, 1995). In short, extant literature attributes a number of benefits to the integration of environmental issues in corporate strategy (Porter and van der Linde, 1995; Shrivastava, 1995; Beaumont et al., 1993; Guimaraes and Liska, 1995) including: (1) cost savings and improvements in firms' efficiency, (2) product quality improvements, (3) increases in market share, (4) getting ahead of competitors and legislation, (5) access to new markets, (6) enhance employee mo-

tivation and satisfaction, (7) improvements in public relations, and (8) access to financial aid.

Among barriers to implement GSCM such as green purchasing practice, a critical factor appears to be economic reasons and issues related to costs (Min and Galle, 1997; Cox et al., 1999). Restrictions to firms' behavior in adopting GSCM practices, such as certain eco-design principles and cooperation, may arise from the enactment of internal procedures (e.g. no sharing of product design issues with suppliers/customers) as well as from conformity with extant regulation (certain products must be manufactured in certain ways). Further, compliance with internal and external procedures posits considerable restrictions to opportunistic behavior of firms as well as increase operational costs, and this in turn may have a negative impact on firms' financial performance (Cordeiro and Sarkis, 1997; Walley and Whitehead, 1994).

Overall, there is potential for both positive and negative economic performance due to corporate environmental practices. Support for this finding is evident in the relationship between environmental management and firms' financial performance, which has been contradictory (Wagner et al., 2001). Whereas some studies suggest a positive relationship between financial performance and proactive environmental strategies (Russo and Fouts, 1997; Judge and Douglas, 1998; Klassen and McClaughlin, 1996), other investigations have found negative relationships (Cordeiro and Sarkis, 1997; Worrell et al., 1995).

The varying results may be due to numerous reasons from the data utilized in the analysis to the definitions of performance that have been operationalized. In our study, we define benefits gained through GSCM as positive economic improvements, including decrease of cost for materials purchasing, decrease of cost for energy consumption, decrease of fees for waste treatment and waste discharge, and decrease of fines for environmental accidents. Also, we define related negative economic performance, as increase of investment, increase of operational cost, increase of training cost and increase of costs for purchasing environmentally friendly materials. This data, unlike many of the previous studies, does not focus on aggregate corporate performance such as share price, market share, return on assets and return on equity, but on more operational level economic and financial performance measures. Since many of these GSCM practices are operationally focused and the economic performance measures are also operationally focused, the following hypotheses are posited.

Hypothesis 2. Enterprises having higher levels of adoption of GSCM practices have better positive economic performance improvements.

Hypothesis 3. Enterprises having higher levels of GSCM practices have (worse) negative economic performance improvements.

2.3. Moderating effects

Thus far, the hypotheses above posit that GSCM practices are generally beneficial for environmental performance and some aspects of economic performance. In addition, we posit that the degree of performance improvements is, in part, dependent on two other factors, QM and JIT program adoptions in manufacturing organizations. Operations management techniques including QM and JIT may help improve operational performance factors such as efficiency, service, and quality (Lee-Ross and Ingold, 1994; McMahon, 1994; Samson and Terziovski, 1999). Although the use of operations management techniques might be considered to have no connection with environmental management, the reduction of environmental impact by means of pollution prevention is, in practice, intrinsically linked to the productive and operational activities of the firm (Hart, 1995).

Even though much of the literature has shown direct relationships between QM/JIT and the economic/environmental outcomes, our focus is more on testing whether these programs play a role in moderating the relationship between GSCM practices and performance. Thus, we consider QM and JIT as two moderators in this paper. QM and JIT direct influences are evident in the results.

2.3.1. Quality management as a moderator

QM can refer to a general broad concept. In this paper, we define it as two main activities, that is, total quality management (TQM) type programs and ISO 9000 standards certification. From an environmental perspective, total quality environmental management (TQEM) and ISO 14000 certification, both borrow heavily from TQM and ISO 9000 standards,

respectively (Kitazawa and Sarkis, 2000). Kitazawa and Sarkis (2000), based on case study experience, also point to the need to have a number of QM and JIT-based programs and principles to take advantage of true source reduction from ISO 14000 and other environmental management system programs.

ISO 9000 certification has become an increasingly popular option for enterprises seeking to improve their internal operations and competitive positions. King and Lenox (2001) found that those establishments that adopt a quality management standard are more likely to adopt an environmental management standard. However, studies that have addressed the relationship between QM and economic performance have not only been limited, but also have been largely contradictory. In a couple of empirical studies Wayhan et al. (2002) and Terziovski et al. (1997) indicated that ISO 9000 certification has a very limited or insignificant impact on financial and organizational performance. Through an exploratory study of 126 firms in the electronics industry, Simmons and White (1999) compared performance results for ISO 9000 registered and non-registered firms and concluded that when firm size is controlled, ISO registered companies were more profitable than non-ISO companies.Based on the literature above we posit our next two hypotheses.

Hypothesis 4. The positive relationship between GSCM practice and environmental performance is stronger in enterprises having higher levels quality management practices adoption than in enterprises having lower levels of quality management practices adoption.

Hypothesis 5. The positive relationship between GSCM practice and economic performance is stronger in enterprises having higher levels quality management practices adoption than in enterprises having lower levels of quality management practices adoption.

2.3.2. Just-in-time practices as a moderator

It has been argued that the JIT philosophy (which comprises many of the same principles as "lean manufacturing") is a double-edged sword that can result in either positive or negative environmental performance. Through two unique surveys of 31 automobile assembly plants in North America and Japan, Rothenberg et al. (2001) suggested that lean production or JIT manufacturing increases air emission of volatile organic compounds (VOCs) but contributes to more efficient use of paints and cleaning solvents. They concluded that three aspects of lean management (buffer minimization, work systems and human resource management, all part of the general JIT philosophy) might be related to environmental management practices and performance. Klassen (2000) put forward that JIT could be a benefit for pollution prevention especially if the two programs are implemented together, and that when managers seek to implement JIT, they should try to include pollution prevention elements. Lean production or JIT manufacturing may also have a significant public good spillover—improved environmental performance (Florida, 1996b; Hart, 1997). Through an empirical analysis of the environmental performance of 17,499 U.S. manufacturing establishments during the time period 1991–1996, King and Lenox (2001) found strong evidence that lean production is complimentary to waste reduction and pollution reduction.

However, early studies such as those by Macdonald (1991) reported that JIT could be bad for the environment. They reference a report claiming that a JIT approach to inventory management and manufacturing wastes fuel, pollutes the environment, and neglects procedures that would be much more environmentally sensitive (NMHC, 1991). Although recognizing the benefits to be gained from JIT methods of controlling inventory, the report concludes that they hurt the environment more than other techniques might. They claim that using JIT methods in fact results in enough waste to adversely impact a company's bottom line. JIT techniques, such as smaller but more frequent deliveries, increase the number of vehicles needed, underutilize those vehicles, and (because of warehouse centralization) result in longer truck journeys. King and Lenox mention that increasing efficiencies in JIT which require smaller batch sizes and more setups could produce more cleaning waste from cleaning of equipment and more disposal of unused process material. Cusumano (1994), McIntyre et al. (1998), Moinzadeh et al. (1997), Rothenberg et al. (2001), and Sarkis (1995) all mention the problems with shipping smaller amounts between plants requiring less efficient and smaller transport vehicles, causing additional congestion and pollution and supply chain inventory

requirements. In addition, Sarkis (1995) mentions that there may be a requirement for additional packaging material that must also be disposed. Decentralized inventory management, which is an element of many JIT delivery schemes (so that suppliers can be closer to manufacturers) may cause increased inventory across the supply chain (see Matthews et al., 2002) who discuss issues of centralized stock keeping and environmental implications). In addition, even though some organizations may internally benefit from reduced inventories, risks of increasing inventory can be passed on to smaller, less powerful suppliers (Munson et al., 1999). Thus with increasing inventory along the supply chain (not just for a single unit in the supply chain) there are increasing possibilities of waste.

Here, we focus on the implementation of a logistics-based JIT system, considering the overall management of materials flow of a JIT system. Thus, we believe that JIT principles (especially those principles external to the organizational boundaries) may require greater environmental resources for managing the quick deliveries and lower inventories than benefits from the JIT philosophy of waste reduction and elimination of waste.

Hypothesis 6. The positive relationship between GSCM practice and environmental performance is weaker in enterprises having more just-in-time practice adoption than in enterprises having less just-in-time practice adoption.

Debates also exist on whether JIT can improve economic performance or not. Using data obtained from a sample of 46 firms that disclosed JIT adoption in their annual reports or 10-K filings for 1985–1989, Balakrishnan et al. (1996) indicated that there was no significant return on assets improvement to JIT implementation. By comparing 201 JIT adopters and matched non-adopters, Michael and Wempe (2002) indicated that "JIT adopters improve financial performance relative to non-adopters, and that profit margin, rather than asset turnover, is the primary source of such improvement." But they also indicated JIT could not bring economic benefits for small enterprises. However, other studies suggest that JIT could bring economic benefits. Mia (2000) provided empirical support that enterprises can benefit in terms of boosting profitability by adopting JIT manufacturing. Dong et al. (2001) concluded that JIT purchasing can directly reduce the costs for buyers. By analyzing the relative performance of JIT and non-JIT plants operating in two distinct manufacturing industries, electronic components and auto-parts, Callen et al. (2000) found that the success of plants associated with greater productivity in inventory usage, lower total and variable costs and higher profits is related to the length of experience with JIT manufacturing. Thus, we find that most organizations will probably introduce JIT principles to aid in the economic performance of organizations. We have found no studies that seek to determine if JIT along with corporate environmental or GSCM practices contributes to improved economic performance. Given the above background literature supporting some economic benefits from JIT implementation, we posit the following hypothesis:

Hypothesis 7. The positive relationship between GSCM practice and economic performance is stronger in enterprises having greater just-in-time practice adoption than in enterprises having less just-in-time practice adoption.

2.4. Control variables

Since large organizations may be more likely than small ones to have well-developed GSCM and other practices, due to extra available resources, we controlled for any extraneous effects of organizational size. Following Dean and Snell (1991), size was measured as the natural logarithmic transformation of the number of full-time employees.

3. Methodology

In this section we provide the methodology for operationalizing the variables and factors, acquiring the data and determining the reliability of factor groupings. The modified hierarchical regression methodology is used to test the various hypotheses, but will be left until Section 4 for further description.

3.1. Operationalization of variables

To operationalize the factors that will be used to test our hypotheses we developed a survey instrument

that included 21 questions pertaining to current GSCM practices and 15 items for measurement of performance. Papers published in both English and Chinese were used for appropriate scale development.

Twenty-one items on GSCM practices, as shown in Table 1, were based on opinions from industrial experts and the literature (Zsidisin and Hendrick, 1998; Walton et al., 1998; Carter et al., 2000). By investigating purchasing managers in Germany, the UK and the USA, Zsidisin and Hendrick (1998) identified four factors for environmental purchasing, hazardous materials, investment recovery, product design and supply chain relationships. The first four items of external GSCM practices, three items of investment recovery and three items of eco-design in our questionnaire (shown in Table 1) were from this paper. Reviews of the most appropriate GSCM practice items were completed with input from industry, government and academic experts. Based on case studies of five companies in the furniture industry, Walton et al. (1998) identified the top ten environmental supplier evaluation criteria. By consulting people from the Bureau of Environmental Protection in Tianjin Economic and Development Zone (the largest industrial zone in China) and Dalian Economic and Technological Development Zone (the second largest industrial zone in China), as well as several environmental managers of companies from these two zones, we chose two items from the ten criteria for investigation, that is, suppliers' ISO 14001 certification which was also listed by Zsidisin and Hendrick (1998), and second-tier supplier environmentally friendly practice evaluation. We added three items on cooperation with customers, which seemed to be a critical aspect of cooperative supply chain management that was missing from the original survey instruments and that management viewed as being important.

Carter et al. (1998) identified that top and middle management support are two key factors on GSCM such as environmental purchasing in US and Germany enterprises. We used these two items and added five other items according to suggestions from experts in academia, governmental agencies and companies in China. Questions were answered using a five-point scale (1: not considering it, 2: planning to consider it, 3: considering it currently, 4: carrying out to some degree, 5: carrying it out fully).

Fifteen questions about GSCM performance developed by the authors focused on environmental performance and operational financial performance. Items were also pretested by the research team using managers from the Bureau of Environmental Protection in Tianjin Economic and Development Zone and Dalian Economic and Technological Development Zone and several environmental managers of companies from these two zones. Questions about performance results from implementing GSCM practices were answered using a five-point scale (1, not at all; 2, a little bit; 3, to some degree; 4, relatively significant; 5, significant).

3.2. Survey questionnaire development

The survey questionnaire was initially in English. Translation of the survey instrument was made into Chinese by one of the research team members who is fluent in the Chinese language. Because the method of collecting the survey information involved close contact between respondents and the researchers. Thus, the research team was available to most of the respondents if any questions should arise. This availability helped clarify any definitions or issues related to the survey instrument and mitigated any translation difficulties. Additional questions pertaining to industry and company characteristics were included in the survey instrument. In addition, experts from academia, governmental agencies and companies in China were asked to review the draft questionnaire to confirm that the questionnaire covered the main aspects on GSCM and can be understood by respondents, as discussed in the previous section. All questions were answered using a five-point Likert scale.

3.3. Data and sample characteristics

The data used in this study consist of survey questionnaire responses from managers in Chinese manufacturing and processing industries. These industries were selected because they are viewed to have the most direct and observable impact on the environment.

The survey instrument was administered using convenience sampling[3], more details are provided in the

[3] Randomly designed nationally focused mail and phone surveys were not used due to the lack of reliable sources of delivery mechanisms and databases for Chinese industry. Thus, a convenience sample was deemed the most feasible approach.

appendix. Due to the difficulties in obtaining data, convenience samples and executive MBA audience samples are often used (e.g. Zirger and Maidique, 1990). Our study methodology also has precedence in of the research work of Christmann and Taylor (2001), who saw the same difficulty in data collection for Chinese organizational practices. They completed their empirical study by surveying Chinese managers participating in two seminars on standards-based management practices conducted by the Asia Pacific Economic Corporation. In addition Luo's (2001) study investigated 60 EMBA students and 55 participants in the Advanced Management Training Program, both in Southeast University in China.

Out of a total of 281 questionnaires administered to all the enterprises and representatives, a total of 186 unique and usable manufacturing enterprise responses were received. The respondents targeted by this study and responding to the survey had middle management or higher experience. This level of respondent is supported by other research such as Carter et al. (1998) who concluded that mid-level managers such as those in purchasing department could, at a minimum, facilitate incremental adoption of environmental practices, which is consistent with our findings from extensive corporate interviews beyond the survey instrument. Bowen et al. (2001b) used middle managers to find positive relationships between middle managers' perceptions of corporate environmental proactivity and GSCM. In another paper, Bowen et al. (2001a), found that the further the middle managers' perceptions of the corporate attitude to environmental issues is in advance of legislation, regulation and other firms in the industry, the more likely the unit is to implement a GSCM practice.

Table 3 shows the distribution of respondent enterprises in terms of industry and enterprise size using employment levels. Notice that a broad swath of industries is represented with no industry dominating the samples. Enterprise sizes ranged from under 500 to over 8000 employees with the majority of companies falling into the relatively large company classification of between 500 and 8000 employees.

Table 3
Rotated factor matrix[a] on GSCM practices

Survey items	1	2	3	4
Providing design specification to suppliers that include environmental requirements for purchased items	0.446	*0.591*	0.116	0.166
Cooperation with suppliers for environmental objectives	0.506	*0.648*	4.202E−02	0.143
Environmental audit for suppliers' internal management	0.306	*0.741*	9.164E−02	5.422E−02
Suppliers' ISO14000 certification	0.350	*0.756*	2.079E−02	1.724E−03
Second-tier supplier environmentally friendly practice evaluation	0.334	*0.716*	8.531E−02	7.643E−02
Cooperation with customer for eco-design	0.208	*0.707*	0.210	0.410
Cooperation with customers for cleaner production	0.159	*0.697*	0.250	0.382
Cooperation with customers for green packaging	0.106	*0.789*	0.162	0.329
Investment recovery (sale) of excess inventories/materials	0.169	0.207	*0.821*	0.158
Sale of scrap and used materials	6.903E−02	8.821E−02	*0.902*	0.104
Sale of excess capital equipment	−5.726E−02	8.843E−02	*0.847*	7.040E−02
Design of products for reduced consumption of material/energy	0.360	8.580E−02	0.312	*0.751*
Design of products for reuse, recycle, recovery of material, component parts	0.217	0.284	7.921E−02	*0.784*
Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process	0.469	0.336	6.451E−02	*0.670*
Commitment of GSCM from senior managers	*0.817*	0.241	0.149	0.269
Support for GSCM from mid-level managers	*0.829*	0.277	0.109	0.207
Cross-functional cooperation for environmental improvements	*0.814*	0.180	7.716E−02	0.276
Total quality environmental management	*0.808*	0.366	3.406E−02	0.203
Environmental compliance and auditing programs	*0.785*	0.208	0.144	0.239
ISO 14001 certification	*0.648*	0.453	−0.126	9.957E−02
Environmental management systems exist	*0.811*	0.328	−4.259E-02	5.338E−02

Extraction method: principal component analysis; rotation method: varimax with Kaiser normalization.
[a] Rotation converged in seven iterations.

To narrow research targets and avoid bias as much as possible, we chose respondents mainly from three types of enterprises within China, namely, foreign direct investment (FDI) enterprises and joint ventures, enterprises exporting products or becoming suppliers of foreign enterprises and traditional heavy polluters such as such as petroleum refineries, chemicals, paper and pulp, textile, and metallurgical industry. Even though three enterprise types were used many of these organizations met more than one criterion. For example, FDI enterprises and joint ventures export products and may also prefer to choose other foreign enterprises in China as their suppliers. Some of these FDI companies and joint ventures operate in transitional heavy polluting industries. Due to higher awareness or pressure, it can be argued that these enterprises in China are innovators in GSCM and their experiences will diffuse to other enterprises (Zhu and Geng, 2003).

3.4. Factor analysis

A factor analysis was conducted to further confirm groupings of GSCM practice and performance from the survey data. Factors were extracted using the maximum likelihood method, followed by a varimax rotation. The Kaiser criterion (eigenvalues > 1) was employed in conjunction with an evaluation of scree plots. Both the scree test and initial eigenvalue test suggested the presence of four and three meaningful factors for practice and performance, respectively, that were retained for rotation. This factor analysis empirically grouped the scale items of GSCM practice as predicted, see Table 4, confirming our original groupings. The four GSCM practice factors explain 71.3% of the inherent variation in their items. A similar factor analysis of the GSCM performance items also grouped the scale items as predicted, see Table 5. The three GSCM performance factors explain 74.8% of the inherent variation. Similarly, two factors of moderators explain 82.9% of the inherent variation. We kept the labels of the four factors on GSCM practices which included internal environmental management, external GSCM, investment recovery, and eco-design. Further analysis confirms the reliability of these four factors with Cronbach's alpha, of 0.94, 0.92, 0.85 and 0.86, respectively, for each group. The three factors on performance can be labeled as environmental performance, positive economic performance and negative economic performance. Further analysis also confirms the reliability of these three factors with levels of Cronbach's alpha equal to 0.93, 0.90 and 0.87, respectively. All Cronbach alpha values are well above the limit of 0.70 established by Nunnally (1978) to ensure the constructs' internal consistency and validity.

Items for each factor on GSCM practice and performance are also shown in Tables 5 and 6, respectively.

Table 4
Rotated factor matrix[a] on GSCM performance influences

Survey items	Factors		
	1	2	3
Reduction of air emission	*0.805*	0.218	0.244
Reduction of waste water	*0.831*	0.325	0.146
Reduction of solid wastes	*0.788*	0.288	0.243
Decrease of consumption for hazardous/harmful/toxic materials	*0.770*	0.222	0.320
Decrease of frequency for environmental accidents	*0.790*	0.278	0.194
Improve a enterprise's environmental situation	*0.788*	0.259	0.172
Increase of investment	0.354	0.274	*0.763*
Increase of operational cost	0.132	0.246	*0.835*
Increase of training cost	0.277	5.903E−02	*0.786*
Increase of costs for purchasing environmentally friendly materials	0.181	0.397	*0.724*
Decrease of cost for materials purchasing	0.276	*0.640*	0.370
Decrease of cost for energy consumption	0.222	*0.790*	0.253
Decrease of fee for waste treatment	0.249	*0.877*	0.192
Decrease of fee for waste discharge	0.349	*0.828*	0.209
Decrease of fine for environmental accidents	0.417	*0.656*	0.129

Extraction method: principal component analysis; rotation method: varimax with Kaiser normalization.
[a] Rotation converged in five iterations.

Table 5
Descriptive statistics for GSCM practices

Items	Mean	Std. Deviation	*N*
Internal environmental management ($\alpha = 0.9413$)	3.56	1.017	168
Commitment of GSCM from senior managers	3.77	1.183	181
Support for GSCM from mid-level managers	3.57	1.085	182
Cross-functional cooperation for environmental improvements	3.62	1.120	184
Total quality environmental management	3.61	1.142	183
Environmental compliance and auditing programs	3.71	1.057	178
ISO 14001 certification	3.21	1.333	173
Environmental management systems exist	3.36	1.201	181
External GSCM practices ($\alpha = 0.9246$)	2.87	1.048	155
Providing design specification to suppliers that include environmental requirements for purchased item	3.24	1.316	182
Cooperation with suppliers for environmental objectives	2.98	1.364	182
Environmental audit for suppliers' internal management	2.78	1.322	175
Suppliers' ISO14000 certification	3.12	1.314	174
Second-tier supplier environmentally friendly practice evaluation	2.68	1.327	176
Cooperation with customer for eco-design	2.67	1.342	180
Cooperation with customers for cleaner production	3.06	1.284	177
Cooperation with customers for green packaging	2.98	1.304	174
Investment recovery ($\alpha = 0.8501$)	3.39	1.075	170
Investment recovery (sale) of excess inventories/materials	3.45	1.289	178
Sale of scrap and used materials	3.50	1.221	179
Sale of excess capital equipment	3.35	1.218	176
Eco-design ($\alpha = 0.8586$)	3.51	1.001	174
Design of products for reduced consumption of material/energy	3.70	1.098	176
Design of products for reuse, recycle, recovery of material, component parts	3.31	1.156	179
Design of products to avoid or reduce use of hazardous of products and/or their manufacturing process	3.56	1.146	180
Moderator 1:quality management	3.95	0.918	180
ISO 9000 serial certification	4.12	1.089	180
Total quality management type programs	3.80	1.046	183
Moderator 2: just-in-time systems implemented	3.11	1.256	170

Note. Scales are: 1, not considering it; 2, planning to consider it; 3, considering it currently; 4, initiating implementation; 5, implementing successfully.

Other descriptive data, including means, standard deviations and number from sample for the GSCM practices and performance measures, are shown in Tables 5 and 6.

4. Results

4.1. Main effects and control variable relationships

One of our first findings in all the results was that firm size did not seem to have a significant relationship with any of the performance measures. It seems that in this sample of Chinese organizations, the extra resources available for larger sized firms did not play a role in contributing to any of the performance measures.

Hypothesis 1 posits a direct, positive relationship between GSCM practice and environmental performance improvement. Hypotheses 2 and 3 posit a direct, positive relationship between GSCM practices and economic performance, including both positive and negative performance. The bivariate correlation results, using Pearson correlation coefficients, are shown in Table 7. Most of these results show a significant relationship among internal environmental

Table 6
Descriptive statistics for GSCM performance

Items	Mean	Standard deviation	*N*
Environmental performance ($\alpha = 0.9375$)	3.71	0.942	175
Reduction of air emission	3.59	1.182	179
Reduction of waste water	3.69	1.142	180
Reduction of solid wastes	3.51	1.110	178
Decrease of consumption for hazardous/harmful/toxic materials	3.72	1.117	176
Decrease of frequency for environmental accidents	3.75	1.127	176
Improve a enterprise's environmental situation	3.87	1.111	179
Positive economic performance ($\alpha = 0.9005$)	3.19	0.964	168
Decrease of cost for materials purchasing	3.35	1.094	173
Decrease of cost for energy consumption	3.31	1.101	174
Decrease of fee for waste treatment	3.00	1.139	176
Decrease of fee for waste discharge	2.98	1.124	173
Decrease of fine for environmental accidents	3.38	1.192	173
Negative economic performance ($\alpha = 0.8741$)	3.50	0.893	157
Increase of investment	3.64	1.063	178
Increase of operational cost	3.55	1.016	175
Increase of training cost	3.49	1.048	177
Increase of costs for purchasing environmentally friendly materials	3.36	1.013	159

Note. Scales: 1, not at all; 2, a little bit; 3, to some degree; 4, relatively significant; 5, significant.

management, external GSCM, eco-design, and investment recovery with environmental performance, positive economic performance and negative economic performance are significant and positive. The only exception is that investment recovery does not have a significant correlation with negative economic performance. Further, multivariate regression analysis, see Step 2 (also most results for steps 3 and 4) of the regressions in Tables 8–11, demonstrate the same results. Thus, Hypotheses 1–3 are strongly supported by our data and results.

4.2. Moderated relationships results

Hypotheses 4–7 posit that QM and JIT moderate the relationship between GSCM practice and performance. Hierarchical moderated regression analysis is used to test these hypotheses. To understand the various relationships between specific sets of GSCM practice factors, we do individual hierarchical moderated regression analyses.

We follow variance partitioning procedures outlined by methodologists (Cohen and Cohen, 1983; Jaccard et al., 1990) and employed in prior empirical operations management research (Dean and Snell, 1991; Boyer et al., 1997; Tatikonda and Rosenthal, 2000; Tatikonda and Montoya-Weiss, 2001). The analysis is conducted in steps (e.g. see Table 8). First, the control variable, the firm size is entered into the regression. Second, one GSCM variable, for example internal environmental management, is entered into the regression. Third, the two moderators, QM and JIT, are entered as a block. Finally, the two interaction terms of internal environmental management and with each of the moderators are entered as a block. If the interaction accounts for a significant amount of incremental variance in the dependent variable, then there is evidence to support the hypothesis that there is a significant moderating effect of QM and JIT on the given GSCM practice method. Evidence of moderation exists when interaction terms account for significant incremental (step) variances in a dependent variable, either individually, signified by the values of the betas, or collectively, signified by the values of the incremental *F*-statistic (Dean and Snell, 1991).

Multicollinearity can be a serious problem in moderated regression analysis. One factor tends to have high correlations with other factors and aspects, leading to inflated standard errors and misinterpretation of the statistical significance of the regression results (Jaccard et al., 1990). To mitigate any potential multicollinearity, we employed "centering," the method

Table 7
Correlations between GSCM practice and performance

	1	2	3	4	5	6	7	8	9	10
Practices										
(1) Internal management (*N*)	1.0 (157)									
(2) External SCM (*N*)	0.687** (137)	1.0 (146)								
(3) Investment recovery (*N*)	0.237** (147)	0.307** (139)	1.0 (159)							
(4) Eco-design (*N*)	0.653** (152)	0.593** (139)	0.395** (155)	1.0 (164)						
Moderators										
(5) Quality management (*N*)	0.524** (155)	0.292** (143)	0.278** (158)	0.404** (164)	1.0 (171)					
(6) JIT (*N*)	0.440** (149)	0.374** (140)	0.191* (156)	0.398** (157)	0.350** (161)	1.0 (162)				
Performance										
(7) Environmental (*N*)	0.567** (148)	0.422** (135)	0.368** (150)	0.466** (154)	0.400** (160)	0.338** (152)	1.0 (162)			
(8) Positive economic (*N*)	0.433** (143)	0.379** (131)	0.213* (142)	0.333** (146)	0.227** (152)	0.318** (146)	0.659** (151)	1.0 (154)		
(9) Negative economic (*N*)	0.376** (134)	0.313* (121)	0.063 (135)	0.208* (140)	0.209* (144)	0.191* (137)	0.584** (141)	0.607** (137)	1.0 (146)	
Control variable										
(10) Firm size[a] (*N*)	−0.029 (99)	0.000 (93)	0.264** (101)	−00.030 (103)	0.243* (109)	0.003 (103)	0.008 (103)	0.042 (98)	−0.050 (89)	1.0 (113)

[a] Since firm size information was missing from the first 43 surveys, our sample size decreased greatly when firm size was introduced as a control variable. This is also true for Tables 8–11.
* Correlation is significant at the 0.05 level (two-tailed).
** Correlation is significant at the 0.01 level (two-tailed).

Table 8
Hierarchical regression with internal environmental management/quality management, JIT interaction

Variable entered	Dependent variable											
	Environmental performance ($N = 94$)				Positive economic performance ($N = 94$)				Negative economic performance ($N = 88$)			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Firm size	0.007	0.017	−0.016	−0.016	0.028	0.035	0.036	0.033	−0.034	−0.029	−0.037	−0.026
Internal environmental management		0.525***	0.405***	0.384***		0.396***	0.337***	0.317***		0.332***	0.301***	0.331***
Quality management			0.157*	0.170*			−0.010	0.026			0.039	−0.059
JIT			0.102	0.121+			0.159*	0.165*			0.029	0.043
Internal environmental management × quality management				0.040				0.079				−0.198*
Internal environmental management × JIT				−0.159*				−0.083				−0.020
F for the step	0.009	66.314***	3.773*	2.987+	0.135	32.420***	2.175	0.976	0.208	21.583***	0.198	3.446*
F for the regression	0.009	33.164***	18.997***	13.953***	0.135	16.290***	9.342***	6.552***	0.208	10.908***	5.503***	4.921***
R^2	0.000	0.276	0.306	0.330	0.001	0.158	0.178	0.188	0.001	0.111	0.113	0.148

Main table contains standardized coefficient betas.
* $P < 0.05$.
*** $P < 0.001$.
+ $P < 0.10$.

Table 9
Hierarchical regression with external GSCM/quality management, JIT interaction

Variable entered	Dependent variable											
	Environmental performance ($N = 87$)				Positive economic performance ($N = 87$)				Negative economic performance ($N = 87$)			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Firm size	0.007	0.010	−0.048	−0.040	0.028	0.030	0.011	0.022	−0.034	−0.033	−0.059	−0.061
External GSCM		0.364***	0.242***	0.236***		0.321***	0.237**	0.218**		0.267***	0.216**	0.220**
Quality management			0.289***	0.332***			0.094	0.168*			0.130+	0.115
JIT			0.143*	0.131+			0.183**	0.165*			0.049	0.053
External GSCM × quality management				0.124+				0.204**				−0.042
External GSCM × JIT				−0.083				−0.082				0.018
F for the step	0.009	26.587***	12.930***	1.707	0.135	20.035***	4.688**	3.540*	.208	13.325***	1.940	0.140
F for the regression	0.009	13.299***	14.026***	9.996***	0.135	10.093***	7.604***	6.399***	0.208	6.774***	4.393**	2.946**
R^2	0.000	0.133	0.246	0.261	0.001	0.104	0.150	0.184	0.001	0.072	0.093	0.094

Main table contains standardized coefficient betas.

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

+ $P < 0.10$.

Table 10
Hierarchical regression with investment recovery/quality management, JIT interaction

Variable entered	Dependent variable											
	Environmental performance ($N = 97$)				Positive economic performance ($N = 97$)				Negative economic performance ($N = 88$)			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Firm size	0.007	−0.064	−0.100	−0.109	0.028	−0.010	−0.018	−0.002	−0.034	−0.047	−0.069	−0.041
Investment recovery		0.360***	0.260***	0.258***		0.192*	0.121	0.140+		0.066	0.006	0.027
Quality management			0.283***	0.275***			0.114	0.106			0.169*	0.170*
JIT			0.175*	0.178*			0.230**	0.212**			0.105	0.083
Investment recovery × quality management				−0.069				−0.023				0.056
Investment recovery × JIT				0.011				0.094				0.084
F for the step	0.009	24.711***	15.150***	0.480	0.135	6.425*	7.599***	0.652	0.208	0.722	4.244*	1.056
F for the regression	0.009	12.361***	14.761***	9.941***	0.135	3.282*	5.565***	3.912***	0.208	0.465	2.363+	1.928+
R^2	0.000	0.124	0.256	0.260	0.001	0.036	0.115	0.121	0.001	0.005	0.052	0.064

Main table contains standardized coefficient betas.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
+ $P < 0.10$.

Table 11
Hierarchical regression with external eco-design/quality management, JIT interaction

Variable entered	Dependent variable											
	Environmental performance ($N = 98$)				Positive economic performance ($N = 97$)				Negative economic performance ($N = 88$)			
	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
Firm size	−0.034	−0.030	−0.060	−0.068	0.028	0.034	0.019	0.025	−0.034	−0.030	−0.060	−0.068
Eco-design		0.181*	0.096	0.114		0.307***	0.207*	0.200*		0.181*	0.096	0.114
Quality management			0.139+	0.120			0.071	0.095			0.139+	0.120
JIT			0.080	0.076			0.188*	0.188*			0.080	0.076
Eco-design × quality management				−0.076				0.093				−0.076
Eco-design × JIT				0.082				−0.032				0.082
F for the step	0.208	5.928*	2.284+	0.755	0.135	18.075***	3.908*	0.731	0.208	5.928*	2.284+	0.755
F for the regression	0.208	3.071*	2.700*	2.047+	0.135	9.112***	6.662***	4.671***	0.208	3.07*	1*	2.700*
R^2	0.001	0.034	0.059	0.067	0.001	0.095	0.134	0.142	0.001	0.034	0.059	0.067

Main table contains standardized coefficient betas.
* $P < 0.05$.
*** $P < 0.001$.
+ $P < 0.10$.

was also used in Tatikonda and Rosenthal (2000), and was recommended by Neter et al. (1985). Centering involves the use of deviation scores for each predictor variable and for the two moderator variables (Cronbach, 1987; Jaccard et al., 1990). Acceptable variance inflation factors, those close to 1, were found in all of the individual GSCM practice regressions.

Table 8 presents the results for the effects of the interaction of two moderators, QM and JIT, and internal environmental management. This table shows that the internal environmental management main effect is highly significant. The incremental *F* for the block of interaction terms is also slightly significant for environmental performance and significant for negative economic performance. The two interaction terms of internal environmental management and QM have significant negative beta for negative economic performance. Thus, Hypothesis 5 is supported for this particular GSCM practice. Hypothesis 4 is not supported by the internal management GSCM practice. The two interaction terms of internal environmental management and JIT have significant negative betas for environmental performance. Thus, Hypothesis 6 is supported. However, the two betas with interaction effects between internal environmental management and JIT for both positive and negative economic performance are not significant. It means that Hypothesis 7 is not supported at this time for this GSCM practice.

Table 9 presents the results for the effects of the interaction of the two moderators, QM and JIT, with external GSCM practices. This table shows that the external GSCM main effect is significant. The incremental *F* for the block of interaction terms is also significant for positive economic performance. The two interaction terms of external GSCM practices and QM have slightly significant positive beta for environmental performance and significant positive beta positive economic performance while the beta for negative economic performance is not significant. Hypotheses 4 and 5 are further supported for this GSCM factor. The two interaction terms of external GSCM and JIT have no significant beta for environmental performance (even though there is a slight negative result). Hypothesis 6 is not supported. Similar to results for interaction effects between internal environmental management, the two betas about interaction effects between external GSCM and JIT for both positive and negative economic performance are not significant. Thus, Hypothesis 7 is not supported.

Table 12
Hypotheses and results summary[a]

Hypothesis	GSCM practice factors (interaction models)			
	Internal environmental management	External GSCM	Investment recovery	Eco-design
H1	Yes	Yes	Yes	Yes
H2	Yes	Yes	Yes	Yes
H3	Yes	Yes	No	Yes
H4	No	Mixed support	No	No
H5	Yes	Yes	No	No
H6	Yes	No	No	No
H7	No	No	No	No

[a] "Yes" means that a hypothesis has been supported. "No" means that there is no support for that hypothesis.

Table 10 presents the results for the effects of the interaction of the two moderators and investment recovery. This table shows that the investment recovery main effect is highly significant for environmental performance and slightly significant for positive economic performance but not significant for negative economic performance. The two interaction terms have non-significant betas and the incremental *F* for the block of interaction terms is also not significant. There is no evidence of moderation by either QM or JIT practices for investment recovery. We found that Hypotheses 4–7 are not supported by the results in Table 10.

Table 11 presents the results for the effects of the interaction of the two moderators and eco-design. This table shows that the eco-design main effect is highly significant, but weaker for negative economic performance. All interaction terms have non-significant betas and the incremental *F* for the block of the interaction terms is also not significant. There is no other evidence of moderation by either QM or JIT practices for the eco-design GSCM practice.

A summary of the comparisons and all the results of the hypotheses support or non-support are shown in Table 12.

5. Discussion of results

5.1. Main effects

The direct relationships between GSCM practices overall and economic and environmental performance expectations are very promising. There seems to be significant 'win-win' opportunities that exist for Chinese manufacturing enterprises that seek to implement GSCM practices. The GSCM practices seem to be doing what is expected of them in terms of positive environmental performance. The economic performance is a plus and the strong relationship exists between GSCM practice and positive economic performance, but the lack of a significant relationship with negative economic outcomes evidences this positive relationship between GSCM and economic performance even further. Of course, for a specific and particular firm this may not be the case.

Another issue is that we are only considering the expectations and beliefs of the relationships, actual financial numbers were not used. Thus, we could not confirm whether positive or negative economic performance actually occurred. Overall, expectations of management in these organizations that win-win opportunities do exist will play a role in lessening the barrier to GSCM practice adoption. Thus, we can foresee that many organizations in China will identify with these early findings. The other issue that may be arising in this situation is that most of these Chinese manufacturers are very early in the adoption stages of these GSCM practices. Thus, much of the "low-hanging fruit" and the "ten dollar bills on the floor" are currently in the process of being picked. Whether these results hold as the adoption of GSCM practices matures is an issue that needs to be investigated.

These results in Chinese manufacturing enterprises are supported by the literature by a number of researchers who have looked at other manufacturing enterprises. Carter et al. (1998) tested internal environmental management items of top- and mid-management support, mission statement, department goals, and training and evaluation for their respective impacts on GSCM such as environmental purchasing. Among all the items, support from top- and mid-level managers was a key to implementing GSCM successfully. An enterprise' top-level management is ultimately charged with the responsibility of maximizing shareholder wealth and, through their strategic leadership, determining the direction of the organization including defining values, vision and strategic intent (Hamel and Prahalad, 1989). Thus, commitment from top management is positively related to GSCM though such commitment is mainly due to technological and commercial reasons rather than environmental reasons (Bowen et al., 2001a). Our investigation demonstrated that internal environmental management including support from top and middle management is highlighted with the highest mean (3.56) among four GSCM practice factors, and can bring better environmental performance.

External GSCM have direct and positive impacts on environmental performance. However, results show that external GSCM practice is not highlighted yet with the lowest mean (2.93) among four GSCM practice factors. Most Chinese enterprises are aware of the importance of GSCM but few have really implemented it due to lack of knowledge and tools (Wu et al., 2001). However, globalization, especially China's entry into the WTO, may result in better GSCM practice (Zhu and Geng, 2002b). First, globalization increases multinational enterprises (MNEs) investment in developing countries where their subsidiaries can be expected to self-regulate their environmental performance more than domestic firms do. Experiences or even lessons from these foreign enterprises to improve environmental performance can be learned by domestic enterprises. Second, MNEs have changed from foreign direct investor to multinational operators of global networks of suppliers (Dunning, 1993). By improving both quality and environmental performance of their products, more Chinese enterprises have become suppliers of foreign enterprises. These foreign enterprises in China might exert pressure on domestic suppliers to self-regulate environmental performance. Finally, globalization may increase export from developing countries such as China to developed countries where customers might use environmental performance as a supplier-selection criterion, which also pressure domestic enterprises in China to self-regulate (Christmann and Taylor, 2001).

Our empirical results indicate that eco-design has direct, positive effects on environmental performance. Our interviews showed that eco-design results in costs saving such as decrease of cost for energy consumption, and fees for waste treatment and discharge. No

matter where in the product life cycle the product lies, most of the impact is 'locked' into the product at the design stage when materials are selected and product performance is largely determined (Lenvis and Gretsakis, 2001). Eco-design is a helpful, emerging tool to improve enterprises' environmental performance by addressing product functionality while simultaneously minimizing life-cycle environmental impacts. The success of eco-design requires the internal cross-functional cooperation among the entire company and the external cooperation with other partners in the whole supply chain (Lenvis and Gretsakis, 2001, p. 13). Discussions with managers in Chinese enterprises found that the interest in eco-design is mainly because of the pressure from regulatory requirements and/or customers. Some Chinese enterprises have begun to implement GSCM on the basis of environmental management systems such as ISO 14001 certification (Zhu and Geng, 2003). Our survey also showed that Chinese designers and product developers are playing an important role in GSCM, and internal cross-functional cooperation has also been encouraged.

In the USA and Germany, enterprises highlight investment recovery as the most important practice for green purchasing (Zsidisin and Hendrick, 1998). In China, the government changed over from a resource subsidy to levy taxes for some resources such as coal and natural gas (Zhu and Cote, 2002). However, investment recovery in China seems to have received much less attention than in developed countries such as the U.S. and Germany due to waste management policies and lack of recycling systems. To attract more investment, industrial zones in China such as TEDA provide subsidies for enterprises to cover solid waste disposal. Since treatment for waste recovery can be expensive, our interviews indicate that many Chinese enterprises consider investment recovery such as material recycling and recovery as costly. Moreover, recycling and recovery sometimes are difficult in China due to a lack of recycling systems and relevant technologies. Except collecting firms for resources such as paper, plastic and steel, no depots for potential usable resources exist in TEDA (Zhu and Zhao, 2003).

In summary, it is evident that there is strong similarity to developed country practices where internal environmental management practices have the greatest impact on both environmental and economic performance in China. Yet, in Chinese manufacturing enterprises, investment recovery has received much less attention, with least influence on performance levels. External SCM and eco-design are two emerging approaches in China and have similar significant impacts to those of developed country findings. Our survey results show that eco-design has a slightly greater impact on environmental performance while it has a somewhat less significant impact on both positive and negative economic performance.

5.2. Interaction effects

The results presented above suggest that both QM and JIT have moderation effects for some level of performance. Whether or not QM programs are implemented in an enterprise has some importance in terms of helping to further enhance the win-win scenario for that enterprise. This moderation is especially true for external GSCM practices that deal with customers and suppliers, or what traditionally has been discussed in the literature as supply chain management. This is quite a significant finding since companies that seek to establish and further nourish these external relationships, from an environmental and economic perspective. Thus, it seems to be difficult to implement these practices unless QM type programs such as (e.g. TQM and/or ISO 9000 certification) have been in a place. That is, QM programs are very important antecedents to many GSCM practices. Our survey shows that QM has been highlighted by majority of Chinese companies. For example, 56 companies (30.1%) have ISO 9000 serial certification, 63 companies (33.9%) were on the process for the certification, 49 companies were considering it while only 18 companies (9.7%) do not consider it or do not plan to get the certification. This finding is interesting in another way; we would have thought that QM programs, which are typically internally focused, would have had more influence on the internal GSCM practices in both environmental and economic performance. As we have seen, only some of the specific programs benefit from QM implementation. Thus, there seems to be agreement with various literature that show implications of general supply chain management practices and performance are influenced by quality management programs, providing better overall organizational performance, even though this literature does show mixed results, depending on

upstream or downstream relationships (see Romano, 2002 for a good review and overview of quality issues in supply chains). Thus, we can add to the evidence that QM programs can help to enhance external GSCM practices and that the lack of these QM programs may actually hurt external GSCM practices' environmental and economic performance.

Internal management practices (of which TQEM and ISO 14000 are in place) can provide less negative economic performance if QM is in place. This is not surprising since it would be assumed that such internal programs could build on previous efforts in this area of waste and cost minimization. Yet, the lack of QM practices does not necessarily mean poorer or better environmental performance.

Yet, similar to design for manufacture principles (and concurrent engineering), a large percentage of the ultimate cost and quality of a product, over its life cycle, is determined in the early stages of product design. Design for manufacturing has been used as a cost minimization and quality control (defect prevention) tool. With design for the environment, prevention is a parallel concern, but more environmentally focused. Yet its integration with a quality-based prevention program, which may be part of many TQM programs, or its absence, does not seem to affect its major purpose of environmental performance relationships with the eco-design factor. Yet, the inclusion of a quality prevention type program does help with economic performance. This result may be due to greater experience and knowledge of design for manufacturability, or concurrent engineering, by these organizations. Clearly, additional research between the prevalence and relationship between design for manufacturing and design for environment type programs, and their success is needed.

The results also show that JIT has negative moderation effects with one of the GSCM practices, internal environmental management. Thus, JIT may also hurt the environmental performance associated with GSCM internal management practices. This is somewhat surprising, but an explanation may be due to the many formalized and maybe complex systems that need to be in place within the internal management programs. JIT (as is lean manufacturing) is usually based on simplified processes and techniques, some of them informally executed. We also found that JIT has no moderation effect for positive or negative economic performance when implementing GSCM practices.

Overall, the analyses showed no statistically significant interaction effects between either of the two moderators and investment recovery or eco-design.

6. Conclusion and future research

GSCM has emerged as an important new archetype for companies to achieve profit and market share objectives by lowering their environmental risks and impacts and while raising their ecological efficiency (Van Hock and Erasmus, 2000). Chinese organizations have made some progress in adoption of GSCM practices. With the requirements of sustainable development and the economy globalization, Chinese companies have begun to change their focus from single plant improvements to the whole supply chains. However, GSCM is still a new concept in China. The adoption rates shown in our investigation are still low. Some Chinese enterprises have recognized its importance and tried to put it into practice, but most of these enterprises may lack experience as well as necessary tools and management skills. The findings in our work begin to use the Chinese manufacturing enterprise experience to explain various relationships on what may and may not work, especially for early adopting companies of GSCM practices. These practices and their relationships to environmental and economic performance were evaluated. We found a number of relationships among the GSCM practices and performance. In addition, moderating effects of quality management and JIT manufacturing operations philosophies showed that in some cases with certain GSCM practices the inclusion or exclusion of these philosophies might cause worse or better performance.

In summary the following practical issues and lessons arose: (1) GSCM practices tended to have win-win relationships in terms of environmental and economic performance; (2) quality management was a positive moderator in that these quality programs along with GSCM practices performed better especially with respect to external GSCM and internal management programs, organizations seriously considering implementing GSCM practices could benefit greatly with introduction of QM practices; (3) JIT programs with internal environmental management

practices may cause further degradation of environmental performance and care, from an environmental perspective, care should be taken when implementing GSCM programs in manufacturing organizations with JIT philosophies in place.

Since a major portion of the world's manufacturing will be taken place in Southeast Asia in the coming decade, GSCM practices will be even more critical (Rao, 2002). Developing countries such as the Philippines, Indonesia, Malaysia, Thailand and Singapore may have similar market and socio-cultural situations on GSCM practices when compared to Chinese enterprises, and thus, enterprises in these countries can also learn from lessons and potential relationships identified in this study. They should also realize that investment in QM programs is necessary for early adoption success, in terms of environmental and economic performance, of GSCM practices. Governmental and multinational corporation policies may encourage organizations in these developing countries to further development of QM programs initially, then aiding these organizations in implementing GSCM practices. Knowledge of win-win opportunities existing in a developing country such as China, with many of the same characteristics as these other countries, is important in further adoption of these practices.

In arriving at these overall results, we must mention the limitations of this study. First, the sample is based on Chinese manufacturing enterprises. These enterprises are only recently adopting many of these practices and have very different characteristics compared to firms in other countries. The issue of whether more mature adopters having similar results, internationally, needs to be investigated. Second, due to difficult data collection, we used a convenience sample of surveys rather than a random investigation. This is a difficult limitation to overcome since the cultural issues and limited understandings on GSCM in China make it difficult to randomly identify and deliver surveys (infrastructure is not as big an issue in China but most Chinese companies are reluctant to answer questions by mail due to culture issues and bias may occur due to limited understandings on GSCM). An advantage of the convenience sample is that we were able to provide common definitions to the respondents. Yet, even with the definitions and education on GSCM concepts, it may still be possible that some respondents may not fully grasp the principles. Yet, overall, we do believe the validity of the results is not hindered for this sample. Third, our study only generally examines relationships between GSCM practice and performance. Further analyses for different sectors are needed and other company characteristics will be needed to help tease out additional information on industry practices and differences. Fourth, antecedents on the motivation behind the adoption of practices may provide additional insights into practice adoption and performance. Fifth, we only considered environmental and economic performance (operational economic performance) influenced by GSCM practice. Other aspects such as general operational performance and possible strategic financial and organizational performance could be investigated. In the case of Chinese corporations, these strategic measures are not as easily available due to the variety of ownership that exists in plants including state, multinational, and joint venture ownership. Additional moderators may also play a role between GSCM practices and performance. Some of these may include types of enterprises (FDI, joint ventures, original equipment manufacture (OEM), independent enterprises) or even industry types (continuous process versus assembling process). Yet, the study can be replicated elsewhere that can take advantage of the availability of strategic organizational and financial data and performance. Finally, due to a smaller sample size some of the statistical power of the moderated hierarchical regression approach may be lost. Larger sample sizes may be helpful to truly determine moderating effects.

Overall, this study provided additional insight into the growing field of the relationships between environmental and operational practices and performance. Clearly, the field has ample space to grow in terms of research and practice.

Acknowledgements

This work is supported by the CIDA Tier 1 ECOPLAN China Project (S-61562), the National Science Foundation of China Project (70202006), the Social Science Foundation of China (03CJY001), the ninth Huo-yingdong Young Faculty Foundation (91082), the Scientific Research Foundation for the Returned Overseas Chinese Scholar, State Education

Ministry and the Liaoning Doctoral Startup Project (2001102090).

Appendix A

Survey methodology details

(1) Surveys during workshops.To get initial information about GSCM practice and performance in Chinese enterprises, we investigated mid-level managers when they participated in workshops. Thirty-six total questionnaires were administered during two workshops for managers on environmental management in September of 2002 in the Tianjin Economic and Technological Area (TEDA) and Dalian Economic and Technological Development Zone (DETDZ), the largest and the second largest industrial zone in China according to GDP. A total of 28 questionnaires were returned and completed.

On the basis of brief results from two workshops, we began to focus on two kinds of Chinese manufacturing industries, that is, traditional heavy polluters, and enterprises exporting products or suppliers of foreign enterprises in China.

Forty-six questionnaires in a training workshop for managers in all kinds of departments from the automobile, electrical and electronic industries were administered in October of 2002 in the School of Management at Dalian University of Technology, and 27 usable questionnaires were collected.

(2) Interviews and site visits.

To further understand the situation of GSCM in Chinese enterprises, interviews and site visits in the Dalian High-tech Zone (DHZ) in Liaoning Province and Zibo Industrial Zone (ZIZ) in Shandong Province were also completed in November and December of 2002. During this time a total of 24 questionnaires were completed. When more than one completed questionnaire was obtained from one enterprise they were aggregated into one questionnaire. Enterprises visited included petrochemical plants, pharmaceutical plants, power plants, electronic and electrical plants, automobile plants and shipyards. In January of 2003, a presentation about GSCM was made for executive MBA students followed by discussions. After the presentation, students who had experience in manufacturing were asked to complete surveys with a total of 10 usable questionnaires acquired.

(3) Surveys during workshops for the second time

In February and March of 2003, mid-level managers from different industries were asked to complete the surveys during three training workshops at Dalian University of Technology. Sixty-six usable questionnaires out of total 100 were acquired after collating several questionnaires from one enterprise into one, simple means were used to collate the multi-company samples. In April 2003, MBA students who were managers from Shandong province were asked to complete the surveys, 31 out of 50 questionnaires received were found to be usable. Before each of the three training workshops and in the MBA program, the objective of the survey and the concept of GSCM were briefly introduced to the respondents such that definitions were clear.

References

Alvarez Gil, M.J., Jimenez, J.B., Lorente, J.C., 2001. An analysis of environmental management, organizational context and performance of Spanish hotels. Omega 29 (6), 457–471.

Balakrishnan, R., Linsmeier, T.J., Venkatachalam, M., 1996. Financial benefits from JIT adoption: effects of customer concentration and cost structure. Accounting Review 71 (2), 183–205.

Beaumont, J.R., Pedersen, L.M., Whitaker, B.D., 1993. Managing the Environment: Business Opportunity and Responsibility. Butterworth-Heinemann, Oxford.

Bowen, F.E., Cousins P.D., Lamming R.C., Faruk A.C., 2001a. Horse for courses: explaining the gap between the theory and practice of green supply. Greener Management International, Autumn, 41–60.

Bowen, F.E., Cousins, P.D., Lamming, R.C., Faruk, A.C., 2001b. The role of supply management capabilities in green supply. Production and Operations Management 10 (2), 174–189.

Boyer, K.K., Leong, G.K., Ward, P.T., Krajewski, L.J., 1997. Unlocking the potential of advanced manufacturing technologies. Journal of Operations Management 15, 331–347.

Callen, J.L., Fader, C., Krinsky, I., 2000. Just-in-time: a cross-sectional plant analysis. International Journal of Production Economics 63 (3), 277–301.

Carter, C.R., Ellram, L.M., Kathryn, L.M., 1998. Environmental purchasing: benchmarking our German counterparts. International Journal of Purchasing and Materials Management 34 (4), 28–38.

Carter, C.R., Kale, R., Grimn, C.M., 2000. Environmental purchasing and firm performance: an empirical investigation. Transportation Research Part E 36, 219–288.

Christmann, P., Taylor, G., 2001. Globalization and the environment: determinants of firm self-regulation in China. Journal of International Business Studies 32 (3), 439–458.

Cohen, J., Cohen, P., 1983. Applied Multiple Regression/ Correlation Analysis for the Behavioral Sciences. Erlbaum, Hillsdale, NJ, USA.

Cordeiro, J., Sarkis, J., 1997. Environmental proactism and firm performance: evidence from security analyst forecasts. Business Strategy and Environment 6 (2), 104–114.

Cox, J., Sarkis, J., Wells, W., 1999. Exploring organizational recycling market development: the Texas Mexico Border. In: Charter, M., Polonsky, M.J. (Eds.), Greener Marketing: A Global Perspective on Greener Marketing Practice. Greenleaf Publishing, Sheffield, UK, pp. 381–394.

Cronbach, L., 1987. Statistical tests for moderator variables. Psychological Bulletin 102, 414–417.

Cusumano, M.A., 1994. The limits of lean. Sloan Management Review, Summer, 27–32.

Dean, J.W., Snell, S.A., 1991. Integrated manufacturing and job design: moderating effects of organizational inertia. Academy of Management Journal 34 (4), 776–804.

Deng, H., Wang, H., 1998. How do Chinese enterprises overcome green barrier. Business Studies 12 (10), 45–47 (in Chinese).

Dodgson, M., 2000. Management of Technology. Routedge, London.

Dong, Y., Carter, C.R., Dresner, M.E., 2001. JIT purchasing and performance: an exploratory analysis of buyer and supplier perspectives. Journal of Operations Management 19 (4), 471–483.

Dunning, J.H., 1993. Multinational Enterprises and the Global Economy. Addison-Wesley, Reading, MA.

Dyer, J.H., Singh, H., 1998. The relations view: co-operative strategy and sources of inter-organizational competitive advantage. Academy of Management Review 23, 660–679.

Florida, R., 1996a. The Environment and the New Industrial Revolution. California Management Review 38 (Autumn), 80–115.

Florida, R., 1996b. Lean and green: the move to environmentally conscious manufacturing. California Management Review 39 (1), 80–105.

Florida, R., Davison, D., 2001. Gaining from green management: environmental management systems inside and outside the factory. California Management Review 43 (3), 64–84.

Frosch, R., 1994. Industrial ecology: minimizing the impact of industrial waste. Physics Today 47 (11), 63–68.

Geffen, C., Rothenberg, S., 2000. Suppliers and environmental innovation: the automotive paint process. International Journal of Operations and Production Management 20 (2), 166–186.

GEMI (Global Environmental Management Initiative), 2001. New Paths to Business Value. GEMI, Washington DC, 2001.

Geng, Y., Cote, R., 2003. Environmental management systems at the industrial park level in China. Environmental Management 31 (6), 784–794.

Godfrey, R., 1998. Ethical purchasing: developing the supply chain beyond the environment. In: Russel, T. (Ed.), Greener Purchasing: Opportunities and Innovations. Greenleaf Publishing, Sheffield, England, pp. 244–251.

Green, K., Morton, B., New, S., 1996. Purchasing and environmental management: interaction, policies and opportunities. Business Strategy and the Environment 5, 188–197.

Guimaraes, T., Liska, K., 1995. Exploring the business benefits of environmental stewardship. Business Strategy and the Environment 4 (1), 9–22.

Hamel, G., Prahalad, C.K., 1989. Strategic intent. Harvard Business Review 67 (3), 63–76.

Handfield, R.B., Nichols, E.L., 1999. Introduction to Supply Chain Management. Prentice Hall, Upper Saddle River, NJ, USA.

Handfield, R., Walton, S., Sroufe, R., 2002. Applying environmental criteria to supplier assessment: a study of the application of the analytical hierarchy process. European Journal of Operational Research 141, 70–87.

Hansmann, K.W., Kroger, C., 2001. Environmental management policies. In: Sarkis, J. (Ed.), Green Manufacturing and Operations: From Design to Delivery and Back. Greenleaf Publishing. Sheffield, UK, pp. 192–204.

Hart, S.L., 1995. A natural-resource-based view of the firm. Academy of Management Review 20 (4), 986–1014.

Hart, S.L., 1997. Beyond greening: strategies for a sustainable world. Harvard Business Review 75 (1), 66.

Jaccard, J., Wan, C.K., Turrisi, R., 1990. The detection and interpretation of interaction effects between continuous variables in multiple regression. Multivariate Behavioral Research 25, 467–478.

Judge, W.Q., Douglas, T.J., 1998. Performance implications of incorporating natural environmental issues into the strategic planning process: an empirical assessment. Journal of Management Studies 35 (2), 241–262.

King, A., Lenox, M., 2001. Lean and green? An empirical examination of the relationship between lean production and environmental performance. Production and Operations Management 10 (3), 244–256.

Kitazawa, S., Sarkis, J., 2000. The relationship between ISO 14001 and continuous source reduction programs. International Journal of Operations and Production Management 20 (2), 225–248.

Klassen, R., 2000. Just-in-time manufacturing and pollution prevention generate mutual benefits in the furniture industry. Interfaces 30 (3), 95.

Klassen, R., McClaughlin, C., 1996. The impact of environmental management on firm performance. Management Science 42 (8), 1199–1214.

Lee-Ross, D., Ingold, T., 1994. Increasing productivity in small hotels: arc academic proposals realistic. International Journal of Hospitality Management 13 (3), 201–207.

Lenvis, H., Gretsakis, J., 2001. Design + Environment: A Global Guide to Designing Greener Goods. Greenleaf Publishing, Sheffield, UK.

Liu, J., Holt, D., Viney, H., 2001. Identifying Environmental Issues in Chinese Manufacturing Companies. Business and Management 5 (Discussion Paper Series). Middlesex University Business School, London, England.

Luo, Y.D., 2001. Toward a cooperative view of MNG-Host government relations: building block and performance implications. Journal of International Business Studies 32.3, 401–419.

Macdonald, M.E., 1991. British report says JIT harms the environment. Traffic Management 30.9, 21–22.

Matthews, H.S., Hendrickson, C., Lave, L., 2002. The economic and environmental implications of centralized stock keeping. Journal of Industrial Ecology 6 (2), 71–83.

McMahon, F., 1994. Productivity in the hotel industry. In: Seaton, A.V., Jenkins, C.L., Wood, R.C., Pieke, P.U.C., Bennet, M.M., McLellan, L.R., Smith, R. (Eds.), Tourism: The State of the Art. JW, West Sussex, pp. 616–625.

McIntyre, K., Smith, H.A., Henham, A., Pretlove, J., 1998. Logistics performance measurement and greening supply chains: diverging mindsets. International Journal of Logistics Management 9 (1), 57–68.

Messelbeck, J., Whaley, M., 1999. Greening the health care supply chain: triggers of change, models for success. Corporate Environmental Strategy 6 (1), 39–45.

Mia, L., 2000. Just-in-time manufacturing, management accounting systems and profitability. Accounting and Business Research 30 (2), 137.

Michael, R.K., Wempe, W.F., 2002. Further evidence on the extent and origins of JIT's effects profitability. Accounting Review 77 (1), 203–225.

Min, H., Galle, W.P., 1997. Green purchasing strategies: trends and implications. International Journal of Purchasing and Materials Management, Summer, 10–17.

Moinzadeh, K., Klastorin, T., Berk, E., 1997. The impact of small lot ordering on traffic congestion in a physical distribution system. IIE Transactions 8 (29), 671–679.

Munson, C.L., Rosenblatt, M.J., Rosenblatt, Z., 1999. The use and abuse of power in supply chains. Business Horizons 42 (1), 55–65.

Narasimhan, R., Carter, J.R., 1998. Environmental Supply Chain Management. The Center for Advanced Purchasing Studies, Arizona State University, Tempe, AZ, USA.

Neter, J., Wasserman, W., Kutner, M.H., 1985. Applied Linear Statistical Models. Irwin, Homewood, IL, USA.

NMHC (National Materials Handling Center), 1991. Gearing Up for the Environment. Report from the National Materials Handling Center of the Cranfield institute of Technology. Cahner Publishing Co., UK.

Nunnally, J.C., 1978. Psycometric Theory. McGraw-Hill, New York.

Porter, M.E., van der Linde, C., 1995. Green and competitive: ending the stalemate. Harvard Business Review 73.5, 120–134.

Rao, P., 2002. Greening the supply chain: a new initiative in South East Asia. International Journal of Operations and Production Management 21 (6), 632–635.

Romano, P., 2002. Impact of supply chain sensitivity to quality certification on quality management practices and performances. Total Quality Management 13 (7), 981–1000.

Rothenberg, S., Pil, F.K., Maxwell, J., 2001. Lean green and the quest for superior environmental performance. Production and Operations Management 10 (3), 228–243.

Russo, M.V., Fouts, P.A., 1997. A resource based perspective on corporate environmental performance and profitability. Academy of Management Journal 40 (3), 534–559.

Samson, D., Terziovski, M., 1999. The relationship between total quality management practices and operational performance. Journal of Operations Management 17 (4), 393–409.

Sarkis, J., 1995. Supply chain management and environmentally conscious design and manufacturing. International Journal of Environmentally Conscious Design and Manufacturing 4 (2), 43–52.

Shrivastava, P., 1995. Environmental technologies and competitive advantage. Strategic Management Journal 16 (Special issue, Summer), 183–200.

Shultz II, C.J., Holbrook, M.B., 1999. Marketing and tragedy of the commons: a synthesis, commentary and analysis for action. Journal of Public Policy and Marketing 18 (2), 218–229.

Simmons, B.L., White, M.A., 1999. The relationship between ISO 9000 and business performance. Journal of Managerial Issues 11 (3), 330.

Tatikonda, M.V., Montoya-Weiss, M.M., 2001. Integrating operations and marketing perspectives of product innovation. Management Science 47 (1), 151–172.

Tatikonda, M.V., Rosenthal, S.R., 2000. Successful execution of product development project: balancing firmness and flexibility in the innovation process. Journal of Operations Management 18, 401–425.

Terziovski, M., Samson, S., Dow, D., 1997. The business value of quality management systems certification. Evidence from Australia and New Zealand. Journal of Operations Management 15, 1–17.

Theyel, G., 2001. Customer and supplier relations for environmental performance. Greener Management International 35 (Autumn), 61–69.

US-AEP, 1999. Sector Based Public Policy in the Asia-Pacific Region.

Van Hock, R., Erasmus, I., 2000. From reversed logistics to green supply chains. Logistics Solutions Issue 2, 28–33.

Von Hippel, E., 1998. The Source of Innovation. Oxford University Press, Oxford, UK.

Wagner, M., Schaltegger, S., Wehrmeyer, W., 2001. The relationship between the environmental and economic performance of firms: what does theory propose and what does empirical evidence tell us? Greener Management International Issue 34, 95–108.

Walley, N., Whitehead, B., 1994. It's not easy being green. Harvard Business Review 72 (3), 46–52.

Walton, S.V., Handfield, R.B., Melnyk, S.T., 1998. The green supply chain: integrating suppliers into environmental management process. International Journal of Purchasing and Materials Management, Spring, 2–11.

Wayhan, V.B., Kirche, E.T., Khumawala, B.M., 2002. ISO 9000 certification: the financial performance implications. Total Quality Management 13 (2), 217–231.

Welford, R., 1995. Environmental Strategy and Sustainable Development: The Corporate Challenge for the 21st Century. Routledge, London, UK.

Worrell, D., Gilley, K.M., Davidson, W.D., El-Jely, A., 1995. When Green Turns to Red: Stock Market Reaction to Announced

Greening Activities. Paper Presented at the Academy of Management Meeting, Vancouver.

Wu, C.Y., Zhu, Q.H., Geng, Y., 2001. Green supply chain management and enterprises' sustainable development. China Soft Science 16 (3), 67–70 (in Chinese).

Zhu, Q.H., Cote, R., 2002. Green supply chain management in China: how and why? The Fifth International Eco-city Conference, August, 2002, Shenzhen, China.

Zhu, Q.H., Cote, R., 2004. Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group. Journal of Cleaner Production 12 (8–10), 1025–1035.

Zhu, Q.H., Geng, Y., 2001. Integrating environmental issues into supplier selection and management: a study of large and medium-sized state-owned enterprises in China. Greener Management International, Autumn, 27–40.

Zhu, Q.H., Geng, Y., 2002a. Analysis on current practices of green purchasing on the basis of international comparisons. Science and Science Technology Management 3, 71–74 (in Chinese).

Zhu, Q.H., Geng, Y., 2002b. Studies on effects of green purchasing in enterprises. China Soft Science 17 (11), 67–70 (in Chinese).

Zhu, Q.H., Geng, Y., 2003. Eco-design model on the basis of EMS. Science and Science Technology Management 24 (4), 19–23 (in Chinese).

Zhu, Q.H., Zhao, Y.P., 2003. A Report on Integrated Solid Waste Management in Tianjin Economic and Development Area, February.

Zirger, B.J., Maidique, M.A., 1990. A model of new product development: an empirical test. Management Science 36, 867–883.

Zsidisin, G.A., Hendrick, T.E., 1998. Purchasing's involvement in environmental issues: a multi-country perspective. Industrial Management and Data Systems 7, 313–320.