Green supply chain management implications for “closing the loop”

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Abstract

In this paper we report on results from a cross-sectional survey with manufacturers in four typical Chinese industries, i.e., power generating, chemical/petroleum, electrical/electronic and automobile, to evaluate their perceived green supply chain management (GSCM) practices and relate them to closing the supply chain loop. Our findings provide insights into the capabilities of Chinese organizations on the adoption of GSCM practices in different industrial contexts and that these practices are not considered equitably across the four industries. Academic and managerial implications of our findings are discussed. © 2006 Elsevier Ltd. All rights reserved.

Keywords: Green supply chain management; Closed-loop supply chains; Empirical study; Sector comparison

1. Introduction

Many industries have experienced increasing globalization and a shifting focus to competition among networks of companies. Supply chain management (SCM) has become an important competitive approach for organizations in this environment. Multinational enterprises have established global networks of suppliers that take advantage of country-industry specific characteristics to build this competitive advantage (Dunning, 1993). Logistics and supply chain managers have to balance efforts to reduce costs and innovate while maintaining good environmental (ecological) performance (Pagell et al., 2004). Green supply chain management (GSCM) has emerged as an approach to balance these competitive requirements (Narasimhan and Carter, 1998).

GSCM and logistics efforts have caused organizations to consider closing the supply chain loop (closed-loop supply chains (CLSC)) (Beamon, 1999; Seuring, 2004). Within CLSC and GSCM practices, recoverable product environments, and the design of these products and materials, have become an increasingly important segment of the overall push in industry towards environmentally conscious manufacturing and logistics
Even though CLSC has significant environmental motivations, regulatory, competitive and economic pressures also play roles in its adoption across industries (Georgiadis and Vlachos, 2004; Guide and Wassenhove, 2001). Here, we specifically investigate the role of environmentally based practices and pressures and what they mean to the management of CLSC.

Chinese enterprises have initiated implementation of a number of environmental practices due to motivational drivers such as exports and sales to foreign customers (Christmann and Taylor, 2001), legislative and stakeholder institutional pressures, many of which relate to institutional and stakeholder theories. Joining the World Trade Organization (WTO) has provided Chinese enterprises with additional opportunities to establish relationships with foreign enterprises further integrating them into their supply chain (Zhu and Geng, 2001). This inclusion has also brought significant challenges to Chinese enterprises such as overcoming ‘green barriers’ and increasing 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 in compliance with ISO 14001, while Ford, GM and Toyota have required their Chinese suppliers to be certified with ISO 14001 (GEMI, 2001). International laws in other regions such as the European Community Directives on Waste Electrical and Electronic Equipment (WEEE) and Registration, Evaluation and Authorization of Chemicals (REACH) have led China to increase organizational efforts for product recovery.

In this study, we aim to examine the adoption levels of GSCM practices in China and to determine if industries differ in the GSCM practices with an emphasis on their specific implications for CLSC management. Previous investigations completed an exploratory analysis that identified factors of GSCM practices and performance. These factors were then examined for relationships between adoption of GSCM practices and eventual performance outcomes incorporating moderating effects of quality management and just-in-time practices (Zhu and Sarkis, 2004a). In additional research, using similar data, an investigation comparing quality management and environmental management was completed for different sized organizations (Zhu and Sarkis, 2004b). Within these studies an industry effect seemed to exist for the adoption of GSCM practices. In this paper, we advance this line of study to logistics and supply chain management research through a more in-depth comparative analysis of different industries, determining the implications on these industries and their enterprises’ readiness to embrace CLSC.

While studies investigating environmental management exist for specific stand-alone industries (e.g. Vachon and Klassen, 2006), we contribute to the body of knowledge by further investigating GSCM practices in a developing economy and the determination of industry differences in embracing GSCM practices. Our study findings provide managerial and theoretical insights for different industries in China focusing on a resource based capabilities through knowledge transfer and inter-organizational/inter-industry learning to improve their GSCM/CLSC practices adoption. The findings also provide policy implications for the Chinese government in supporting GSCM/CLSC practices among different industries. The results of this investigation are also useful for developed country organizations that have invested or plan to invest in China, especially in the four industries examined by this study.

We will begin with a literature review in Section 2, introducing the relationship between CLSC and GSCM as well as defining the study elements. It is followed by additional research background of GSCM in China in Section 3, in which we will explain our selection of industries and the theoretical grounding of our investigation in contingency resource based, institutional, and stakeholder theory that help to further develop insights into these industrial differences. Section 4 describes the research design and measures developed for this study. Data analysis and results are presented in Section 5. Section 6 discusses the results with an evaluation of GSCM implementation in Chinese manufacturing industries. Section 7 concludes the paper by providing managerial implications and identifying areas for future research in GSCM.

2. GSCM dimensions and relationships to CLSC

The GSCM practices investigated in this study include internal environmental management, green purchasing, customer cooperation with environmental concerns, investment recovery, and eco-design dimensions (Zhu and Sarkis, 2004a).

Internal environmental management is central to improving enterprises’ environmental performance (Carter et al., 1998; Melnyk et al., 2002). It is generally believed that senior managers’ support is necessary and,
often, a key driver for successful adoption and implementation of most innovations, technology, programs and activities (Hamel and Prahalad, 1989). Yeung et al. (2003) found that senior management’s confidence is the most influential factor for the development of their quality management system. Similarly, cross-functional programs encompassing GSCM and CLSC practices are not for the “faint of heart” and require management’s support for successful implementation (Matthews, 2004; Seitz and Peatty, 2004). To ensure progress for environmental management, top management must be fully committed (Zsidisin and Siferd, 2001; Rice, 2003). Support needs to also exist from mid-level managers for successful implementation of environmental practices (Carter et al., 1998; Bowen et al., 2001). GSCM crosses all departmental boundaries within and between organizations, and this cooperation and communication is important to successful environmental practices (Zhu and Geng, 2001; Aspan, 2000).

External GSCM practices have become increasingly important for manufacturers. The first external GSCM practice, green purchasing, is an emerging approach in Chinese enterprises, which focuses on the inbound or upstream segment of a product’s and organization’s supply chain (Zhu and Cote, 2002). Zsidisin and Hendrick (1998) in a multinational investigation identified key factors for green purchasing including providing design specification to suppliers that include environmental requirements for purchased items, cooperation with suppliers for environmental objectives, environmental audits for supplier’s internal management, and suppliers’ ISO14001 certification. Walton et al. (1998) put forward ten top environmental supplier evaluation criteria, among these, second-tier supplier environmentally friendly practice evaluation was viewed as the second most important criterion. In addition, large customers have exerted pressure on their suppliers for better environmental performance, which results in greater motivation for suppliers to cooperate with customers for environmental objectives (GEMI, 2001). Customer cooperation and green purchasing fit within van Nunen and Zuidwijk’s (2004) process perspective, which concerns types of customer relationships that occur in CLSC. In China, research has also shown that customer pressure is a primary driver for enterprises to improve their environmental image and practices (Christmann and Taylor, 2001). Without green purchasing and customer cooperation practices, product take-back and other product reintroduction markets may not become as developed (van Hoek, 1999).

United States and European enterprises have considered investment recovery as a critical aspect of GSCM (Zsidisin and Hendrick, 1998) and CLSC (Thierry et al., 1995). Investment recovery typically occurs at the back end of the supply chain cycle or as a method to “close the loop”. Investment recovery fits within van Nunen and Zuidwijk’s (2004) process perspective which concerns the different types of recovery processes that occur in CLSC. Toffel (2004) has stated that concerns for the end of life products are motivated by legislation across Europe. Even in non-regulated markets, some manufacturers have engaged in product recovery to reduce production costs, enhance brand image, meet changing customer expectations, protect aftermarkets, and preempt pending legislation or regulations. Sale of excess inventories and capital equipments are also aspects of investment recovery. As an example, in the USA, many firms, as part of their reverse logistics operations, have started selling unwanted products in online auctions (Tibben-Lembke, 2004). In China, investment recovery continues to grow, where pressures from the government has shifted focus from resource subsidies to levying taxes for some resources such as coal and natural gas (Zhu and Cote, 2002). The other set of practices defining the “back-end” of the supply chain includes the relationship with customers on environmental issues. In many cases, international companies are now emphasizing the need for their suppliers to maintain an environmentally benign position and requiring their many Chinese suppliers to comply so that these Chinese organizations’ products are not boycotted due to environmental reasons.

Most of the environmental influence of any product or material is ‘locked’ into the product at the design stage of a product, when materials and processes are selected and product environmental performance is largely determined (Lewis and Gretsakis, 2001). Pioneering firms have learned that making product returns profitable relies on good product design (Krikke et al., 2004). It has been argued that for effective product stewardship and reverse logistics practices, eco-design (which would include design for disassembly, design for recycling, and design for other reverse logistics practices) is necessary (van Hoek, 1999). Thus, eco-design or Design for Environment (DfE) is an important and emerging GSCM practice to improve companies’ CLSC. Eco-design practices best fit within van Nunen and Zuidwijk’s (2004) product perspective, which concerns types of product oriented relationships that occur in CLSC. In our description here, eco-design is meant to address product functionality while simultaneously minimizing life-cycle environmental impacts. The
success of eco-design requires internal cross-functional cooperation within the company and the external cooperation with other partners throughout the supply chain.

In developed countries, organizations have put significant effort in optimizing their forward SCM and logistics practices and are paying increasingly substantial attention to their reverse logistics functions (Krikke et al., 2004). Though manufacturers in developing countries such as China have made some progress on GSCM, both their forward and reverse SCM practices are generally at early adoption stages (Zhu and Sarkis, 2004a). This study represents one of few investigations on elements of both forward and reverse SCM and the adoption of GSCM practices in developing countries such as China. We also examine if industry types matter in the adoption of GSCM practices across industries in China.

3. Theoretical framework and hypothesis development

Due to heterogeneous pressures from various stakeholder groups, different industries have variations, though commonalities may exist, in their adoption of GSCM and CLSC practices. An explanation of similarities and differences may be derived from three theoretical perspectives, i.e., the ‘contingent’ resource based view, institutional theory, and stakeholder theory. First we will provide some reasoning for the industries selected in this study, and then we will explain why we may theoretically expect differences in our investigation.

3.1. Emerging industrial issues in Chinese supply chains

We focus on the following industrial supply chains: coal-burning power generation, chemical/petroleum, electrical/electronic, and automobile industrial groups. These groupings of industries represent organizations that would appear in a specific product supply chain. For example, during investigation of the power generating industry, we included companies throughout their supply chains, that is, respondents not only included power plants, but also suppliers within this industry such as technology and equipment providers.

Chinese coal-burning power supply chain enterprises and chemical/petroleum companies are traditional polluters and have experienced higher environmental regulatory pressure (Zhang, 2002). The electrical/electronics industry has experienced some of the highest regulatory pressures. For example, take-back obligations, especially in Europe, have been designed for electronics (Fleischmann et al., 2000). On the other hand, the electrical/electronic industry in China has a long-term history of international business through export of products or as suppliers to multinational companies. Compared to other industries, the electrical/electronic industry in China seems to have adopted more environmental management practices including CLSC. Experiences in this industry can be disseminated to other industries in China. The automobile industry is included due to WTO implications for this industry. Also, this industry has significant potential to reduce life-cycle impacts through CLSC management. In developed countries automobile supply chains are product categories that have taken great measures to incorporate CLSC such as take-back obligations in developed countries (Fleischmann et al., 2000). Even though China’s burgeoning automobile industry may lag on such activities it has started to experience such pressures. In addition, the Chinese government has stipulated stricter envi-

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3 These groupings of industries represent organizations that would appear in a specific product supply chain. For example, during investigation of the power generating industry, we included companies throughout their supply chains, that is, respondents not only included power plants, but also suppliers within this industry such as technology and equipment providers.

4 They were selected because their products’ life-cycle impacts may be greatest and thus face some of the highest pressures for investment recovery practice. In China, resource shortages have been seriously experienced in these two industries. For the coal-burning power industry, electricity is in short supply not because of the production capacity but due to lack of resources such as coal and oil. As one of main products of the chemical/petroleum industry, gasoline used by vehicles has been mixed with 10% of ethanol, which has been demonstrated in three northeast provinces of China since October 1, 2004 (Jiang, 2004).

5 Though China has not yet established such regulations, international laws in other regions such as the European Community Directive on Waste Electrical and Electronics Equipment (WEEE) have caused China to reevaluate their investment recovery and reclamation programs. Nearly one quarter of exported electronics/electrical appliances in China are sold to the European Community, and in 2003 products with sales of about 30 billion US dollars are related to the WEEE. It was estimated that Chinese companies will pay about 3–5% of the sales price for the treatment of used products which is about 0.9–1.5 billion US dollars (CCTV-2, 2004).

6 Using ISO14001 certification as an example, the electronic and communication device manufacturers accounted for 71% of total certified organizations in China by the end of 2001 (Zhu and Zhao, 2004).

7 The automobile industry is a promising industry since it will generate a huge market as China’s economic prospects improve. After China’s entry into the WTO, international leading automobile groups such as General Motors, Daimler-Chrysler, Ford, Toyota and Honda have increased their investment in China not only for automobiles but also for investment recovery.
3.2. Theoretical characterizations of industrial variations

The differences in the industrial GSCM practices may be accounted for by contingency resource based, institutional, and stakeholder theories. The practical differences were presented in our previous section. We now use various theories that support why these differences exist amongst industries.

Contingency resource based theory, argues that industry uncertainty, complexity and munificence are three key task environment factors which may affect the implementation of proactive environmental strategies, e.g. GSCM and CLSC practices, enabling firms to build up their resource capacities (Aragon-Correa and Sharma, 2003). Managers facing uncertain business environments tend to be more proactive, take greater risks, and use more innovative strategies than managers in less turbulent environments (Miles and Snow, 1978; Paine and Anderson, 1977). Power generating and chemical/petroleum industries face significant risks and uncertainties due to increasing and evolving regulatory pressure, e.g. greenhouse gas emissions and hazardous waste regulations. Thus, we argue that these two industries may have experienced more pressure to implement proactive environmental strategies (build up resource capacities) such as GSCM and CLSC practices anticipating these pressures persist in the future. However, Carter and Carter (1998) found that supply uncertainty sometimes does not result in proactive environmental practices such as establishing an alliance with suppliers because organizations prefer to minimize the need due to scarce managerial resource allocation. Complexity in the business environment is generally defined as proliferation and diversity of factors and issues in that environment (Duncan, 1972; Smart and Vertinsky, 1984; Tan and Litscher, 1994). Less complexity can result in more proactive environmental practices (Aragon-Correa and Sharma, 2003). The chemical/petroleum and automobile industry may be more complicated, having less incentive to implement GSCM and CLSC. Munificence is the degree to which the general business environment can support a sustained rate of organizational growth (Starbuck, 1976) or sales growth (Dess and Beard, 1984). We can also find that heterogeneous industry forces may exist in a single industry causing conflicting pressures.

Institutional theory provides another theoretical lens to account for the differences in GSCM practices across industries. Neo-institutional theory (DiMaggio and Powell, 1983; Scott, 1995) argues that the diffusion of administrative innovations like GSCM and CLSC practices in a certain industry is an institutional process subject to competitive and institutional effects. The institutional process occurs through coercive, mimetic, and normative mechanisms, and structural isomorphism is the consequence (DiMaggio and Powell, 1983). In this process, environmental concerns driving early adoption will be replaced by a different set of determinants from later adopters. The early GSCM and CLSC adopters could enjoy greater benefits because they are aware of more opportunities for economic gains by adopting GSCM and CLSC and are free from isomorphic pressures. As a result, they adopt these practices based on their unique environmental concerns and therefore attain a more sophisticated level of adoption. On the other hand, later adopters seek legitimacy benefits by conforming to isomorphic pressures (Westphal et al., 1997). It is reasonable to speculate that later adopters of GSCM and CLSC practices use legitimacy rather than environmental concerns as the basis of their actions, their adoption of practices are likely to be compromised (DiMaggio and Powell, 1983).
Stakeholder theory places shareholders as one of the multiple stakeholder groups managers must consider in their decision making process (Donaldson and Preston, 1995). In a process-type industry, e.g., power plants, a higher degree of vertical integration exists in their processes and the number of stakeholders involved in their supply chain is typically far less than those in the assembly line industry, e.g., automobile industry. Due to the complexity of managing the supply chain, it is more difficult for firms in the assembly line industry to cater to the requirements of the voluminous stakeholders in their supply chain. As a result of the supply chain complexity, the adoption levels for GSCM and CLSC practices are expected to differ across industries.

The above discussion highlights the different industrial practices and the theoretical reasons to account for the differences in the adoption of GSCM across the four industries in China. Therefore, we hypothesize that:

Hypothesis: The adoption of the five GSCM practices is different among the four industries in China.

4. Research methodology

The five dimensions of GSCM practices in this study were adopted from Zhu and Sarkis (2004a) where the twenty-two measurement items were developed on the basis of opinions from industrial experts and the literature (Zsidisin and Hendrick, 1998; Walton et al., 1998; Carter et al., 2000).

Data collection occurred in three phases including a pilot test, convenience surveys and a random survey, whose results were eventually aggregated.

(1) Pilot test: We initially completed a pilot test to validate and refine the measurement instrument, i.e., a survey questionnaire. A pilot test was conducted in two workshops for managers on environmental management in the Tianjin Economic and Technological Area (TEDA) and Dalian Economic and Technological Development Zone (DETDZ), the largest and the second largest industrial zones in China according to gross domestic product. Based on the suggestions from 28 respondents in the two workshops, we made minor modifications to the survey questionnaire.

(2) Convenience surveys: The second stage involved the application of convenience surveys. To minimize the possibility of misunderstanding the questionnaire items by respondents, we drew a convenience sample of the participants in workshops offered in the School of Management at the Dalian University of Technology. To ensure respondents’ proper understanding of questionnaire items, a presentation about GSCM at each training workshop was made. All the respondents during the site visits were also interviewed. Within this stage, a total of 158 usable manufacturing enterprises responses were received.

(3) Random survey: The third stage of data acquisition was an administration of the survey via postal mail with follow-up telephone calls. We carried out a random survey in this stage. Due to the difficulties in data collection from all regions within China, the random survey was conducted in Dalian, a typical industrial city with large number of manufacturers belonging to the four targeted industries of our study. The targeted respondent companies were drawn from the list of Dalian Manufacturers with a focus on the four industries we identified earlier. Out of a total of 1000 questionnaires mailed, 128 usable organizational responses were received from manufacturing enterprises.

(4) Sample aggregation: Overall, a total of 314 responses were received. Multiple responses from the same manufacturer were aggregated into one usable organizational response. The targeted samples and respondents of this study possess managerial experience at the middle and upper management levels.

**Footnotes:**

14 These stakeholders groups include internal, external, and environmental constituents. Similar to shareholders, the other stakeholders may place demands upon the firm, bestowing societal legitimacy.

15 The measurement items were put into a survey questionnaire which requested the target respondents to answer using a five-point Likert scale (1 = not considering it, 2 = planning to consider it, 3 = considering it currently, 4 = initiating implementation, 5 = implementing successfully). We collected data in three stages. The survey questionnaire was initially developed in English by the authors through email communications. The survey items were translated into Chinese by two of the research team members who are fluent in the Chinese language.

16 The school provides training for manufacturers all over China, and the convenience survey was considered as an appropriate method for data collection in this study (see details in Appendix). Supplemental surveys were also completed with interviews and site visits to the Dalian High-tech Zone in Liaoning province and the Zibo Industrial Zone in Shandong province to triangulate the survey results.
There are advantages of using this three step approach in data collection. First, the respondents in our convenience samples are “key informants” on the environmental management practices that are being planned or adopted in their companies. These groups of respondents are knowledgeable on the topic of GSCM practices under investigation and help to ensure the quality of the data collected in this study. Second, the random survey contributed to triangulation for helping confirm the quality of the responses in our convenience samples allowing for more generalizability to the wider Chinese manufacturing context.

We performed a Chi-square test to compare organizational characteristics of the two groups of respondent manufacturers, i.e., the convenience samples and the mail survey samples to test the potential respondent bias. The test results indicate that no difference, at a 5% level of significance, exists between the two groups on ownership, firm size and questionnaire responses on the items for measuring GSCM. It is therefore reasonable to combine the samples collected from the three stages for data analysis.

Our next step is to ensure the data quality. To evaluate the potential non-respondent bias of the data collected, we divided the 128 returned organizational responses collected from the random survey into two groups representing the theoretical “respondents” and “non-respondents”, respectively. Before proceeding to data analyses, we eliminated those organizational responses with missing values on any of the 22 measurement items for the adoption of GSCM. After taking out the responses with incomplete data, 171 usable organizational responses collected from the four industries remained for our subsequent data analyses. The demographic profile of the usable organizational responses in this study is shown in Table 1.

### 5. Data analysis and results

Table 2 provides the descriptive statistics, Cronbach’s alpha values, and item-total correlations for the five GSCM factors amongst Chinese manufacturers. The high values of Cronbach’s alpha (>0.70) and of the item-total correlation coefficients (>0.40) for the five factors underlying GSCM suggest that all five latent GSCM factors fit the data reasonably well.

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17 This type of respondent is consistent with other similar research such as Carter et al. (1998) who concluded that middle level managers such as those in the purchasing department could facilitate incremental adoption of environmental practices. The results are consistent with our findings from extensive corporate interviews beyond the survey research. Similarly, Bowen et al. (2001) used middle level managers to find positive relationships between middle level managers’ perceptions of corporate environmental proactivity and GSCM.

18 We do acknowledge the limitations that a full geographical sample will need to be completed to corroborate our findings.

19 The first group includes 82 completed questionnaires which were returned within two weeks after the mailing. The second group includes 46 completed questionnaires which required follow-up telephone calls and returned after the cut-off date for the first mailing. We evaluated non-response bias using the t-test to determine if there were significant differences in the mean values of the 22 items and the five GSCM practice factors (see Section 5 for calculation of the mean values) between the two groups for each industry. The results showed that no differences between the groups at the $p > 0.05$ level for any of the GSCM items and factors, suggesting that non-response bias is not a major problem in this study (Armstrong and Overton, 1977).
To validate the measurement scales for GSCM, a confirmatory factor analysis (CFA) is performed, hypothesizing that the five underlying GSCM factors, i.e., internal environmental management, green purchasing, customer cooperation, investment recovery and eco-design, would adequately fit the data collected. The results in Table 3 show that a five-factor measurement model fits the data acceptably.²⁰ All of the measurement items significantly loaded on the constructs on which they were hypothesized to load. These results gave us confidence that the measures are indeed valid and reliable.

After obtaining satisfactory results in both the reliability and validity tests, we calculated the mean value for each of the five GSCM factors.²¹ As is apparent from Table 2, manufacturers in our samples have on average initiated three GSCM practices, namely, internal environmental management, investment recovery and eco-design with mean values of 3.65, 3.49 and, 3.53, respectively. However, the sample manufacturers have on average only started to consider green purchasing and customer cooperation practices with mean values of 3.05 and 3.07, respectively, a bias to favor more internally focused practices in their adoption of GSCM.

Table 4 provides a summary of the means and standard deviations for all 22 measurement items on the adoption of GSCM practices as reported by the sample companies in the four industries, namely, power generating, chemical/petroleum, electrical/electronic, and automobile companies. It should be noted that all items on internal environmental management have attained mean values over or close to 4.00 except for those sample companies in the automobile industry. In addition, all mean values of the two GSCM practices, i.e., investment recovery and eco-design, are between 3.00 and 4.00 for all the four industries.²²

We performed a one-way analysis of variance (ANOVA) to determine if any significant differences exist in the adoption of the GSCM practices, as perceived by the respondent companies in the four industries.²³ The F-test results in Table 5 show that GSCM and two underlying factors, internal environmental management and green purchasing are significantly different (at the 5% level) across the four Chinese industry groupings.

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²⁰ The chi-square goodness-of-fit statistic was statistically significant, indicating that the model was significantly different from the data. However, because large samples are likely to lead the chi-square statistic to reject valid models (Bagozzi and Yi, 1988), we also investigate other statistics of fit: the Comparative Fit Index (CFI), Goodness-of-Fit Index (GFI), Normed Fit Index (NFI), Tucker-Lewis Index (TLI), and the Root Mean Square Residual (RMR). These statistics suggest that the data fit the measurement model reasonably well ($\chi^2 = 680.19; \text{df} = 199; \text{CFI} = 0.90; \text{GFI} = 0.82; \text{NFI} = 0.87; \text{TLI} = 0.89; \text{RMR} = 0.076$). In addition, we examined the patterns of the standardized residuals and these residuals have no impact on the model fitness.

²¹ In this study, a manufacturer achieving a mean value of 3.00–3.99 in a GSCM factor suggests that the manufacturer seeks to implement that GSCM practice. Achieving a mean value of 4.00 or above in a GSCM factor suggests that a manufacturer has implemented that GSCM practice to a certain extent.

²² This finding indicates that our respondent companies in all four industries have considered these two GSCM practices and initiated their adoption. However, mean values for items on green purchasing and customer cooperation for environmental objectives vary among the four industries. All the items on green purchasing and customer cooperation for environmental objectives for the electrical/electronic industry have a mean value over 3.00, while most of the items for the automobile industry have mean values below 3.00 and two of the mean values are only slightly greater than 3.00, namely, 3.03 for the item on “cooperation with customer for cleaner production” and 3.08 for the item on “cooperation with customers for green packaging”. The only exceptional item for the automobile industry is the one on cooperation with customers for using less energy during product transportation, attaining a relatively high mean value of 3.29.

²³ We used the arithmetic mean of all items measuring a particular factor of GSCM, e.g. IEM, to represent the value of that GSCM factor. The adoption level of GSCM was determined by an average of the value of the five GSCM factors. The value of the five GSCM factors and the adoption level of GSCM were compared across the four industries for our hypothesis testing.
However, no significant difference exists in the other three GSCM factors, namely, customer cooperation for environmental objectives, investment recovery, and eco-design. The hypothesis that the four industries vary in the extent of their adoption of GSCM is partially supported.

6. Discussion

Due to depleting resources and serious environmental problems, China’s governmental bodies have introduced increasingly strict environmental regulations. With globalization, especially after China’s entry into the
WTO, Chinese manufacturers have started to experience green barriers. Because of these two main pressures, GSCM has become an emerging management approach for Chinese manufacturers to improve both their environmental and logistics performance, much of it directly motivated by economic gains.

We have posited that due to extant issues facing various industrial sectors, which can be generalized under contingent resource based, institutional, and stakeholder theories, the adoption of these practices will tend to vary. Others have also argued for these differences, where, for example, using an economic input–output model of the USA economy with 519 commodity sectors, McMichael et al. (1998) found that different industries have different direct and indirect environmental effects by emissions (toxic, harmful, and ozone depleting) and resources used (electricity and fuels). Differing drivers and pressures as well as potential improvements that companies can make has caused manufacturers in different industrial sectors to adopt GSCM practices at varying levels.

In our general findings we see that the automobile industry lags behind the other three industries, which may result from a high level of complexity in the adoption of GSCM practices based on contingency resource based theory and a larger number of stakeholders based on the stakeholder theory. Table 5 shows that power generating and chemical/petroleum supply chain companies have implemented GSCM successfully while electrical and electronic companies have initiated GSCM due to mimetic and normative (competitive and benchmarking) mechanisms.
<table>
<thead>
<tr>
<th>Construct/factors</th>
<th>Power supply chain ($n = 53$)</th>
<th>Chemical/petroleum ($n = 38$)</th>
<th>Electrical/electronic ($n = 18$)</th>
<th>Automobile ($n = 62$)</th>
<th>$F$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>GSCM</td>
<td>3.58</td>
<td>0.746</td>
<td>3.43</td>
<td>0.564</td>
<td>3.57</td>
<td>0.950</td>
</tr>
<tr>
<td>IEM</td>
<td>3.92</td>
<td>1.056</td>
<td>3.88</td>
<td>0.836</td>
<td>3.98</td>
<td>0.990</td>
</tr>
<tr>
<td>GP</td>
<td>3.26</td>
<td>1.035</td>
<td>3.16</td>
<td>0.917</td>
<td>3.50</td>
<td>1.193</td>
</tr>
<tr>
<td>CC</td>
<td>3.30</td>
<td>1.039</td>
<td>2.94</td>
<td>0.943</td>
<td>3.26</td>
<td>1.238</td>
</tr>
<tr>
<td>IR</td>
<td>3.53</td>
<td>0.952</td>
<td>3.39</td>
<td>0.974</td>
<td>3.55</td>
<td>1.224</td>
</tr>
<tr>
<td>ECO</td>
<td>3.69</td>
<td>1.065</td>
<td>3.50</td>
<td>1.076</td>
<td>3.49</td>
<td>1.105</td>
</tr>
</tbody>
</table>

*Note. Scales: 1 = not considering it, 2 = planning to consider it, 3 = considering it currently, 4 = initiate implementation, 5 = implementing successfully.*
These differences point to the capabilities or motivation for furthering the CLSC practices of GSCM in China. Clearly, with lagging GSCM practices, the automotive industry may see the largest barriers, due to lack of knowledge, systems, markets, technology, for closing the supply chain loop. For those seeking to implement these GSCM and CLSC practices in China by finding early possible success stories should seek exemplary imitative processes and practices in the electrical and electronics industries. Conversely the automobile industry has the largest potential to adopt these practices due to their lagged positioning. Since the automobile industry is a growing sunrise industry, closing the loop in this industry will eventually become an imperative.

6.1. Internal environmental management

Internal environmental management is one of the most important GSCM practices organizations must adopt to improve their environmental performance. Table 5 indicates that most of our respondent companies in China, except those in the automobile industry, attain a high mean value for this specific practice, namely, 3.92 for power supply chain companies, 3.88 for chemical and petroleum companies and 3.98 for electrical and electronic companies, respectively. Yet, the automobile industry tends to be lagging in the adoption of GSCM practices on internal environmental management, which may explain the overall lag for this industry. Table 4 shows that the two items in the internal environmental management factor with the lowest values for the automobile industry, are ISO 14001 certification (the sixth item) and environmental management systems (EMSs, the seventh item).

The lagging internal environmental management practices for the automobile industry implies numerous challenges. Due to regulations in the export receiving countries, especially the EU’s WEEE regulations, the electronic companies in China have taken measures to close the loop in their supply chains. Unlike the electrical/electronics industry, the automobile industry mainly targets the Chinese market and consumers, whose expectations may be different. Thus, stakeholder and normative isomorphic pressures are different for this industry where managers do not have to respond as much in terms of the adoption of internal environmental management practices due to lower consumer and international regulatory pressures. Even so, it is expected that international partners investing in China such as GM, Daimler-Chrysler, Ford, Toyota and Honda will exert internal management pressures on the Chinese automobile companies to close the loop in their supply chain by such means as take-back obligations. Many of these automobile companies also require suppliers, divisions, and partners to be ISO 14001 certified or have appropriate environmental management systems in place. It is likely that internal environmental management in the automobile industry will be influenced through partner relationships.

Zhu and Sarkis (2004b) demonstrated that quality management has a strong relationship with EMSs. Thus, under the increasing pressure to provide quality products, the automobile industry in China can improve their EMS practice by learning from experiences of their quality management programs.

6.2. External GSCM (supplier/customer relationship)

Cooperation with both suppliers and customers has become extremely important for closing the supply chain loop for organizations and products. Nevertheless, Table 5 shows that all mean values of the GSCM factors on green purchasing and customer cooperation for environmental objectives are the lowest compared to the other three GSCM factors in each of the four industries.

The electrical/electronic industry had a higher mean value for green purchasing (3.50) when compared to the other three industries. This industry also indicated a relatively larger mean value for customer cooperation (3.26), which is attributable to their long-term international experiences and more advanced closed-loop supply chain practices, leading these companies to face greater institutional pressures especially from direct competitors (mimetic) and supply chain partners and the market (normative) isomorphic pressures. Another reason may be that most of the respondents in this industry are joint ventures or private companies, rather than state-owned facilities, which may allow them to more easily develop relationships without the additional burdens of government bureaucracies. These relationship characteristics support the contingent resource based perspective of industrial influences, which include the complexity of these joint venture relationships and lower uncertainty levels (having stronger relationships with a broad knowledge of practices), implying
greater adoption of green purchasing. Among the 18 respondent companies in the electrical/electronics industry, seven are joint ventures while five are private companies.

The automobile industry indicated the lowest mean value for both GSCM factors on green purchasing (2.66) and customer cooperation factors (2.93), respectively. Further investigation into the demographic profile of the respondent companies indicates that this result may have its foundation in the ownership characteristics of organizations in this industry. In China, most companies in the automobile industry are state-owned, which is also the case for our data set where 54 of 62 automobile companies are state-owned, representing 87.1% of the samples. Even so, leading automobile companies in China have started to integrate environmental concerns into their supplier selection (Zhu and Geng, 2001). As international competition increases in the Chinese market, it is expected that development of other types of industry ownership, as is evident in the electrical and electronics industry, will bring about greater partnership opportunities. This evolving situation presents significant opportunity for Chinese automobile companies to learn from their international partners, as they further develop supplier and customer collaborative relationships.

6.3. Investment recovery

Table 2 showed that the mean value on investment recovery across all industries is relatively higher than the external supply chain practices with a mean value of 3.49 on investment recovery, higher than that of green purchasing (3.05) and customer cooperation for environmental objectives (3.07). The implication is that investment recovery seems to be completed internally, or for internal environmental reasons, than for supply chain reasons (thus external contingency resource based and institutional pressures do not play a significant role and industry differentiation is lessened). Even though investment recovery is more mature in China than other practices, it does not mean that closing the loop across industries in China is actually occurring. Internally, the investment recovery practices that we focused upon were for supply of these products for the closed-loop supply chain (the market push). Yet, Chinese organizations have not fully developed the systems to pull these products back into their system, which implies that normative and mimetic institutional pressures are not as prevalent and would not cause industries to learn or require changes in this GSCM practice.

Our results also indicate that the four industries do not show a significant difference in this GSCM practice. Overall, and comparatively, investment recovery in China seems to have received much less attention than developed countries such as the US and Germany, which have more mature waste management policies and recycling systems. The total annual value of reusable or recyclable resources has been estimated to be between 30 and 35 billion RMB (3.63–4.23 billion US dollars). It is estimated that about 5 million tons of used steel, 0.2 million tons of used colored metal, 14 million tons of used paper and similar amounts used plastics and glass are pending reuse (SEPA, 2004). To attract more investment, industrial zones in China provide subsidies for enterprises to cover solid waste disposal. Since treatment for waste recovery can be expensive, many Chinese enterprises consider investment recovery such as material recycling and recovery as costly (Zhu and Sarkis, 2004a). Moreover, recycling and recovery sometimes are difficult in China due to the lack of recycling systems and relevant technologies. For example, except collecting firms for resources such as paper, plastic and steel, no depots for potential usable resources exist in TEDA (TEDA, 2003).

Yet, the markets for such resource recovery can be substantially larger since many of the resource recovery operations such as remanufacturing, reuse, and reclamation, even in developed countries can be mainly manual operations, which require significantly more labor costs. China, which has these lower labor costs, may find that resource recovery across the supply chain may provide its industries with a better competitive advantage. Thus, potentially, we see this investment recovery across the supply chain as one that will emerge and dominate, especially for internationally linked industries such as the automobile and electrical/electronics industries.

6.4. Eco-design

Eco-design or design for environment (DfE) is a helpful, emerging tool to improve companies’ environmental performance and help organizations close the supply chain loop by addressing product functionality while simultaneously minimizing life-cycle environmental impacts. One of key aspects for eco-design is to facilitate
reuse, recycling and recovery through smart design such as easy to disassemble used products, a critical design characteristic for closed-loop supply chain management. The success of eco-design requires internal cross-functional cooperation among the entire company and the external cooperation with other partners throughout the supply chain. Results in Table 2 show that eco-design has received slightly more attention, across our investigated industries, than investment recovery. Similar to investment recovery, all three activities are being considered or initiated with mean values between 3.00 and 4.00 (Table 4). Table 5 indicates no significant difference of this GSCM practice among the four industries.

Lagging eco-design practices continue to bring challenges to closing the supply chain loop in China. One obvious example is that the electronic industry will potentially experience economic loss after WEEE is brought into effect. Without further indications of the adoption of these eco-design practices, it will be unlikely that this path will be altered. Moreover, none of these four industries has shown significant initiative to implement better eco-design practices. Thus, it will probably be through foreign knowledge infusion, normative and mimetic institutional pressures, from international partners or counterparts for these practices to become more prevalent. The issue of where in the supply chain these organizations fit, e.g. parts suppliers, original equipment manufacturers, distributors, etc., may also influence the rate of adoption of the eco-design practice. Incorporating Chinese industrial culture and characteristics into the eco-design aspects of international partners may make closing the loop easier. For example, we have already mentioned the manual capabilities of Chinese industry. Designing products and materials such that an average worker in China can understand how to disassemble or recover materials quickly and accurately should be an objective for products that flow through or back into Chinese markets and organizations. Another emergent pressure is increasing scarcity of resources in China, where materials and energy tend to be more expensive. As a result, products consuming less materials and/or energy tend to be more profitable and/or garner more market share in China, which is consistent with conclusions from our interviews.

7. Summary, conclusions and future research

An increasing number of organizations in Asia, Europe and North America engage in voluntary or mandatory end-of-life product management. Moreover, since developments in product take-back are driven by a mixture of environmental concerns and economic opportunities, the most promising corporate end-of-life strategies create both economic and environmental values (Geyer and Jackson, 2004). Many opportunities still exist in many of the emerging countries, with no greater opportunities than those that exist within China. We have argued and observed how many GSCM practices have implications for effectively closing the supply chain loop. Adoption of these practices is fundamental to China’s involvement in this critical industrial practice. We have seen that adoption of many of these practices is in the initial stages in most of the industries we investigated.

Under pressure from foreign customers and partners and increasingly strict domestic environmental regulations, Chinese manufacturers will probably further their adoption of the five major categories of GSCM practices. There is evidence in the literature of significant environmental and economic benefits (win-win’s) that can be accrued from the adoption of these practices. However, Chinese manufacturers are still lacking the knowledge, experience and tools to effectively and efficiently improve their environmental performance from the adoption of these principles. With a relatively long-history of international business experience, the electrical/electronic industry in China has the highest level of the adoption of GSCM and seems best positioned to most rapidly innovate to close the manufacturing supply chain loop there. This positioning is most evident in this industry’s internal environmental management and external cooperation with suppliers and customers practices.

Given increasingly high regulatory pressures and governmental scrutiny, power supply chain companies and chemical/petroleum supply chain companies have also started adoption consideration of nascent GSCM practices, while their external GSCM implementation is still relatively weak. But, this lack of external linkages and the necessity to close the manufacturing supply chain loop may not be seen as necessary by management due to product and market characteristics. Internal manufacturing and process emphasis on closing the ‘little’ loop of manufacturing may gain priority, with such practices as recovery of energy, chemicals and fuels within the manufacturing process. Yet, elements of these industries, e.g. the plastics divisions, will more likely be feel-
ing the brunt of pressures from customers and suppliers. These industry heterogeneity characteristics (for all our industries) and where these organizations operate within the supply chain will require further investigation.

Even under increasing competitive pressure after China’s entry into the WTO, the automobile industry still lags behind the other three industries in their adoption of GSCM practices, and thus, indirectly lags in their closed-loop supply chains. To gain and keep their competitiveness within the international business arena and to avoid green barriers, it is important for Chinese manufacturers to improve their environmental image through environmental tools such as the adoption of GSCM. Again, depending on the role within the automotive supply chain (parts and component, manufacturers, remanufacturers, assemblers, etc.), the level of adoption may vary. Arriving at the diffusion of these GSCM practices throughout such supply chains needs investigation for this industry as well.

In terms of all practices, investment recovery seemed to gain less attention in China, especially when compared to developed countries. However, more Chinese manufacturers have realized the importance of GSCM including investment recovery due to potential regulatory pressure in China as well as pending marketing pressure from Europe when they export products. Overall, lagging eco-design practices seem to be one of the big challenges to close the supply chains in China and this is true for all industries. This overall lag may require further promotion by the Chinese government and related professional societies, as well as collaborative involvement and incentive.

There are several academic contributions of this study to the logistics literature. First, we extend the “green” perspective research in logistics management. While there are studies on measuring supply chain performance (e.g. Lai et al., 2002), the environmental aspect of supply chain management, which is an important part of supply chain performance in contemporary business logistics, has received less research attention. This study widens the avenue for further research in this area with an empirical investigation of the adoption of GSCM in four industries in China. Second, we examined the adoption of logistics practices, i.e., GSCM and CLSC related practices, in different industrial contexts. We found that contextual differences across industries would lead firms to embrace logistics practices at differing levels. Our cross-industry investigation in China provide theoretical insights to logistics researchers on how and why the adoption of logistics practices may vary in different industrial contexts. This study contributes to theory development in logistics research on the adoption of logistics practices. For instance, under what situations would companies in different industries take GSCM or CLSC as a way to pursue supply chain performance, or to meet the institutional or stakeholder pressures? Will certain GSCM factors be more or less important in some industries than in others and under what circumstances? Answers to such questions are critical for advancing the knowledge in logistics management research. Furthermore, we have introduced to the logistics literature the varying aspects of GSCM and a validated scale for measuring the five different factors of the GSCM construct. Our discussion on the construct of GSCM and its measurement provide logistics researchers a useful conceptual and methodological reference to pursue further studies in this under-explored logistics management research area.

Along this line of academic contributions, there are several limitations in our study and we leave them for future research. First, motivations and barriers on why organizations do or do not implement typical GSCM practices, and closing the supply chain loop, have to be explored. Understanding such reasons can help governments to establish suitable regulations to promote environmental practices in industries and aid industrial organizations to address barriers they may face internally or through their supply chains. Second, relationships between the adoption of individual GSCM practices and performance can be examined. With such results, we can provide suggestions for individual industry on how to improve their environmental performance and gain economic benefits as well through the adoption of certain GSCM practices.

Other limitations are methodological. For example larger random samples that are broadly dispersed throughout China will be required to get a more accurate portrayal of the adoption of these GSCM practices. Replication and cross-cultural/multi-national investigations can also aid the generalization of these findings. Questions on whether Chinese industry is truly lagging other countries throughout the world need to be answered with replications of this study.

The dynamic nature of these GSCM practices and their early stages of adoption also call for a longitudinal analysis of the results to truly determine whether these general GSCM practices truly contribute to further adoption of explicit CLSC practices such as reverse logistics throughout China. Investigation in a multinational
setting (incorporating countries with more advanced closed-loop systems), can help us to further investigate this relationship between the adoption of GSCM and CLSC.

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Appendix. Convenience survey environment

The National Center for Industrial Science and Technology in the School of Management at Dalian University of Technology was established in 1980. The Center was directly proposed by Mr. Deng Xiaoping. The center is the first joint training project between Chinese and American stakeholders. Since 2001, it has been one of nine training bases for industries in China designated by the State Economic & Trade Commission. In recent years, the center has provided training for manager in four main industries targeted by our study. Since managers involved in training programs are representatives from these industries throughout China, we can argue that responses from them can generally represent situations in China for these industries.

References


