Environmental Management and Manufacturing Performance: The Role of Collaboration in the Supply Chain

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Abstract

As corporations attempt to move toward environmental sustainability, management must extend their efforts to improve environmental practices across their supply chain. The literature characterizing environmental management within the supply chain has been slowly building but remains sparse. Using a survey of North American manufacturers, this paper examines the impact of collaborative green supply chain practices (GSCP) on manufacturing performance. Collaborative GSCP were defined to include the interactions between organizations in the supply chain, including such aspects as joint environmental goal setting, shared environmental planning, and working together to reduce pollution or other environmental impacts. These practices can be directed either upstream toward suppliers or downstream toward customers. The influence of collaboration in each direction was empirically assessed for multiple objective and perceptual measures of manufacturing performance using a sample of plants in the package printing industry. Generally, the benefits of collaborative green practices were broadest with suppliers. In contrast, collaboration with customers yielded mixed outcomes. Overall, evidence emerged that upstream practices were more closely linked with process-based performance, while downstream collaboration was associated with product-based performance.

1. Introduction

Over the last decade, environmental management has become important for manufacturers as they face intense scrutiny from diverse stakeholders groups, including end-consumers, industrial customers, suppliers, and financial institutions (Henriques and Sadorsky, 1999). Given this context, manufacturing managers have adopted various strategies to address the impact of their operations and products on the natural environment. To date, research has started to link some of these strategies, which can take the form of an environmental management system (Melnyk et al., 2003), the
selection of different environmental technologies (Klassen and Whybark, 1999) and waste reduction techniques (King and Lenox, 2002), to organizational performance.

In contrast, research is only beginning to examine the impact of boundary-spanning activities such as green purchasing (Zsidisin and Siferd, 2001), reverse logistics (Carter and Ellram, 1998), product stewardship (Snir, 2001) and design for the environment (Chen, 2001) on organizational performance. All of these activities, related to supply chain management, require varying degrees of interaction with other organizations in the supply chain, whether upstream with the suppliers or downstream with the customers. While some of these environment-related interactions have proven to be economically desirable and serve as good complements to an organization’s environmental strategy (Bowen et al., 2001; Florida, 1996; Geffen and Rothenberg, 2000), efforts continue to identify clear patterns.

Along these lines of inquiry, this paper makes three contributions. First, the construct of environmental collaboration in the supply chain is defined and operationalized within the growing number of terms attached to green supply chain activities. Second, the theoretical basis for linking environmental collaboration to manufacturing performance is established from two related research streams. Finally, the implications of this form of supply chain relationship for a multi-dimensional assessment of performance are empirically examined.

This paper is structured into six additional sections. Next, a review of the relevant literature helps to establish a link among environmental management, supply chain management, and organizational performance. The third section introduces and defines
the construct of environmental collaboration, and hypothesizes how it might be theoretically linked to the different dimensions of manufacturing and environmental performance. Following the research methodology (Section 4), the results are presented (Section 5) and the implications for research and practice are discussed (Section 6). Finally, several conclusions are drawn, and several avenues for future research are offered in Section 7.

2. Supply chain and environmental management

This section aims to bring together two important, but often studied separately, fields in operations management: supply chain management and environmental management. In doing so, a theoretical basis for the linkage emerges for bringing together environmental initiatives in the supply chain and organizational performance. This basis draws heavily on the resource-based view of the firm (RBV) (Barney, 1991) and recent research applying it within operations management (Schroeder et al., 2002).

The RBV posits that a firm, through the set of resources it possesses, can develop capabilities providing competitive advantage. In order for a resource to provide sustainable competitive advantage it needs to be (i) valuable, (ii) rare, (iii) having only a few substitutes, and (iv) difficult to imitate (Grant, 1996b). The application of RBV within operations management is sparse but can provide important insights (Amundson, 1998; St. John et al., 2001). For example, manufacturing synergy among business units of large corporations, measured by the number of common activities within their respective value chain, can generate manufacturing competencies (St. John and Harrison, 1999). As discussed in the following section, the RBV offers a sound theoretical lens to both
understand potential interactions between firms in supply chains on environmental issues, as well as the basis for developing improved environmental performance.

2.1 *Strategic resource development in the supply chain*

Strategic resources can take on several forms, ranging from tacit, relational resources to codified, proprietary technological resources. Inter-organizational learning, one of such potential resource that can be developed through supply chain management, entails a problem solving approach that involves suppliers and/or customers (Schroeder et al., 2002). As such, this learning can instill additional capabilities in organizations (Dyer and Singh, 1998; Grant, 1996a; Lorenzoni and Lipparini, 1999; Teece et al., 1997). This supply chain-driven process of capability development is often referred to as the relational view of supply chain management, and is a complementary perspective to the RBV (Chen and Paulraj, 2004; Dyer and Singh, 1998). The relational view suggests that organizational capabilities can be developed by the combination of resources existing in different organizations in the supply chain (Dyer and Nobeoka, 2000; Dyer, 1996; Kaufman et al., 2000; Takeishi, 2001). This perspective has been supported with recent empirical evidence. For example, greater supply chain integration was associated with enhanced operational performance such as manufacturing lead time, productivity, and on-time delivery (Chen et al., 2004; Frohlich and Westbrook, 2001; Liker and Wu, 2000).

Organizations increasingly rely on their supply network to handle more complex technologies and higher customer expectations. Greater collaboration among organizations in the supply chain can lead to operational benefits including greater innovation (Dyer and Nobeoka, 2000), faster time-to-market (Dyer, 1996) and better financial performance (Carr and Pearson, 1999) – all critical to a firm’s competitiveness.
However, greater collaboration, taking the form of knowledge sharing or flexibility in logistical management, is not always beneficial. Activities such as supplier development, investment in information technologies, and inter-organizational product development teams can require significant deployment of resources from the buying and/or supplying organizations. Hence, several authors warn against blind application of these supply chain practices throughout the entire supply network, as trade-offs exist and diminishing returns occur (Buvik and John, 2000; Hartley and Choi, 1996; Rigging and Mukhopadhyay, 1994). Recent studies have found that greater collaborative supply chain strategies did not systematically improve flexibility and cost performance in the buying organization (Dong et al., 2001; Shin et al., 2000).
2.2 RBV and the natural environment

The natural-resource-based view of the firm (NRBV), as its label implies, offers an extension of RBV to environmental management (Hart, 1995). An environmental management strategy founded on strategic resources that exhibit the properties proposed by the RBV can theoretically create a sustained competitive advantage (Russo and Fouts, 1997; Sharma and Vredenburg, 1998). For instance, resources derived from proactive environmental management can generate operational capabilities such as the ability to more easily manage technological change (Russo and Fouts, 1997), increased stakeholder integration (Sharma and Vredenburg, 1998), and continuous improvement routine (Hart, 1995).

The NBRV was the theoretical grounds for two survey-based studies involving manufacturing organizations. Klassen and Whybark (1999) found evidence that the selection of pollution prevention technologies enabled manufacturing organizations to develop capabilities difficult for competitors to replicate. Using survey data from the furniture industry, a greater emphasis on pollution prevention technologies improved cost, delivery, flexibility, and environmental performance. From a related perspective, Christmann (2000) argued that manufacturing organizations can develop complementary capabilities that flow from environmental management to other areas of competitiveness. For example, developing skills in the use of an early application of pollution prevention technologies and in finding innovative solution to environmental challenges can build a synergistic combination of process-related capabilities. This combination, in turn, was found to yield a cost advantage relative to major competitors.
3. **Environmental collaboration and manufacturing performance**

The limited understanding of environmental management in the supply chain has hampered the development of a widely-accepted framework that characterizes and categorizes environmental activities. At this point, a wide variety of definitions, terms and conceptualizations can be found in the research and practitioner literature (Zhu and Sarkis, 2004; Zsidisin and Siferd, 2001). For example, Bowen et al. (2001) defined green supply as the buying organization’s intent to improve the environmental performance of purchased input and/or of the suppliers that provide them. As such, green supply includes a wide variety of activities such as cooperation between organizations to minimize the logistical impact of the material flows, and gathering environmentally related information about purchased materials and components. Others have proposed definitions more focused on the purchasing function, suggesting that green supply activities consist of the involvement of the purchasing function in facilitating internally-driven environmental activities such as recycle, reuse and source reduction (Carter and Carter, 1998; Min and Galle, 2001; Zsidisin and Siferd, 2001). Yet others have proposed definitions that extend beyond departmental functions (e.g., purchasing) to the organization as a whole (Vachon and Klassen, forthcoming; Zhu and Sarkis, 2004). Here, the focus is on collaboration between a focal plant and its suppliers and/or its customers. *Environmental collaboration* in the supply chain includes a direct involvement of an organization with its suppliers or customers to jointly develop environmental solutions (Florida, 1996; Geffen and Rothenberg, 2000; Rao, 2002).
3.1 Environmental collaboration

While not unrelated to the definition of Bowen et al. (2001), the construct of environmental collaboration shifts the focus from a product to characterizing the supplier-customer relationship. Thus, environmental collaboration captures the notion of joint planning and solution finding between organizations. Because supply chain management is increasingly driven by multi-functional teams, activities outside the purchasing or supply department also must be captured, including downstream customers (e.g., Frohlich and Westbrook, 2001). Finally, this construct refines the concept of ‘external green supply chain management’ (Zhu and Sarkis, 2004), which combined two set of activities and two directions in the supply chain. In terms of activities, it is important to separate uni-directional, control-oriented activities (i.e., monitoring) and bi-directional, relational activities targeting improvement (i.e., collaboration) (Vachon and Klassen, forthcoming). Similarly, separating upstream supplier-related collaboration from downstream customer-related collaboration has both theoretical and managerial implications.

The focus on collaboration in this paper is important for several reasons. First, based on the four criteria for defining a strategic resource (RBV), collaborative is expected to offer a competitive advantage, as these activities are difficult to replicates and socially complex. In contrast, monitoring activities of suppliers that entail audits, questionnaires and environmental certification (e.g., ISO 14001) are easily replicated. Second, collaboration can be initiated by either upstream or downstream supply chain partner, but then requires long term commitment by both. However, given the likely imbalance in power in the relationship, with either the supplier or customer wielding more power
depending on such factors as size and access to markets, to name a few; it is conceivable the implications of upstream versus downstream collaboration could differ.

Environmental collaboration activities include knowledge sharing activities pertaining to greener product design or process modification (Global Environmental Management Initiative, 2004) and planning for reducing waste in the logistics process (Bowen et al., 2001). Hence, environmental collaboration focuses less on the immediate outcome of the supplier- or customer- environmental efforts (e.g., compliance to existing regulations), and more on the means by which more environmentally-sound operations or product might be achieved. Because each focal plant acts as a buying organization to its suppliers and as a supplier to its customers, such collaboration can take place simultaneously upstream with the suppliers as well as downstream with the customers. Castrol, a lubricant producer supplying the automotive industry, offers anecdotal evidence of the benefits and challenges of environmental collaboration (Reiskin et al., 2000). Castrol worked with one of its customer’s plants to ensure proper use of its chemical products. This interaction resulted in process modifications leading to significant savings through less chemical use at the customer’s plant, hence improving environmental performance. Similar anecdotal evidence has been reported for the automotive industry (Geffen and Rothenberg, 2000; Global Environmental Management Initiative, 2001). Specifically, a paint and coating supplier worked on-site in the paint shop of an automaker to develop a better product-based solution to the ever-increasing pressure faced by the automakers to reduce volatile organic compound (VOC) emissions.
3.2 *Linking environmental collaboration to manufacturing performance*

Environmental collaboration include the exchange of technical information and require a mutual willingness to learn about each other’s operations in order to improve environmental practices (Canning and Hanmer-Lloyd, 2001; Geffen and Rothenberg, 2000). They also include cooperation to reduce the environmental impact associated with material flows in the supply chain (Bowen et al., 2001; Carter and Carter, 1998). As noted earlier, these practices take the form of joint planning and decision-making regarding environmental issues, which is consistent with examples and cases presented in the green supply chain literature (Geffen and Rothenberg, 2000; Hall, 2000; Handfield et al., 1997; Walton et al., 1998).

Again several cases in the literature illustrate the linkage between environmental cooperation and operational performance. For example, Xerox, a leading firm in the photocopier industry, leveraged its Asset Recycle Management program to generate an annual savings of $300 to $400 million (Hart, 1997). These savings were the end result of a broad array of managerial practices that have reshaped the Xerox supply chain. In particular, Xerox favored partnerships with its suppliers as one critical approach to fostering the design of more environmentally friendly products (Xerox, 1999). By interacting with its key suppliers to design products that are easier to remanufacture, Xerox developed a capability difficult for the competition to replicate, which lead to improved environmental and operational performance (Reinhardt, 1999).

The competitive advantages generated by environmental collaboration are twofold. First, collaboration includes knowledge integration and cooperation between organizations, which are recognized as resources that might generate competitive
advantage (Grant, 1996a; Simonin, 1997). As such, manufacturing organizations adopting collaborative activities with their suppliers and customers can develop organizational capabilities (Lorenzoni and Lipparini, 1999), which can be expected to translate not only into improved environmental performance, but also into other dimensions such as cost and quality (Hart, 1997; Porter and van der Linde, 1995). Case evidence supports the linkage to improved productivity (Geffen and Rothenberg, 2000), while limited survey has highlighted improved product quality (Gavaghan et al., 1998) and financial performance (Carter et al., 2000). Thus, collaboration is expected to positively influence operational performance (Aragon-Correa, 1998; Porter and van der Linde, 1995).

**Hypothesis 1:** As environmental collaboration increases, a plant’s manufacturing performance which includes cost, quality, delivery, and flexibility improves.

Second, environmental collaboration is directly associated with a proactive environmental management orientation (Bowen et al., 2001), which extends beyond supply chain management, to respond efficiently and effectively to new environmental challenges and regulations (Bonifant et al., 1995; Klassen and Whybark, 1999).

**Hypothesis 2:** As environmental collaboration increases, a plant’s environmental performance improves.

4. **Research design**

4.1 **Sample**

The relationship between environmental collaboration and manufacturing performance was tested using a plant-level survey of the North American package
printing industry (United States and Canada). A focused, single industry approach was adopted to control for the type of manufacturing processes and workflow, which are quite standardized in this industry, market expectations, echelon in the supply chain, and environmental regulations. Legislative requirements and customers concerns in this industry were actively pushing a number of plants to investigate and implement a range of new environmental technologies that reduced waste and VOC emissions, including both controls, such as oxidizers to burn emissions, and prevention, such water-based inks.

A survey instrument was developed based on the previously reviewed literature and a series of extensive interviews with different stakeholders of the package printing industry. A total of six semi-structured interviews with industry experts (three of which reviewed the questionnaires) were conducted. These experts were former executives of large package printing organizations, two government representatives (one from Canada and one from the United States) and the environmental manager of a large printing industry association. These interviews were supplemented by six plant visits and six semi-structured interviews with plant managers. After these interviews and visits, the questionnaire was further revised and modified to refine and clarify the constructs and items.

A North American sample of 366 plants with at least 90 employees was compiled from two exhaustive sources: the Packaging Sourcebook (United States) and Scott’s Industrial Directory (Canada). After an initial telephone call to the plant manager to confirm contact information and to introduce the research project, a three-wave survey process similar to that prescribed by Dillman (2000) was followed. Conducted in 2002, the survey was offered in both English and French to each potential respondent to
encourage participation. A total of 84 completed surveys were received, representing a response rate of 23%. A chi-square test of independence revealed no evidence that the respondent pool differed significantly from the target pool along (i) the geographical location of the respondents (U.S. vs. Canada); (ii) the three segments of the industries (folding box, flexible packaging and labels); and, (iii) parent company size (companies with more than three plants vs. companies with three or less plants).

4.2 Environmental collaboration

Two scales were designed to capture the use of collaborative activities over the prior two years to build a causal linkage with changes in performance over the same time period. An existing scale in logistics (Ellinger et al., 2000) combined with specific knowledge from the green supply chain literature (Bowen et al., 2001; Carter and Carter, 1998) was synthesized to construct new, multi-item scales to assess the extent of environmental collaboration. One five-item scale focused on collaborative activities with primary suppliers, and an analogous five-item scale focused on major customers (Appendix A). It should be stressed that all items were structured such that the responding plant manager could accurately assess the relationship from the perspective of her/his plant, i.e., the manager did not have to speculate about the operations of another organization. (For example, Did your plant engage in the following environmental activities with your primary suppliers?; To what extent did your plant engage in the following environmental activities with your major customers?).

First, the measure of sampling adequacy was assessed, with a score above 0.8 being considered meritorious (Hair et al., 1998). This measure was 0.88 for environmental collaboration with suppliers and 0.91 for environmental collaboration with customers.
In addition, the Bartlett test of sphericity assessed the significance of bivariate correlation estimates for all items in each scale. The test was highly significant for both scales with p-values below .001 (Table 1).

Next, exploratory factor analysis was used to clean and refine these scales. This approach, rather than confirmatory factor analysis (CFA), was used because of the relatively small sample size. To begin, the unidimensionality of each scale was explored by conducting a factor analysis on each scale individually. For each, the items loaded on only one factor, with variance extracted exceeding 87% in both cases (FA1 and FA2 in Table 1). The reliability of each scale, measured using Cronbach-α, also was above the recommended threshold of 0.7 (Nunnally, 1978). Finally, when evaluated collectively, all ten items loaded on their expected scales (FA3, Table 1) with all factor loadings exceeding .80. Items averages were used in subsequent analysis.

4.3 Manufacturing performance

Manufacturing performance was defined and measured by a combination of multi-item scales and objective metrics. While many studies of performance in operations management have employed perceptual measures (Chen et al., 2004; Dong et al., 2001; Rosenzweig et al., 2003; Zhu and Sarkis, 2004), relatively few have simultaneously used objective measures (Flynn and Flynn, 1999; Frohlich and Westbrook, 2001; Vachon and Klassen, 2002). For perceptual measures of performance, 13 items captured the four traditional dimensions of manufacturing performance – cost, quality, delivery and flexibility.
In addition, perceptual measures (three items) were added for environmental performance, similar to Judge and Douglas (1998). These items required the respondent to evaluate his/her plant’s performance against major competitors (see Appendix A).¹

As before, exploratory factor analysis was performed on these multi-item scales (Table 2). The test for sampling adequacy, at 0.726, was deemed acceptable (Hair et al., 1998). The Bartlett’s test for sphericity also was highly significant (p < .001), and the values of Cronbach alpha exceeded the recommended threshold of 0.70. The cumulative variance extracted was above 70% for the four manufacturing performance dimensions and the environmental management scale (Table 2). One item was deleted and not use for further analysis because of cross-loading (i.e., g1_g). The items were averaged for each of the five performance scales.

[Insert Table 2 Here]

Objective data were collected for two dimensions of manufacturing performance: quality and delivery. For quality, the percent of production that is scrapped or returned from the customers was requested from the respondent. On-time delivery, throughput time, and set-up time (make-ready) are three additional metrics used to evaluate delivery performance. Respondents were asked to report both current and prior performance (previous two years). These figures permitted an assessment of the improvement (or deterioration) experienced by the plant during the two-year period preceding the survey. The percentage of improvement in each of the four objective metrics was computed and used as a dependent variable. Because such improvement is highly contingent on the

¹ At first glance, given the research objectives, there might be concern about social desirability. However, as noted later in Table 3, the overall scale mean was lower for environmental performance than any of the manufacturing performance dimensions, as the variance was higher. Thus, no evidence was found.
starting level of performance (*e.g.*, it is easier to improve by 1% your cycle time when it is 10 days then when it is 1 day), the lagged performance measures were introduced as an independent variable in the regression analysis.

4.4 Control variables

Six variables were used to control for the following characteristics: plant size (the natural logarithm of the number of employees), parent company size (the natural logarithm of the number of employees), average age of the presses (a key piece of process technology, in years), extent of investment in new manufacturing equipment during the previous two years (as percentage of sales), supply base (number of suppliers normalized by the number of employees at the plant), and customer concentration (percentage of sales coming from the three largest customers).

5. Empirical results

5.1 Model development

In total, the empirical analyses considered nine models—five perceptual and four objective performance measures. The independent variables were grouped into two major sets to employ hierarchical regression:

1. Control variables that include plant size, parent company size, reinvestment rate, age of presses, supplier base, and customer concentration. For the objective performance measures, prior performance was also added.

2. Environmental collaboration, including both upstream, supplier collaboration and downstream, customer-oriented collaboration.
For each regression model, the block of six control variables was first introduced, followed by a block of the two environmental collaboration variables. By structuring the analysis this way, the incremental variance explained by the environmental collaboration variables could be assessed explicitly. The incremental squared multiple correlation coefficient ($R^2$) are reported for each model, along with the coefficient estimates for the full model (i.e., all independent variables).

Pairwise correlations for performance metrics and all independent variables are presented in Table 3. From these correlations, model specification adjustments were needed to examine the impact of environmental collaboration on performance: the high correlation between the supplier and customer environmental collaboration variables (0.64) indicated that the two variables should be considered both individually and simultaneously to assess their impact on manufacturing performance.

[Insert Table 3 Here]

5.2 Environmental collaboration

The regression analysis results are presented in Tables 4 and 5 for the perceptual and objective performance measures, respectively. Overall, the results provide substantial support for H1. Thus, empirical evidence was found that environmental collaboration among organizations in the supply chain taking the form of cooperating in environmental planning, establishing common environmental goals, and jointly addressing product/process-related issues positively impact manufacturing performance.

First, although environmental collaboration was not significantly linked with cost performance (Model 1), collaboration was positively linked with quality performance.
The results for the quality scale suggest that environmental collaboration with suppliers (Models 2a, p < .05) and customers (Model 2b, p < .05) were related to at least two aspects of quality: product durability and conformance to specifications. Environmental collaboration with customers also was associated with greater quality improvement, as measured by reduced scrap rates during the preceding two-year period (Model 6b, p < .05; Model 6c, p < .10). Hence, collaboration with customers on environmental aspects can create synergy that fosters improvement across the broader supply chain network extending from supplier to customer.

[Insert Table 4 Here]
[Insert Table 5 Here]

Second, a positive relationship was found between environmental collaboration and the delivery performance scale, providing support for another dimension of manufacturing performance. For instance, collaboration upstream with suppliers was linked to better delivery performance (Models 3a and 3c, p < .01). This result was corroborated by the objective measure of on-time delivery (Model 7a, p < .05; Model 7c, p < .10), where supplier collaboration was positively associated with improvement. Hence, engaging in joint environmental planning and goal setting with the suppliers can improve the competitiveness in regards to speed and delivery reliability, as measured through perceived performance against primary competitors and the percentage of deliveries made on-time. (Although customer collaboration appears to be make on-time delivery worse (Model 3c), this spurious result is caused by collinearity, as indicated by Model 3b.)
Finally, the analysis of the relationship between environmental collaboration and flexibility performance identified another aspect in support of H1. A positive relationship between collaboration with suppliers and the manufacturing flexibility was identified (Models 4a, p < .01; Model 4c, p < .05). A similar result holds for environmental collaboration with customers (Model 4b, p < .05).

For environmental performance (H2), as expected, strong support was found linking collaboration with performance (as suggested by the substantial $\Delta R^2$ of 0.21 in Model 5c). Both environmental collaboration with suppliers (Model 5a, p < .01) and customers (Models 5b, p < .01) were significantly linked to overall environmental performance. This survey-based finding is consistent with the anecdotal evidence reported by other researchers. An internal environmental planning and environmental problem-solving culture – two characteristics of an environmental management system such as ISO 14001 – has been observed to improve environmental performance (Jayathirtha, 2001; Kitazawa and Sarkis, 2000; Raiborn et al., 1999). The results here indicate that a plant’s environmental performance can further benefit from extending these activities beyond firm boundaries to collaborate actively with major customers and/or primary suppliers.

5.3 Control variables

While not the primary focus of this paper, it is interesting to quickly note that a number of control variables were related to performance, for the most part in the expected direction. First, customer concentration was related to better manufacturing performance, or greater improvement, across several dimensions including cost (Model 1, p < .05), quality (Model 2, p < .10; Model 6, p < .10), and delivery (Model 3, p < .05; Model 7, p < .05). Together, these results suggest that a smaller customer base offers
significant competitive benefits. However, these findings must be tempered with strategic concerns about a potential over-dependency on a few customers, and short-versus long-term performance.

In contrast, having a larger supplier base was linked with greater improvements in on-time deliveries (Model 7, p < .05). This last result is not counter-intuitive as more suppliers can reduce the risk of material stock-out. Finally, recent investment in equipment yielded significant improvements in several manufacturing performance metrics, including cycle time and set up time (Model 8, p < .10; Model 9, p < .05). Again this is not surprising as a lot of the investments in the printing industry in recent years targeted presses automation (e.g., rolls auto-cleaner) and make-ready technologies (e.g., computer-to-plate).

6. Discussion

6.1. Linking the findings to the existing empirical literature.

The findings highlighted in the previous section indicate that environmental collaboration with primary suppliers and major customers, defined as encompassing joint environmental planning activities and cooperation in finding solution to environmental challenges, can have a significant positive impact on both manufacturing and environmental performance.

The positive linkage between environmental collaboration different dimensions of manufacturing performance adds further support to the growing body of literature espousing the natural resource-based view of the firm (Hart, 1995). The results obtained here complement those reported in previous research. For example, a strong linkage has
been noted between the extent of involvement of external stakeholders, including customers and distributors, in the implementation of an ISO-certified environmental management systems and the degree of competitive advantage derived from the ISO 14001 certification (Delmas, 2001).

Empirically, the results are also consistent with a recent study that linked environmental activities in supply chain to environmental performance and cost competitiveness. For example, Rao (2002) found a significant and positive relationship between the degree of dissemination of environmental knowledge by buying organizations in the supply chain and these organizations’ environmental performance. Another study found a positive link between green supply chain practices (including a mix of collaboration and monitoring activities) and both environmental and economic performance (Zhu and Sarkis, 2004). Furthermore, considering that environmental performance, as one component of operational performance, ultimately has repercussions for financial performance (Klassen and McLaughlin, 1996), the results here also enrich our understanding of how different aspects of green supply chain management affect operational performance (Carter et al., 2000; Christmann, 2000; Melnyk et al., 2003; Sarkis and Cordeiro, 2001). For example, environmental purchasing, defined as the involvement of the purchasing function in environment-related projects within the organization, was positively linked to net income and negatively linked to cost (Carter et al., 2000). Finally, the results provide support to proposition that an organization with proactive environmental management will develop innovative solutions to environmental, which in turn leads to improvement in other facets of the organization’s operations (Aragon-Correa, 1998; Porter and van der Linde, 1995; Russo and Fouts, 1997).
6.2. Theoretical implications

While it is important to consider these findings against the backdrop of earlier empirical work, assessing theoretical implications ultimately lays the groundwork for systematic improvements in practice and future research. Environmental challenges invariably demand complex solutions because of the numerous interactions between firms, their supply chain networks, regulators, and the public. For the supply chain network, environmental collaboration requires organizations’ respective know-how and technologies to, first, be shared, and second, to be integrated. More specifically, two direct outcomes of environmental collaboration are the development of knowledge sharing routines and the development of the capability to integrate external resources (Dyer and Singh, 1998). Such a combination of resources can lead to a competitive advantage (Grant, 1996b; Lorenzoni and Lipparini, 1999; St. John and Harrison, 1999). While not the only pathway to improvement, environmental collaboration can initiate or prompt the development of capabilities for integration of internal and external know-how and technologies. This tacit capability, as it expands and deepens, can build a resource that is difficult to replicate, leading in turn to a competitive advantage, consistent with the natural resource-based view (Hart, 1995).

Juxtaposed with RBV, further theoretical development based on the relational view of the firm (Dyer and Singh, 1998) has contributed to the emergence of the collaborative paradigm in the supply chain literature (Chen and Paulraj, 2004). This paradigm proposes that organizations operate within a network of inter-dependent relationships developed and fostered through strategic level interaction. The primary emphasis of the research related to this view focuses on activities pertaining to supply chain performance.
such as lower cost, faster time-to-market, and improved quality are considered. For example, information sharing and integration improves supply chain efficiency through lower inventory and better delivery performance (Cachon and Fisher, 2000; Lee et al., 2000). Similarly, faster innovation cycle and product quality was positively linked to strategic level integration (Dyer, 1996; Kaufman et al., 2000; Trent and Monczka, 1999). All of these competitive dimensions are primarily associated with what could be viewed as “core” operations or products.

However, the research conducted within the relational paradigm is rather silent on historically peripheral (non-core) activities such as those related to the natural environment. Yet, environmental issues increasingly cannot be managed in isolation from other supply chain activities. Thus, not only must buyer-supplier relationships evolve and mature through time (Dwyer et al., 1987; Webster, 1992), but as these relationships develop, environmental collaboration can form one component. Hence, the linkage between strategic core matters and non-core concerns (i.e., environmental management in the supply chain) implies that the scope of collaborative paradigm must be similarly expanded. One theoretical framework under which the boundaries of the relational paradigm might be enlarged is to consider supply chain management within the broader context of sustainable development (Lamming et al., 1999). Sustainable development and the triple bottom-line capture the three dimensions of economic, social and environmental performance (sometimes termed the 3Ps of profits, people and planet).

6.3. Managerial implications

Together, these results have direct implications for practice. Environmental collaboration with suppliers contributed to a relatively broad range of competitive
benefits, while collaboration with customers offered a comparably narrower set. Collaboration with suppliers on environmental issues was linked to improvement in three traditional dimensions of manufacturing performance — quality, delivery and flexibility — in addition to environmental performance. In contrast, if quality performance is manufacturing’s primary strategic thrust, then collaboration with the customers can offer a further synergistic mechanism to achieve competitive gains.

6.4. Limitations

While studying a single industry allows for greater control over contextual and operational factors, it is not without its drawbacks. First, using a single industry that forms a single echelon in the supply chain allowed greater specificity in detailing and surveying the types of integration activities underway, but potentially limits external generalizability. Future research would benefit from expanding this investigation across multiple echelons in a supply chain, possibly using either a case- or survey-based approach.

A second limitation of the design of this study is the fact that it used only one respondent, which might potentially create grounds for bias. Second, any potential bias introduced by the single respondent cannot be explicitly ruled out; however, earlier research suggests no major concerns (Youndt et al., 1996), and careful targeting of a knowledgeable respondent can assist in overcoming potential problems with common method variance (Miller and Roth, 1994).
7. Conclusions and future research avenues

This study focused on the impact of environmental collaboration in the supply chain on manufacturing and environmental performance. Environmental collaboration was defined as the interaction between organizations in the supply chain pertaining to joint environmental planning and shared environmental know-how or knowledge. As such, any monitoring or control elements usually included in green purchasing or green supply chain (e.g., plant audits, questionnaires) were explicitly excluded from the study. That way it was possible to evaluate the impact of potential resource building environmental activities in the supply chain.

Environmental collaboration with primary suppliers was predominantly linked to superior delivery and flexibility performance. Similarly, environmental collaboration with customers was predominantly linked to better quality performance. Hence, upstream collaboration was essentially linked to process-based performance taking the form of fast deliveries, reliable deliveries, and greater ability to cope with unforeseen events. In contrast, downstream collaboration was associated with product-based performance taking the form of conformance to specifications and durability. One key supply management activity, if not the most important, is to assure the quality of inputs used in the production process. Therefore, environmental collaboration with customers can easily be predisposed to integrate product-based quality and environmental issues explaining the results of this paper. On the other hand, buying organizations want quality inputs because defective or sub-par inputs will ultimately be reflected in their own product quality and in other performance dimensions such as delivery.
These results suggest a link that would exist between environmental management in the supply chain and quality management practices within a plant. The link between internal environmental management and quality management systems has been established in the literature (Chen 2001; Curkovic et al. 2000; King and Lenox 2001). However, very little research was conducted on the potential link between environmental activities in the supply chain and internal quality management practices. Most likely, environmental collaboration, being a form of proactive environmental management, will be linked to quality management practices geared towards preventing failures rather than having an emphasis on troubleshooting or on appraisal activities.

The dichotomy observed regarding the impact of upstream and downstream collaboration on different manufacturing performance is important for future research in the supply chain field. First, a lot of studies in recent years combined upstream and downstream activities in one unified construct (Rosenzweig et al., 2003; Zhu and Sarkis, 2004). While conceptually correct, this approach can hide some important research contributions as suggested by the results of this paper. Alternatively, some studies pulled together different dimensions of manufacturing performance within one organizational performance construct (Rao, 2002; Krause et al. 2000; Prahinski and Benton 2004) which can lead to a similar shortcoming in the findings.

One important organizational characteristic, outside the scope of this paper, could have furthered our understanding of the collaboration-performance relationship: the capacity of an organization to absorb knowledge transfers. Such capacity varies greatly among organizations (Cohen and Levinthal 1990; Lane and Lubatkin 1998) and can be insightful in studying the collaboration-performance relationship. In fact, greater
absorptive capacity helps organizations to cultivate and transform knowledge acquired in the supply chain more effectively. Hence, it can be expected that higher degree of absorptive capacity will moderate the collaboration-performance relationship.

Finally, a possible extension to the current research would be to expand this line of research to the service sector. The greater part of environmental management research has been concentrated in the manufacturing sector, with special emphasis on industries with a high environmental impact such as the chemical (Christmann 2000), furniture (Klassen and Whybark 1999), electronics (Krut and Karasin 1999), and automotive (Geffen and Rothenberg 2000) industries. While the service sector represents more than 75% of the industrialized economy, it has not attracted much attention in the environmental management literature (Salzman 2000). Some studies based on anecdotal evidence in the hospitality industry (Enz and Siguaw 1999) and in the health care industry (Messelbeck and Whalley 1999) have started to build the recognition that service operations can be harmful to the environment. However, theoretical and conceptual development is practically nonexistent in the literature.
APPENDIX A  Questionnaire Items

**Environmental Collaboration with Suppliers**
During the past two years, to what extent did your plant engage in the following environmental activities with your primary suppliers (inks, substrates, equipment)? *(1=not at all, 4 = moderately, 7 = great extent)*
- D2a Achieving environmental goals collectively.
- D2b Developing a mutual understanding of responsibilities regarding environmental performance.
- D2c Working together to reduce environmental impact of our activities.
- D2d Conducting joint planning to anticipate and resolve environmental-related problems.
- D2e Making joint decisions about ways to reduce overall environmental impact of our products.

**Environmental Collaboration with Customers**
During the past two years, to what extent did your plant engage in the following environmental activities with your major customers? *(1 = not at all, 4 = moderately, 7 = great extent)*
- E2a Achieving environmental goals collectively.
- E2b Developing a mutual understanding of responsibilities regarding environmental performance.
- E2c Working together to reduce the environmental impact of our activities.
- E2d Conducting joint planning to anticipate and resolve environmental-related problems.
- E2e Making joint decisions about ways to reduce the environmental impact of our product.

**Manufacturing Performance**
For each of the items listed below, how does the plant compare relative to your primary competitors? *(1 = far worse than competitors, 4 = about the same as competitors, 7 = far better than competitors)*
- g1_a Production costs.
- g1_b Total product costs.
- g1_c Labor productivity.
- g1_d Conformance to design (e.g., color intensity/structural property).
- g1_e Product durability (e.g., color fading, substrate resistance).
- g1_f Perceived overall product quality.
- g1_g Promptness in solving customer complaints. (dropped)
- g1_h Order fulfillment speed.
- g1_i Manufacturing throughput time.
- g1_j Meeting delivery due date.
- g1_k Ability to change delivery date.
- g1_l Ability to change output volume.
- g1_m Ability to change product mix.
- g1_n Solid waste disposal.
- g1_o Air emissions.
- g1_p Water emissions.

What percentage of customer orders is delivered accurately (e.g., quantity and specifications) at the time promised?

| two years ago (2000) | _____ % on time | now (2002) | _____ % on time |

For a typical job, about how much time elapses from the start of the first operation until a batch of products is finished (including imaging, pre-press and post-press operations if any)?

| two years ago (2000) | _____ days | now (2002) | _____ days |
On average, approximately how much time does it take to make a changeover on the press (i.e., set-up time or make ready time)?

two years ago (2000) ______ hours now (2002) ______ hours

What percentage of production does not meet specifications resulting in scrap or returns from customers (also known as spoilage or first-pass scrap rate):

two years ago (2000) ______ % scrap now (2002) ______ % scrap

Control Variables

A4 Please indicate the number of suppliers that your plant has for each of the following: substrates (all of them), inks, and all other suppliers (maintenance, equipment, transportation). (number of suppliers)

B3 Please indicate the percentage of your plant’s total sales represented by your three largest customers (customer concentration)

F3 On average over the past two years, what percentage of the plant’s total capital budget was allocated to investments in environmental projects? (% of environmental investment)

H1 As of the beginning of January 2002, how many employees (full-time equivalent) work at your plant? (plant size)

H2 As of the beginning of January 2002, how many employees work in the entire organization (parent company) including your plant? (firm size)

H9 On average, over the last two years, about what percent of annual sales has been invested in new manufacturing equipment? (reinvestment rate)

H12 What is the average age of the presses (in year)? (age of presses)
References


---- (2001), "New Path to Business Value." (www.gemi.org)


Xerox (1999), "Environment, Health and Safety Report."


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KMO adequacy: .884 .909
Bartlett test: 555.0 510.1
p-value of Bartlett test: .000 .000
Eigenvalue: 4.414 4.388 7.229 1.591
Variance explained (%): 88.28 87.75 44.3 43.9
Cronbach’s alpha: .967 .965

**Extraction method:** principal component analysis; **rotation method:** varimax with Kaiser normalization.
(rotation converged in 3 iterations)
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Eigenvalue  1.489  4.732  1.736  1.102  2.522
Cronbach α  .799   .792   .765   .799   .857

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**Notes:**
- N for bivariate correlations varies from 76 to 83 because of missing data.
- Correlations greater than 0.285 are significant at p < 0.01; correlations greater than 0.230 are significant at p < 0.05.
- <sup>a</sup> The % improvement during the 2000-2002 period.
- <sup>b</sup> Natural logarithm of the number of employees in the plant.
- <sup>c</sup> Natural logarithm of the number of employees in the parent company.
- <sup>d</sup> Percentage of annual sales invested in new equipment over the last two years.
- <sup>e</sup> Total number of suppliers scaled by plant size (number of employees).
- <sup>f</sup> The % of sales coming from the three largest customers.
### Table 4  Impact of Environmental Collaboration: Perceptual Performance Metrics\(^a\)

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<td>.199</td>
<td>.373(^**)</td>
<td>.621(^**)</td>
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<td>.383(^*)</td>
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<td>.160(^\dagger)</td>
<td>.358(^*)</td>
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<td>.216(^*)</td>
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<td>.144(^\dagger)</td>
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<td>.160(^*)</td>
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Notes:
\(^a\)Standardized betas (\(β\)) are reported and the t-statistics are reported in parentheses.
\(^\dagger\)p-value < 0.10, \(^*\)p-value < 0.05, \(^**\)p-value < 0.01
Table 5  Impact of Environmental Collaboration: Objective Performance Metrics$^a$

<table>
<thead>
<tr>
<th>Control variables</th>
<th>Scrap rate$^b$</th>
<th>On-time delivery</th>
<th>Cycle time</th>
<th>Set-up time</th>
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<td>-.141 -.142 -.134</td>
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<td>.011 .024 .011</td>
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<td>.021 .033 .021</td>
<td>.246* .218† .233†</td>
<td>.300* .330** .302*</td>
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<td>.115 .104 .112</td>
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<td>.190</td>
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<td>.925** .921** .925**</td>
<td>.188† .198* .206†</td>
<td>.204* .182† .204†</td>
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<tr>
<td>ΔR$^2$</td>
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<td>.919** .919** .919**</td>
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<td>76 76 76</td>
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</table>

Notes:
$^a$Standardized betas ($β$) are reported and the t-statistics are reported in parentheses.
$^b$An outlier case was not included in this regression (standardized residual was -4).
†p-value < 0.10, * p-value < 0.05, ** p-value < 0.01

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