Evaluating Mexico's
Green Supply Chains Program

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Abstract

We assess the economic and environmental performance of an innovative program for greening small and medium-sized enterprises (SMEs) within the supply chains of major manufacturers in Mexico. The program is a public/private partnership that uses large "anchor" companies to solicit SME participation, and provides education on eco-efficiency to selected SME employees, who generate their own projects to implement the ideas they have learned. We compute payback periods and net present values of the projects implemented during the pilot phase of the program, and also quantify a variety of environmental benefits. Overall, the Mexican green supply chain program appears to offer a promising model for diffusing eco-efficiency techniques to SMEs.

Keywords: Supply chain management, eco-efficiency, sustainable development

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1. Introduction

The "greening" of small and medium-sized enterprises (SMEs[1]) is an emerging topic in Latin America and in other parts of the world, as they are considered cornerstones of development by regional and national governments and donor organizations (Blackman, 2006; Pietrobelli & Rabellotti 2006; Beck et al., 2005; Sage, 2000). Their significant contribution to employment generation, their potential for economic improvement and technological innovation, as well their considerable contribution to environmental degradation put them at the top of the agendas of many of these institutions. Their role and the importance of their contribution to sustainability will grow as globalization advances (Ruzzier et al., 2006; Vercelli, 2001).

As a result of this political interest, a range of instruments and technical assistance programs have been designed during the last decade to improve the environmental and business performance of SMEs (Parker et al., 2009; European Commission, 2007; ECLAC, 2006; Pratt & Mauri, 2005; Montalvo, 2002; Kemp, 2000; OECD, 1997). A small number of studies have attempted to identify the challenges and barriers to improving sustainability in this sector. These studies, as well as the observed results of the technical assistance programs, find disappointing results to date in the "greening" of SMEs (Parker et al., 2009; Van Berkel 2006; Stone 2006; Vives et al., 2005; MAVDT-IDEAM- 2005; Rothenberg & Becker, 2004; Friedman & Miles, 2002).

Several reasons are given to explain why greening SMEs is challenging (Blackman, 2006; Granek & Hassanali, 2006; Hitchens et al. 2005; Vives et al., 2005; Schaper, 2002; Friedman & Miles, 2002; Hilson, 2002, 2000; Hillary, 2000). In the first place, SMEs have fewer resources and organizational capacities, compared to larger firms, to implement sustainable practices. Smaller companies generally have less financial slack and retained earnings with which to start environmental improvement programs or to invest in cleaner technology (Mitchell, 2005). Additionally, their human resources are typically less educated and less specialized, which explains why most technical assistance programs rely for improvement on (costly) external consultants (Parker & Redmond, 2009; Batra & Mahmood, 2003; OECD, 1997).

Other drivers of greening---such as requirements from environmental authorities, markets and or the surrounding community---are absent for many SMEs. Especially in emerging markets, these firms are difficult for environmental authorities to pursue (Blackman, 2009; 2006; 1997; Leal, 2005), which blunts one of the traditional drivers for environmental improvement (Boons et al., 2000; Baas, 2005). To make matters more difficult, imposing environmental requirements on this group of enterprises is not politically popular. Indeed, for SMEs in Latin America, the traditional driver of regulatory enforcement is almost non-existent (Maranto-Vargas & Gomez, 2007; Van Hoof & Herrera, 2007; Vives et al., 2005; Wells & Galbraith, 1999).

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[1] Official definitions of small and medium sized enterprises differ widely around the world; generally in developed countries, ranges of employment go up to 500 and annual turn-over up to U$D 20 million (Ayyagari et al., 2007). In developing countries, as in most of the Latin American countries, official SME statistics cover smaller enterprises up to 250 employees and about U$D 2.000.000 as annual turn-over (Vives et al., 2005; Zevallos, 2003).

Most SMEs in emerging markets tend to serve local markets where green "niches" are still incipient (Fundes, 2003; Grotz & Braun, 1993). As a result, incentives or pressures for environmental improvement from international clients are largely absent. In addition, non-governmental organizations (NGOs) and communities are often too weak to impose meaningful pressure on SMEs (Blackman, 2009; Londoño Toro, 2008). Compounding matters, transparency and availability of environmental information is often scarce in developing countries (Ehrenfeld et al., 2002). Considering all of these challenges, SMEs seem almost untouchable using the traditional drivers for the greening of companies and few, if any, new pathways appear to be emerging.

Research on the greening of SMEs in developing countries is still sparse and mainly descriptive (Blackman, 2006; Vives et al., 2005; Schaper, 2002; Hillary, 2000). Some studies have been published in the last 10 years in specialized journals such as the *Journal of Cleaner Production*. They focus primarily on the levels of adoption of specific environmental practices in SMEs in different regions, though sometimes they evaluate the causal relations between specific characteristics of SMEs and performance.

This paper is one of the first studies to empirically analyze the performance of green supply chain approaches as mechanisms for diffusing pro-active environmental management practices among SMEs in emerging markets. It assesses the cost-effectiveness of an innovative green supply chain pilot program developed in Mexico that leverages stakeholder relationships and learning-by-doing. We provide a summary of the program, explore its environmental and economic performance, and study the variables that influence outcomes of the green supply chain pilot program.

The rest of the paper is organized as follows. Section 2 provides a literature review and offers a simple conceptual framework for understanding the GSCP. Section 3 presents an overview of the program and its participants. Section 4 and 5 presents an assessment of the financial and environmental benefits of the program. Section 6 explores the factors that explain variation in performance. Section 7 concludes.

2. Conceptual Framework

In this section, we briefly review the growing literature on green supply chains and its conceptual frameworks as background information useful to understanding the basic design of the Mexican Green Supply Chain program.

Green supply chain approaches and related concepts have emerged over the last two decades as strategies for integrating environmental concerns into supply chain strategies (Bai & Sarkis, 2010; Lee, 2009; Seuring & Muller, 2008; Dimitratos et al., 2008; Vachon & Klassen, 2007; Srivastava, 2007; Zu et al., 2006; Tsouflas & Pappis, 2005; Chen, 2004; Hult et al., 2003). The interest in the integration of environmental management and supply chain management finds its origins in the increasing awareness and understanding of the relation between global production chains and sustainability.

Form a societal point of view, supply chains play an important role in regional development (Vachon & Mao, 2008). Corporations and their subsidiaries have an important impact on entrepreneurial output and network activities (Dimitratos et al, 2008). Their decisions affect the transfer of know-how in technology and management, and the enhancement of innovation for first, second and sometimes even third-tier suppliers (Dimitratos et al, 2008, Linton et al., 2007). Additionally, global supply chains affect environmental and social well being as they not only generate economic value and benefits to the customer, but also take steps to reduce the environmental and social impact of their different stages of production (Seuring & Muller, 2008; Sarkis, 2002). The social and environmental burden of an entire supply chain is often assigned, in the public eye, to a "focal" company, typically a large multinational at the top of the chain (Kovacs, 2008). Roberts (2003) emphasizes the importance of NGOs in holding focal companies responsible for environmental and social problems at earlier stages of their supply chain. The concepts of the ecological and carbon footprint offer a similar way of interpreting environmental and social impacts (Wackernagel et al., 1999). Altogether, these trends affect the "rules of the game" in the business context through take-back regulation, restrictions on the use of hazardous substances, and shifting preferences in consumer demands (Hoffman & Woody, 2007).

From a business perspective these environment-related changes in the market demand new perspectives on competitive advantage (Hart, 1995), including supply chain management practices. To determine the main motives for undertaking green supply chain initiatives, Aberdeen (2008), conducted a survey of 335 multinational companies around the world. He found the most important motive to be the "desire to be a leader for sustainability" (cited by 51% of the firms), followed closely by "rising cost of energy" (49%), "competitive advantage/differentiation" (48%), and more distantly by "current of expected government compliance) (31%) and "rising cost of inbound and outbound transportation" (24%).

Seuring & Muller (2008) present an integrative framework for the green supply chain concept that integrates the societal and business perspectives. Figure 1 illustrates the various pressures and incentives used by stakeholders to influence the behaviors of focal companies. The same figure shows how these pressures are passed on the their suppliers. Depending on the specific context, barriers or supporting factors such as internal capabilities (e.g. existence of ISO 14000 systems) or external market trends (e.g. oil prices) hinder or support cooperation.

====Figure 1 about here====

Hines & Johns (2001) identify four main mechanisms for supply chain management. Their approach starts with the common mechanism of developing questionnaires asking suppliers about their environmental performance; these questionnaires are often integrated into already existing practices used for quality control and are part of the supplier selection process (Hines & Johns, 2001, Birett, 1998). A second management technique that requires more resources and commitment is site visits carried out by company personnel or third parties. Third and forth are the mechanisms of partnering and mentoring. In these mechanisms, customers and suppliers work closely together on a number of levels and in a fairly integrated way to improve the operational efficiency of each (Hines & Johns, 2001).

Green supply chain initiatives can be seen as programs striving to transfer and disseminate environmental management practices through the entire supply chain by using the relationships between large buying firms and their suppliers (Lee, 2008). This idea can be especially useful in the context of an emerging market, like Mexico, where institutional drivers of environmental management in SMEs are weak and transactions costs to reach out to them are relatively high (Montiel et. al., 2009).

Building on the green supply chain concept and related experiences such as the Green Suppliers Program of the United States Environmental Protection Agency (EPA)[2], and considering the particular conditions of an emerging market context, the Commission on Environmental Cooperation in North America (CEC) designed the Mexican Green Supply Chain program. This innovative program employs a public/private partnership in order to trigger focal companies to diffuse eco-efficient practices throughout SMEs of their supply chain in Mexico.

3. Program Overview

In June 2004, the Council of Ministers of the Commission for Environmental Cooperation (CEC) issued a public communiqué known as the Puebla Declaration following its Eleventh Regular Session. It instructed the CEC Secretariat to strengthen its program with strategic plans beginning in 2005 aimed at achieving results in three priority areas (CEC, 2006): information for decision making, trade and environment, and capacity building, with special emphasis on Mexico. The Green Supply Chains Program was designed as a way to implement this mandate.

One key part of the program's design is the use of multinational companies as drivers to motivate SMEs to participate. This exploitation of "supply chain power" is also one of the key features of the US Environmental Protection Agency's Green Suppliers Program, and is supported on the notion that an important client can influence the behavior of its providers (Aberdeen, 2008; Suering & Muller, 2008, Cote et al., 2008; Simutupang & Sridharan, 2005). Of particular interest is that "supply chain power" can be an effective source of influence in contexts where other traditional drivers, such as enforcement of environmental regulation, are costly or limited in their implementation (Seuring & Muller, 2008; Srivastava, 2007).

At the same time, the strategy of involving multinational anchor companies in the GSCP also supposes that large companies benefit from their participation in the program. To obtain the commitment of the focal companies in the program, several arguments were used, including an improvement in their competitiveness as a result of process

[2]www.greensuppliers.gov/gsn/home.gsn

optimizations, Corporate Social Responsibility, leadership positioning, and improved relationships with suppliers (CEC, 2006).

The program design integrates concepts for strengthening the client-supplier relationship, optimizing operational processes through pollution prevention, and building capacities through experiential learning. Figure 2 describes the organizational structure of the GSCP and the main roles and activities for which each partner was responsible. The initial invitations to anchor companies came from the CEC, SEDESU[3] (the regional environmental authority in the state of Queretaro), and the Global Environmental Management Initiative (GEMI). These invitations offer the promise of improved regulatory relationship and visibility for the participating anchor companies, factors that have often been found to motivate firms to join Public Voluntary Environmental Programs sponsored by regulatory authorities. (Lyon and Maxwell 2007) The anchor companies then selected a group of suppliers to invite, who themselves might reasonably expect improved reputations and better relationships with a major client.

====Figure 2 about here====

At the heart of the GSCP is a 10-week eco-efficiency educational training program that emphasizes learning by doing, which was presented free of charge to participants by a group of trained service providers. As mentioned in the Introduction, most prior programs aimed at greening of SMEs have employed external consultants, whose recommendations are often not implemented. The GSCP utilizes a different model, in which the recommendations for change are made by the participants themselves. Using the eco-efficiency concepts and frameworks they were learning, the companies participating in the program were required to generate projects that contribute to increasing their productivity, competitiveness and environmental performance. Since anchor companies as well as SMEs sent participants to the program, the class experience itself and networking between the participants provided a direct opportunity for building relationships between clients and suppliers. More importantly, the scheme encourages the creation of group projects that improve interactions within the supply chain and offer new business opportunities. The learning-by-doing training method aims at capacity building and empowerment of employees inside each company through the way they engage their eco-efficiency projects (Dieleman, 2007). At the completion of each cycle of the program, there is a well-publicized ceremony to honor the participants and provide recognition for their efforts.

With this new program design for its Green Supply Chains Program, the CEC aims at creating an effective, replicable, cooperation-based mechanism for promoting competitiveness through pollution prevention in SMEs that supply large companies. The program aims to fulfill part of the CEC's mandate to promote cooperation in protecting and improving the environment, in the context of increasing economic and trade links in the North American region.

[3] www.queretaro.gob.mx

The total costs of program operation were around U$D 350,000 (Jose Carlos Fernandez, telephone interview, January, 2009). These costs involved the payment of the service providers, the logistical costs of the capacity building process and promotional events. The CEC provided finance for the payments of service providers, and the anchor companies of the supply chain provided the logistical support for the capacity building process of their own supply chain. Investments related to the implementation of the improvement projects were provided by the individual enterprises.

The first two phases of the program, which took place in 2005 and 2006, included participation by six leading multinational companies (Bristol Myers Squibb, Colgate-Palmolive, Clarion Industries, SIKA, Janssen-Cilag, Jumex) and 65 SMEs of their supply chains in Mexico. In September 2007 a third group of multinationals and local supply chains entered the program, among them Nestlé, Grupo Modelo, Henkel, La Corona, Guardian Industries, Bombardier, Collins & Aikman, and Donnelly, involving altogether 79 suppliers (CEC, 2008).

Overview of Program Statistics

During the pilot phase of the GSCP, 14 multinational corporations with operations in Mexico participated in the program. The involvement of eight of them was coordinated by the Mexican Global Environmental Management Initiative (GEMI)[4], while the multinationals with operations in Queretaro were selected and coordinated by the regional environmental authority SEDESU (CEC, 2008). Table 1 shows their main characteristics and period of participation.

====Table 1 about here====

The participating anchor companies were asked to take on a number of commitments: (CEC, 2005) (i) select and invite at least 10 providers from their supply chain, (ii) provide logistics (meeting room and drinks), during the development of the program (10 meetings), (iii) assign a representative to oversee the activities of the program (workshop meetings, communications) and (iv) follow up on the evaluation of the results and the implementation of the designed eco-efficiency projects. No additional out-of-pocket expenses were required for anchor company participation due to the offer of the CEC and SEDESU to assume the operational cost for the design and development of the GSCP pilot program (CEC, 2005).

Before proceeding to a more detailed analysis of participation in the program, we present some statistics that give an overview of the firms involved. Table 2 shows the number of SMEs participating within each supply chain (note that some supply chains participated more than once), by type of product supplied. The most common type of product

[4] The Mexican chapter of the Global Environmental Management Initiative (GEMI) is a business association of leading multinationals with operations in Mexico, which promote and share their sustainability practices and leadership (www.gemi.org.mx).

supplied was raw materials, followed closely by packaging and services. JUMEX had the largest number of SME participants, with 26, while Bombardier had the smallest number, with 6.

====Table 2 about here====

Table 3 shows the size of the companies involved, measured by number of employees, broken out by: (i) supply chain, and (ii) the type of good or service provided. The average number of employees in our anchor companies was 1,995; the average number of employees in SMEs that supply to them was 191.

====Table 3 about here====

Participating SMEs typically sent either one or two employees to participate in the program. The majority of participants had technical educations, though a substantial minority had business educations. Participants varied widely in their amount of experience, with two supply chains sending participants with only a maximum of 3 years of experience, while several others sent participants with 10 or more years of experience.

The results of the program can be seen in the improvement projects implemented as a result of the learning-by-doing training program. A total of 146 enterprises, comprising 132 SMEs and 14 focal companies, formulated improvement projects using eco-efficiency and cleaner production strategies. The projects included the implementation of good housekeeping practices (adopting sound operation and maintenance procedures), modification of technology (changes in equipment and technology, substitution of input materials) and new activities (on-site recycling, modification of products).

4. Cost/Benefit Analysis

In this section, we present an analysis of the aggregate financial performance of projects in the program. We begin by presenting results on the payback period associated with projects in the program. This is an extremely simple measure, and considered simplistic by financial analysts. However, it is easily accessible to policymakers and managers of SMEs. We then turn to calculating the financial benefits of the program using the more standard measure of net present value. The data underlying our analysis were provided by the program participants as they designed their projects; it is important to note that they represent expected savings based on engineering estimates.

Payback

Overall, the projects generated by the program appear to have been extremely beneficial from an economic perspective. Excluding one project deemed to be an outlier, the mean payback period was 0.68 years, or just over 8 months, with a standard deviation of 1.05

years.[5] This is an extremely short payback period, and indicates that the projects were highly profitable for the companies involved. Table 4 presents the payback period information for each of the supply chains in the program.

Net Present Value

An alternative, and more sophisticated, way of evaluating the economic benefits of the projects is to calculate their net present values (NPVs). This requires making assumptions about the duration of the benefits obtained from the projects, as well as the discount rate to be used. Table 4 presents NPV results under several different assumptions. We considered two different real discount rates, 10% and 20%, as well as two different benefit durations, perpetual and 5 years. Regardless of how one computes the economic benefits of the program, they are impressive. Even at a real discount rate of 20%, and a duration of benefits of just 5 years, the average project had a NPV of $158,641. Over the whole set of 146 projects, this yields a total NPV of $23,161,586. If one uses a real discount rate of 10%, and benefits last in perpetuity, the average project produces a value of $746,366 and the program as a whole produced $108,969,436. Other values fall between these two extremes. Regardless of the details one assumes, however, the value created by the program is impressive.[6]

====Table 4 about here====

It is interesting to examine more closely the performance of the top firms on the list. The chain with the highest average NPV of projects was Guardian Industries, with an average project value of $465,351, when evaluated according to our most pessimistic assumptions. This is a company with extensive experience in lean manufacturing and implementation of 6-Sigma programs, so it may not be surprising that they were able to perform well in this arena, too. They had hoped that the program would help to induce some of their transportation suppliers to make a substantial technology change, which was not ultimately accomplished. Nevertheless, the projects implemented in the Guardian supply chain were very successful. This was in large part due to the participation by TDR, a supplier who invested $138,351 in a project that is projected to save $516,784 per year. The second highest average was accomplished at IACNA. This may be because of the politics surrounding IACNA's acquisition of Collins and Aikman during the program. The target company was under pressure from SEDESU to reduce its waste output, and IACNA needed certification from SEDESU to complete the acquisition, which meant that SEDESU possessed a strong regulatory threat that could be imposed on IACNA. The third highest average financial performance was from Grupo

[5] The outlier project involved a company in the Bristol Meyers Squibb chain that made a modest investment of $3,450 to obtain an annual economic benefit of $15, for a payback period of 226 years. Furthermore, the only environmental gain associated with the project was a reduction in water use of 5 cubic meters/year.

[6] It is essential to keep in mind that these values are based on expected costs and benefits, not actual outcomes; there may be errors in estimation of the costs, benefits, discount rates, or benefit durations. Nevertheless, the numerical estimates were produced with care using the tools presented through the program, so we feel reasonably confident of their accuracy.

Modelo; our interviews with them suggested that they took an unusually strategic approach to selecting their SME participants and projects, which is consistent with their overall high economic performance. The selection and invitation of the suppliers was done by the purchasing department, whose representatives participated in all the workshop meetings. As the corporate officer of environmental health and safety (EHS) stated “It’s the intention of GM to develop its own Green Supply Chain Program in order to accompany the application of its life cycle strategy on a corporate scale.” (Fernando Aguirre, onside interview 5 th of May 2008)

5. Environmental Performance of the Program

The original motivation for creating the GPSC was to reduce the environmental impacts of SMEs in Mexico. Section 3 showed that the financial performance of firms in the program has been excellent. In this section we turn to their environmental performance. Overall, the program has also had substantial environmental impacts. Table 5 summarizes the aggregate impact of the program in various environmental dimensions.

====Table 5 about here====

To provide some perspective, the average Mexican uses 1,823 kwh/year,[7] so the program has offset the electricity use of roughly 3,384 citizens. An alternative perspective is that a large 2-megawatt wind turbine running at 35% capacity generates 6,132,000 kwh/year, so in terms of fossil-fired electricity avoided, the GSC pilot program has contributed roughly the same environmental benefits as one large wind turbine. With regard to carbon dioxide emissions, the average Mexican is responsible for 4.24 tons/year of CO_2,[8] so the program has offset the emissions of roughly 2,104 average Mexican citizens. In terms of water use, the average urban Mexican uses 270 liters/day,[9] or about 99 cubic meters/year. Thus, the program offset the water use of about 2,835 average urban Mexican citizens.

Table 6 presents summary information regarding the environmental performance of the participants, again broken out by supply chain.

====Table 6 about here====

It is clear from the table that improved efficiency in the use of electricity is the single most consistent source of environmental benefits from the program. Reductions in CO_2 emissions were also achieved in all supply chains, and water use reductions were also

[7] http://www.iaea.org/inisnkm/nkm/aws/eedrb/data/MX-elcc.html
[8] http://www.carbonplanet.com/country_emissions
[9] www.conagua.gob.mx SISTEMA NACIONAL DE INFORMACIÓN DEL AGUA (SINA) (National water system in Mexico).

quite common. Savings on natural gas usage or avoided waste disposal were more varied and idiosyncratic.

6. Econometric Analysis of Participation and Performance

The foregoing sections have provided a picture of the overall financial and environmental benefits of the GSCP. This section makes use of econometric analysis to explore how program results at participating firms were affected by factors such as industry effects, organization size, regional effects, and the backgrounds of the program participants.

The dependent variables to be considered are: 1) Financial benefits (NPV or payback period), 2) Environmental benefits (greenhouse gas reductions, water savings, reduced waste, reduced use of raw materials), and 3) Implementation rates for projects identified in the program

In particular, we examine whether "better" projects---that is, projects with larger NPV, shorter payback, and better environmental outcomes---are proposed by larger firms, firms in particular industries, firms supplying particular anchor companies, or participants with particular characteristics. In addition, we explore whether firms were more likely to implement their projects if they were larger, their program participants were in technical or operations positions, or they proposed projects with larger benefit/cost ratios.

6.1 Data

Our data were collected directly from participating companies through surveys completed by company representatives. We have data for each participating company including the number of employees, the anchor company to whom they supply, and the type of good or service supplied (e.g, packaging material, printing and promotional material, raw materials, services, or indirect supplies). We also have fairly extensive data on the projects undertaken, including the up-front investment required, expected monetary savings per year, expected energy savings, and expected environmental improvements. Summary data were presented in Tables 4 and 5 above. In addition, we know what type of project was implemented by each firm (procedure change, technology change, or addition of a new activity), and the extent of project implementation. Finally, we know how many participants each company sent to the program, their educational backgrounds (technical, administrative, or other), their positions within the company (directive, operations, administrative, commercial), and their number of years experience with the company. A full list of the variables included in our analysis is presented in Appendix A.

6.2 Econometric Specifications

We utilize ordinary least squares (OLS) estimations to explore the drivers of better quality projects (both financially and environmentally), and implementation rates. We begin by exploring the factors associated with "better" projects. For our economic analysis, we focus on the determinants of project NPV. We have no information about the duration of the benefits from the proposed projects, so will make the simplifying assumption that they all produce benefits into the indefinite future; that is, we will treat the benefits from each project as a perpetuity. Thus, the net present value of a project that produces annual savings of X, when the interest rate is r, is simply X/r. If the investment required for the project is I, then NPV = X/r-I.

Our econometric specification is

$$y_{ijk} = \alpha_j + \beta x_i + \gamma_k + \varepsilon_{ij}$$

where

y_{ij} = NPV for the project(s) of firm *i* in supply chain *j* in industry *k*
α_j = Effect of supply chain *j*
γ_k = Dummy variable indicating firm is in industry *k*
x_i = Vector of independent variables described above
ε_{ijk} = Error term

A similar specification is employed for environmental benefits.

We are also interested in which firms were more likely to implement proposed projects, focusing on the effects of (a) firm size, (b) projected economic benefits of the project, and (c) the educational background and employment role of program participants. In addition, it is appropriate to include a number of control variables, including: the type of product or service supplied by the firm, the type of project under consideration, the region in which the company is located and the identity of the anchor company. The dependent variable is the percentage of implementation achieved for the project.

Our specification is then

$$y_{ijk} = \alpha_j + \beta x_i + \gamma_k + \varepsilon_{ijk}$$

where

y_{ij} = Implementation level for the project(s) of firm *i* in supply chain *j*
α_j = Effect of supply chain *j*
γ_k = Dummy variable indicating firm is in industry *k*
x_i = Vector of independent variables described above
ε_{ij} = Error term

6.3 Results

Results for OLS estimation of the determinants of NPV of projects are presented in Table 7. Three basic specifications are tested, which vary based on whether dummy variables for anchor companies and type of supply are included. A fourth specification is also included which drops the observation with the lowest NPV, as a robustness check. The explanatory power of all the regressions is relatively weak. The most striking result is that larger firms tend to propose projects with greater NPV. Quantitatively, a firm with

1,000 more employees would propose a project whose NPV was about $150,000 greater. This is an important result because it suggests that larger firms have not wrung out all efficiencies from their production processes. Indeed, the low-hanging fruit seems at least as plentiful in larger firms. We also find that participants with more experience, and those with technical educations, tend to propose more valuable projects, though these effects are not statistically significant. Finally, participants in marketing positions propose less valuable projects, though the effect is not significant at conventional levels. The positive coefficient implies that participants with more experience are willing to accept projects with longer payback periods. However, estimation 4 shows this result is not robust to dropping the single observation with the longest payback period; when this observation is dropped, none of the independent variables have significant explanatory power.

====Table 7 about here====

Results for environmental improvements are presented in Table 8. In estimation 1, on electricity savings, we find that none of the independent variables have significant explanatory effects. Furthermore, none of the supply chain dummies are significant. Results for natural gas savings (not shown) are similarly insignificant, except that anchor companies showed no systematic advantage relative to SMEs. Results for CO_2 reductions show that participants in administrative positions tended to generate projects with larger CO_2 reductions, while participants in marketing tended to generate projects with smaller CO_2 reductions. Finally, results for water use savings show that larger firms generated larger reductions in water use. Regressions on the other environmental outcome variables generated no significance on any explanatory variables.

====Table 8 about here====

Finally, we turn to implementation rates, results for which are presented in Table 9. This regression has much greater explanatory power than the others, with an adjusted R-squared of just over .50. A number of variables have significant effects. First, it appears that "more cooks spoil the broth," since implementation rates decline with the number of participants from a single firm. Second, participants with technical educations or business administration educations were more likely to implement their proposed projects than were other employees. Finally, participants in administrative or marketing positions tended to achieve lower implementation rates. Somewhat surprisingly, participating firms were no more likely to implement a project with a high NPV than a low one.

====Table 9 about here====

Our analysis in sections 3 & 4 of the overall impacts of the GSCP was quite positive, especially regarding the economic benefits to participating firms. When it comes to assessing what factors led to success, however, the explanatory power of our regressions is relatively weak, making it difficult to say much about the factors that explain variation in economic or environmental benefits from participation in the program. One interpretation of this combination of results is that the methodology of the program is quite robust, so it produces results regardless of the characteristics of the firms in the program. In order to test this hypothesis, we would need to have a reliable control group of SMEs that were not in the program. This may be possible in future work as the program continues to grow.

7. Discussion and conclusions

Overall, we conclude that the Mexican Green Supply Chain experience offers a promising model for engaging SMEs to improve their environmental management practices. Our research shows how a public-private alliance between an international public organization such as the CEC, a regional environmental authority such as SEDESU, a group of large focal companies and local suppliers can work together achieve mutual economic and environmental benefits.

The public institutions interested in reducing the environmental burden of local SMEs found innovative ways to reduce the transaction costs of reaching out to this challenging group of enterprises. By benefiting from the supply chain power of the large focal companies and the efficient learning-by-doing approach, the average cost to formulate eco-efficiency projects was brought down to less than U$S 2,500 per company[10]. This value is significantly lower than the estimated expenses of technical assistance programs organized around external consultancies. Experience with technical assistance of comparable eco-efficiency projects shows significant higher costs (Batra & Mahmood, 2003). Additionally, reductions of the environmental harms produced by SMEs are impressive. These findings comport with the ideas of Blackman (2006), who suggests "group approaches" as a main strategy to make progress towards environmental management of SMEs in emerging markets.

Both the large anchor companies and SMEs obtained significant economic benefits from their participation in the program. We found that the average SME participant in the program generated a project that had a payback period of roughly eight months and generated a net present value of over $150,000; saved 1,900 cubic meters of water each year; saved 42,000 kwh/year of electricity; reduced carbon dioxide emissions by 61 tons/year; and cut waste disposal by 1,455 tons. Arguably the economic savings generated by the program are at least as impressive as the environmental improvements. Additional benefits of the program included improved supply chain relationships, improved reputation with a variety of stakeholders, and lower internal costs.

[10] Operational cost of the program summed up to U$D 350000. Within this budget, 146 companies formulated eco-efficiency projects. This makes up average costs of U$D 2400 per company.

In terms of the drivers of success, we found that larger companies undertook projects with higher net present values, and generated greater carbon reductions and water use savings, though not greater electricity savings. These results are consistent with the findings from Hitchens et al. (2005) and Friedman & Miles (2002) in their research on the environmental performance of SMEs in Europe.

The impressive results confirm the presence of unexploited “win/win” opportunities in companies for eco-efficiency projects to both save money and reduce environmental damages. This would imply that focal companies as well as SMEs should not require substantial incentives to participate. Nevertheless we remain mindful of the often-heard eco-efficiency and cleaner production paradox (Baas, 2006; Moors et al. 2005; Zilahy, 2004); “when these strategies are so attractive, why isn’t everyone doing it?” Parker et al. (2009), in their review of interventions to encourage SMEs to make environmental improvement, show that mentoring is a key element of progress in environmental management. Our case illustrates how the mentoring of SMEs can be assured through supply chain approaches. However, further research on the implementation rates of projects and the generation of follow-on projects is needed to gain a deeper understanding of the potential of the GSC model. In addition, expanding the sample size and the use of a control group of SMEs who did not participate in a similar program are needed to confirm the value and replicability of the GSC model, as well as to understand the motives and needs of the focal companies for their participation.

The Secretary of Natural Resources of the Mexican Government, SEMARNAT, has decided to continue the described model. Since September 2008 SEMARNAT has been leading an ambitious green supply chain program identical to that described here in which about 600 SMEs have participated to date (Arturo Rodriguez, telephone interview, 25 of August 2010). The results and data gathered in this complementary experience will provide useful data for deeper academic research on this topic.

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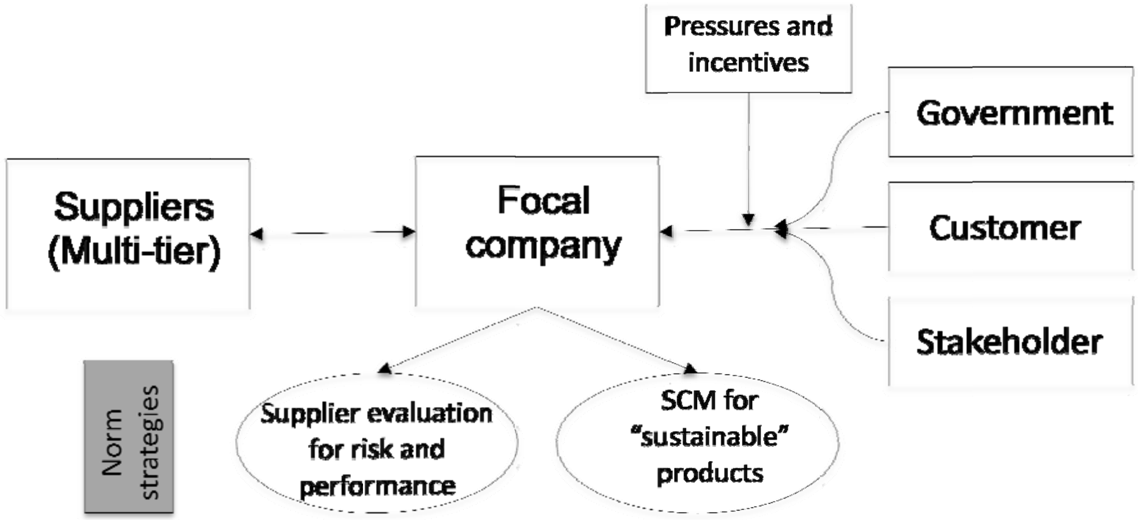

Figure 1: Triggers for Sustainable Supply Chain Management
(from Seuring and Muller 2008)

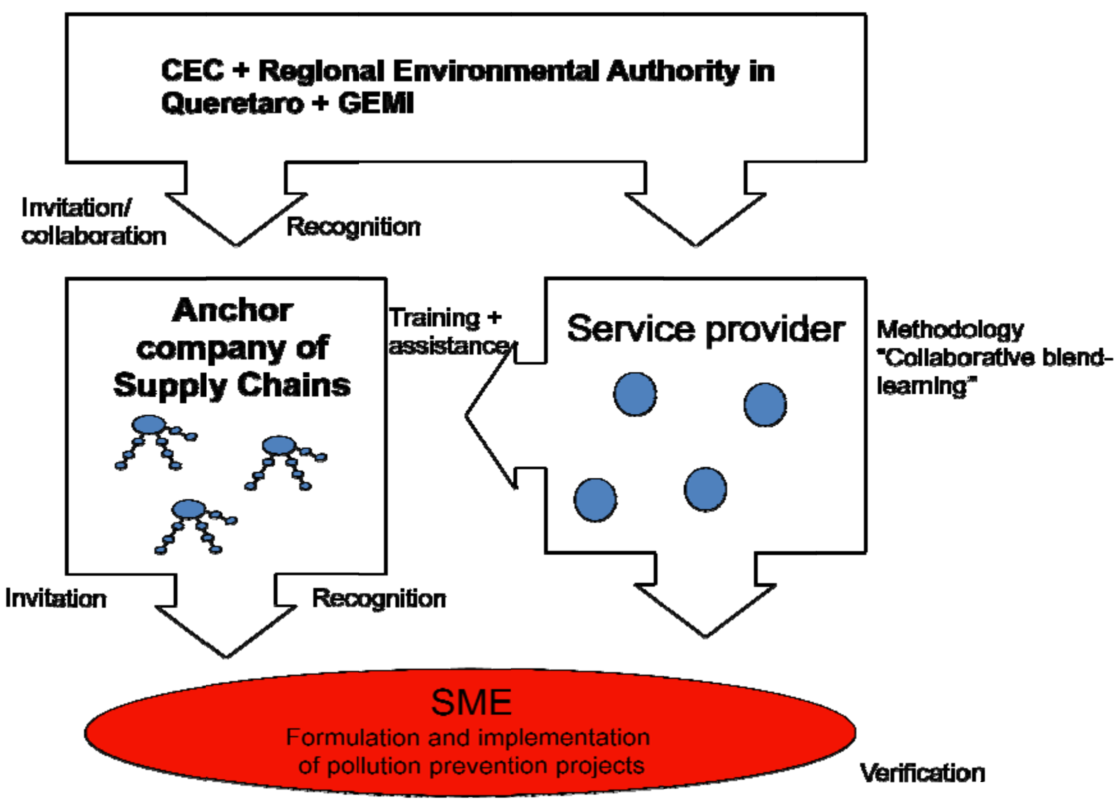

Figure 2: Operative Structure of the Green Supply Chain Program

Table 1 Multinationals who participated in the Mexican GSCP

Sector	Multinational	Location	Invitation	Period of participation
Pharma-ceutical	Bristol Myers Squibb (BM) Janssen Cilag (JC)	Mexico DF Mexico DF	GEMI GEMI	05/06 + 06/07 05/06
Chemical	Colgate–Palmolive (CP) SIKA (SK) HENKEL (HK) Fabrica Jabones la Corona (CR)	Mexico DF Queretaro Mexico DF Mexico DF	GEMI SEDESU GEMI GEMI	05/06 + 06/07 06/07 07/08 07/08
Food	JUMEX (JM) Grupo Modelo (GM) Nestlé (NE)	Mexico DF Mexico DF Mexico DF	GEMI GEMI GEMI	06/07 + 07/08 07/08 07/08
Aircraft mfg	Bombardier (BB)	Queretaro	SEDESU	07/08
Auto parts mfg	Guardian Industries (GI) IACNA (IA)	Queretaro Queretaro	SEDESU SEDESU	07/08 07/08
Electronics	Clarion (CL)	Queretaro	SEDESU	05/06
Publicity & commun-ications	RR Donnelley (RD)	Queretaro	SEDESU	07/08

Table 2: Number of Suppliers by Supply Chain and Type of Participant

Supply Chain	Packaging	Printing& Promotion	Raw Material	Service	Indirect Supplies	Total SMEs
BB	4		2			6
BM	5	4	5		3	17
CL	3	1	1		2	7
CP	2	7	7	1	2	19
CR	1	2	7	4		14
GI	1		1	9		11
GM	8	1	1	3	4	17
HK	1	2	2	7	2	14
IA	2	1		5		8
JC	2	7				9
JM	11	3	9	2	1	26
NE		1	6	1		8
RD	3		3	4		10
SK			5	5	1	11
TOTAL	**43**	**29**	**49**	**41**	**15**	**177**

Table 3: Number of Employees by Supply Chain and Type of Participant

Supply Chain	**Anchor Company**	**Packaging**	**Printing& Promotion**	**Raw Material**	**Service**	**Indirect Supplies**
BB	740	60		48		
BM	1800	190	203	113		31
CL	747	223	10	2		228
CP	1200	383	115	210	57	235
CR	3860	145	118	285	294	
GI	275	250		31	109	
GM	4500	227	150	80	109	131
HK	886	25	90	244	523	335
IA	250	78	20		69	
JC	1000	105	107			
JM	5000	381	146	93	12	110
NE	2500		250	234	135	
RD	650	22		185	143	
SK	N/A			409	313	15

Table 4: Economic Benefits of Green Supply Chain Projects, by Supply Chain

Supply Chain	Payback (Years)	NPV ($) @10% Perpetuity	NPV ($) @20% Perpetuity	NPV ($) @ 10% 5 Years	NPV ($) @ 20% 5 Years
BB	0.23	206,011	100,619	64,185	49,776
BM	0.57	436,458	210,969	133,646	102,817
CL	0.16	243,737	120,872	77,879	61,080
CP	0.67	369,405	168,142	102,060	74,543
CR	0.80	1,002,367	432,096	251,248	173,243
GI	0.46	1,948,187	947,042	602,230	465,351
GM	1.15	1,218,146	575,199	358,558	270,653
HK	0.74	428,899	185,920	108,624	75,404
IA	0.43	1,235,810	591,605	372,317	284,240
JC	1.07	465,774	211,145	127,771	92,958
JM	0.35	747,713	369,412	237,437	185,715
NE	1.11	1,523,537	618,313	341,163	217,399
RD	0.17	569,825	278,858	178,118	138,337
SK	2.62	874,934	361,729	202,975	132,809
AVERAGE	**0.684**	**746,366**	**346,427**	**213,322**	**158,641**

Table 5: Aggregate Environmental Benefits of the Green Supply Chain Program

Environmental Measure	**Annual Benefits**	**5-Year Benefits**
Electricity Savings (kwh/year)	6,199,095	30,995,474
Natural Gas Savings (m^3/year)	1,060,564	5,302,818
Diesel Fuel Savings (liters/year)	303,939	1,519,695
CO_2 Emissions Reduction (tons/year)	8,922	44,611
Water Use Savings (m^3/year)	279,424	1,397,121
Effluent Reduction (m^3/year)	1,748	8,741
Avoided Waste Disposal (tons/year)	212,467	1,062,333
Reduced Raw Material Use (tons/year)	22,058	110,292

Table 6: Environmental Benefits of Green Supply Chain Projects, by Supply Chain

Supply Chain	Electricity Savings (kwh/year)	Natural Gas Savings (m^3/year)	CO_2 Emission Reductions (tons/year)	Reduced Water Use (m^3/year)	Avoided Waste Disposal (tons/year)
BB	69325	3	45	0	7
BM	24378	0	16	195	3
CL	35224	0	23	1613	10
CP	94996	15	62	2123	100
CR	28744	66364	164	450	0
GI	87750	1	372	3690	219
GM	59916	0	39	4702	0
HK	58056	0	38	3487	84
IA	3150	0	2	0	243
JC	3321	0	2	0	25736
JM	15131	15726	44	3384	6
NE	16703	0	11	489	1
RD	51539	0	34	119	4
SK	2818	0	9	2585	44
AVERAGE	**42460**	**7264**	**61**	**1914**	**1455**

Table 7: Determinants of Project NPV (US $)

Variable	1	2	3	4
Employees	142.98*** (3.18)	156.26*** (3.53)	166.0323*** (3.11)	165.91*** (3.10)
Participant Experience	1944.159 (.43)	5168.858 (1.10)	3235.153 (.68)	3650.085 (.72)
Number Participants	82878.8 (1.08)	57541.37 (.74)	17445.63 (.22)	16953.42 (.21)
Technical Education	-128656.2 (-1.28)	-34954.53 (-.38)	29084.82 (.27)	28600.71 (.27)
Administrative Education	-166745* (-1.77)	-35059.2 (-.87)	-52707.7 (-.68)	-53678.5 (-.54)
Unspecified Education	-122397.7 (-1.12)	-119569.1 (-1.09)	-129088.9 (-1.17)	-128953.1 (-1.16)
Supervisory Job	22519.1 (.35)	24470.46 (.38)	20656.02 (.31)	22618.75 (.34)
Operations Job	101607.8 (1.58)	85678.96 (1.28)	58441.14 (.87)	58733.16 (.37)
Administrative Job	177152.9 (2.08)	60991.38 (.67)	51802.58 (.55)	51268.92 (.54)
Marketing Job	11616.34 (.74)	-17903.46 (-1.05)	-21194.33 (-1.22)	-21461.81 (-1.23)
Anchor Dummies	No	Yes	Yes	Yes
Supply Type Dummies	No	No	Yes	Yes
Adjusted R-squared	.0976	.1729	.1968	.1937

t-statistics in parentheses
* = Significant at 10% level
** = Significant at 5% level
*** = Significant at 1% level

Table 8: Determinants of Environmental Benefits

Variable	Electricity Savings	CO_2 Reductions	Water Use Savings
Employees	-11.08 (-.60)	.0098 (.31)	4.988*** (5.72)
Participant Experience	-155.755 (-.10)	-1.366 (-.49)	-73.66 (-.95)
Number Participants	-17221.98 (-.68)	9.908 (.21)	-930.44 (-.72)
Technical Education	-369.74 (-.01)	-13.032 (-.21)	713.62 (.41)
Administrative Education	-28,581.27 (-.84)	-46.125 (-.79)	317.97 (.20)
Unspecified Education	-13286.34 (-.35)	-56.998 (-.87)	173.25 (.10)
Supervisory Job	14085 (.62)	48.14 (1.23)	-237.37 (-.22)
Operations Job	6557.79 (.28)	-.793 (-.02)	-1022.764 (-.98)
Administrative Job	21557.9 (0.67)	120.07** (2.16)	1408.67 (.92)
Marketing Job	-3,376.65 (-.57)	-20.235** (-1.97)	-340.48 (-1.20)
Anchor Dummies	Yes	Yes	Yes
Supply Type Dummies	Yes	Yes	Yes
Adjusted R-squared	.1115	.0843	.3863

t-statistics in parentheses
*   = Significant at 10% level
** = Significant at 5% level
*** = Significant at 1% level

Table 9: Determinants of Implementation Rates

Variable	Total Implementation Rate
NPV	-7.39×10^{-7} (-.10)
Employees	-.006 (-1.42)
Participant Experience	-.126 (-.33)
Number Participants	-11.57* (-1.87)
Technical Education	19.48** (2.25)
Administrative Education	18.25** (2.27)
Unspecified Education	3.88 (.42)
Supervisory Job	-8.13 (-1.61)
Operations Job	-6.749 (-1.21)
Administrative Job	-15.89** (-2.13)
Marketing Job	-4.96*** (-3.89)
Anchor Dummies	Yes
Supply Type Dummies	Yes
Adjusted R-squared	.4768

t-statistics in parentheses
* = Significant at 10% level
** = Significant at 5% level
*** = Significant at 1% level

APPENDIX A: Data Employed

Company Characteristics

supplychain	reference to the anchor company of the supply chain
employees	number of employees
supplytype	type of supply (1) packaging material; (2) printing + promotion material; (3) raw material; (4) service; (5) indirect supplies

Project Characteristics

Project Costs and Benefits

projects	number of projects formulated
plannedinvt	planned total investment (in mexican pesos MX$)
plannedbenefits	planned total economic benefits (in mexican pesos MX$/year)
plannedelecsav	planned energy savings (KwH/year)
plannedgassav	planned energy saving (m3 gas/year)
planneddieselsav	planned energy savings (liters of diesel/year)
plannedco2sav	planned saving in greenhouse gasses (ton CO2/year)
plannedwaterusesav	planned water use savings (m3/year)
plannedwatcontamprevent	planned prevention of water contamination (m3/year)
plannedwastedisprevent	planned prevention of waste disposal (ton/year)
plannedrawmatsprevent	planned prevention of raw material use (ton/year)

Project Types

proceduretype	number of best practice projects formulated
technologytype	number of technology change projects formulated
newactivitytype	number of new activity projects formulated

Project Implementation

procedureimplement	%-age implementation of best practice projects
technologyimplement	%-age implementation of technology change projects
newactivityimplement	%-age implementation of new activity projects
totalimplement	%-age implementation of all project(s)

month	month of the participation in the programme
year	year of the participation in the programme
withdrawn	the company withdraw the programme or didn't formulate a project (0) withdraw or didn't present a project; (1)presented at least one project
Momwithdrawn	moment in which the company withdrew from the program (0) completed;

	(1) 1 - 3 meetings; (2) 4 - 9 meeting; (3) company completed training but didn't present its project

Participant Characteristics

noparticip	number of participants in the training program per company

Participant Education

proftec	number of participant with a specific profile; technical education
profadm	number of participant with a specific profile; administrative education
profnoesp	number of participant with a specific profile; education not specified

Participant Position

partdir	number of participants in directive positions within the company
partoper	number of participants in operations positions within the company
partadm	number of participants in administrative positions within the company
partcom	number of participants in commercial positions within the company
partexper	maximum year experience of participants within the company

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