Energy Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Short Communication

Green supply chain management and environmental performance of firms in the bioenergy sector in Brazil: An exploratory survey

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HIGHLIGHTS

- To achieve sustainable development, supply chains must become greener.
- Little is known about these subjects in the context of firms in the bioenergy sector.
- This research is based on an exploratory survey.
- GSCM practices strengthen the EP of firms in the sector.

ARTICLE INFO

Article history:
Received 9 April 2014
Received in revised form
17 June 2014
Accepted 18 June 2014

Keywords:
Green supply chain management
Environmental performance
Sustainable supply chain management
Sustainable operations
bioenergy
Brazil

ABSTRACT

To achieve sustainable development, supply chains must become greener. In this context, the importance of green supply chain management (GSCM) increases because it can contribute to improving firms' environmental performance (EP). However, little is known about these subjects in the context of firms in the bioenergy sector (sugarcane and ethanol production in Brazil). Thus, the objective of this work is to present the results of a survey conducted on 80 micro-, small-, and medium-sized firms that are suppliers in the Brazilian bioenergy sector (sugarcane and ethanol production). These results indicate that GSCM practices strengthen the EP of firms in the sector. Therefore, this article contributes to the existing literature because it addresses the relationship between GSCM and EP in an understudied sector (sugarcane and ethanol production).

1. Introduction

This work focuses on using structural equation modeling (SEM) to understand the relationship between green supply chain management (GSCM) practices and environmental performance (EP). Although this relevant relationship has been studied in various industrial sectors as power generating, chemical/petroleum, electrical/electronic and automobile (Zhu et al., 2007a), searches in the Scopus and Institute for Scientific Information (ISI) Web of Science database indicate that there is a dearth of studies on this topic in the Brazilian bioenergy sector (sugarcane and ethanol production).

In Brazil, the bioenergy sector occupies a relevant position in the national economy. For example, during the 2011/2012 harvest, the financial turnover of firms in this sector was about $25 billion USD, which represented 3% of the Brazilian gross national product (GNP) (PROCANA). This sector is also responsible for creating millions of direct and indirect jobs in Brazilian society (PROCANA). Given the importance of this sector, a study with suppliers of bioenergy (sugarcane and ethanol production) is justified.

This study seeks to answer the following question: What is the relationship between GSCM practices and the EP of micro-, small-, and medium-sized firms that supply the bioenergy (sugarcane and ethanol production) sector in Brazil?

The study assumes the existence of a positive relationship between GSCM practices and the EP of micro, small and

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http://dx.doi.org/10.1016/j.enpol.2014.06.019
0301-4215/

medium-sized companies that supply the bioenergy (sugarcane and ethanol production) sector in Brazil.

2. Brief conceptual background

Zhu and Sarkis (2006) state that green supply chain management (GSCM) encompasses all supply chain activities related to ecological/environmental and economic issues; these activities may range from the initial raw material phase to the end user. According to Vachon and Klassen (2006), GSCM consists of a set of environmental practices that support the improvement of the environmental performance of two or more organizations within the same supply chain. The GSCM practices considered in this study are based on the work of Zhu and Sarkis (2004), that include (a) support from top management; (b) International Organization for Standardization (ISO) 14001 certification; (c) environmental audits at supplier sites; (d) cooperation for environmental management; (e) cooperation for ecodesign; (f) the sale of scrap and used materials; and (g) reductions in the use of dangerous and toxic materials.

According to Srebotnjak (2007), environmental performance (EP) assessments consist of evaluating the results of a system from a perspective centered on reducing the impact of environmental problems by developing and improving policies and procedures that seek to enhance the relationships among traditional objectives and sustainability. For example, EP metrics include (a) reductions in water consumption (Jeswani and Azapagic, 2011); (b) reductions in the number of environmental accidents (Hunt and Auster, 1990); (c) reductions in the emission of atmospheric pollutants (Mensah and Blankson, 2013); (d) reductions in the consumption of dangerous/toxic materials (Zaabi et al., 2013); and (e) reductions in the production of solid waste (Lin et al., 2013).

However, little is known about the relationships among the aforementioned concepts in the Brazilian bioenergy sector (sugarcane and ethanol production), which produced approximately 560 million tons of sugarcane during the 2011–2012 harvest.

3. Research methodology

Based on the research framework and the research hypothesis (H_1) that the adoption of GSCM practices may improve environmental performance (EP) of firms (Fig. 1), data were collected through an email survey sent to approximately 1000 micro, small, and medium-sized firms (suppliers of inputs for sugarcane and ethanol production) between February and October of 2013.

The questionnaire was sent to the owners/general managers of these companies. Responses were received from 80 firms. Based on the G*Power 3 software program (Faul et al., 2007), under the specified parameters, the minimum acceptable sample size was about 70 answered questionnaires; therefore, the 80 questionnaires received were sufficient to satisfy the minimum sample size requirement.

The first version of the questionnaire was screened by selected Brazilian scholars and managers within the sector of bioenergy (sugarcane and ethanol production) in order to verify the quality of the questionnaire. Based on this process of feedback, a final version of the questionnaire was obtained. The final version of the questionnaire used in this research was divided into three main sections. In the first section, we first asked for information regarding the number of employees in the surveyed firm aiming to classify firms based on their size (micro-, small-, or medium-sized firms). The questionnaire also included a second section on GSCM practices. We inserted some GSCM practices obtained from the research of Zhu and Sarkis (2004); these selected practices were validated in the literature and utilized in prior studies (Jabbour et al., 2013; Zhu et al., 2013). Thus, for GSCM practices a five-point *Likert* scale was adopted in which 1 corresponded to "not implemented" and 5 corresponded to "completely implemented." The following seven GSCM-related assertive were included in the questionnaire:

(1) Top management is committed to environmental management in the supply chain. (V1)
(2) The firm (supplier) has received ISO 14001 certification. (V2)
(3) Environmental audits are conducted at supplier plants/sites. (V3)
(4) Communication between focal company and suppliers allows environmental improvements in the supply chain. (V4)
(5) There is cooperation between focal company and suppliers to use environmentally friendly packaging (i.e., returnable packaging). (V5)
(6) Scrap and used materials are sold. (V6)
(7) The firm (supplier) develops product designs to reduce or avoid the use of dangerous and toxic materials. (V7)

Finally, within the questionnaire, a third section on EP was inserted. There were five items in the questionnaire that measured EP. Managers/owners were asked about the EP measures of their firms in the last five years. These items also utilized a five-point *Likert* scale; in this case, 1 corresponded to "complete disagreement," and 5 corresponded to "complete agreement." The following survey assertive related to EP variables:

(1) The firm (supplier) reduced its water consumption. (V8)
(2) The firm (supplier) reduced its number of environmental accidents. (V9)
(3) The firm (supplier) reduced its emission of atmospheric pollutants. (V10)
(4) The firm (supplier) reduced its consumption of dangerous/toxic materials. (V11)
(5) The firm (supplier) reduced its quantities of solid waste (V12)

The SmartPLS 2.0 (beta) software application was used to analyze the questionnaire results by SEM.

4. Results

For the GSCM practices construct (Table 1), the highest mean ratings were 3.638 (for V6—"Scrap and used materials are sold."), 3.175 (for V7—"The firm (supplier) develops product designs to reduce or avoid the use of dangerous and toxic materials"), and 2.450 (for V1—"Top management is committed to environmental management in the supply chain"), whereas the lowest average ratings were 1.450 (for V2—"The firm (supplier) has received ISO 14001 certification"), 1.600 (for V3—"Environmental audits are conducted at supplier sites"), and 2.000 (for V5—"There is cooperation with between focal company and suppliers to use environmentally friendly packaging").

For the EP construct, the highest average rating was 4.050 (for V9—"a reduction in the number of environmental accidents"), and the lowest average rating was 3.650 (for V8—"a reduction in water consumption") (Table 2). All average ratings for the EP construct were higher than the average ratings for the GSCM construct.

Additionally, Table 3 shows that GSCM practices have some correlations. Table 4 shows that some correlations between environmental performance variables are present too.

The study hypothesis was tested by SEM, which was performed with the SmartPLS 2.0 (beta) software application. Certain GSCM variables did not fit the model and were therefore removed.

Table 5 presents the results for the empirically tested model, including various indicators that measure model quality (average variance extracted [AVE], composite reliability, R^2, Cronbach's alpha, and communality). These indicators lie within satisfactory

Please cite this article as: Stefanelli, N.O., et al., Green supply chain management and environmental performance of firms in the bioenergy sector in Brazil: An exploratory survey. Energy Policy (2014), http://dx.doi.org/10.1016/j.enpol.2014.06.019