Transportation Research Part E 73 (2015) 84–95

Contents lists available at ScienceDirect

Transportation Research Part E

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

A bilevel programming model for corporate social responsibility collaboration in sustainable supply chain management

Che-Fu Hsueh *

Department of Marketing and Distribution Management, Chien Hsin University of Science and Technology, Taoyuan 32097, Taiwan

ARTICLE INFO

Article history:
Received 29 August 2014
Received in revised form 14 October 2014
Accepted 18 November 2014
Available online 9 December 2014

Keywords:
Sustainable supply chain management
Corporate social responsibility
Bilevel programming
Variational inequality

ABSTRACT

This study proposes a bilevel programming model in which the supply chain (SC) director determines optimal performance levels of corporate social responsibility (CSR) and compensation for all SC actors, thus maximizing total SC profits. Given the fixed CSR performance levels, the equilibrium product flows are determined in the lower-level model, in which the profit-maximizing behavior of the individual SC actor is considered and formulated as a variational inequality. The test results show that it is possible to improve not only performance of CSR, but also the profits of both individual SC actors and the whole SC through proper SC collaboration.

1. Introduction

The development of industrial technology enables companies to pursue their growth and profits at a very fast pace. This can lead to severe impacts on our environment and society. Consumers, governments, and other stakeholders are pressuring companies to be more responsible for their business operations and to strike a balance between profitability and sustainability. Therefore, the integration of environmental, social, and economic aspects of sustainability, known as triple bottom line (Elkington, 1997), has become an important issue to both managers and researchers.

Sustainability is not just an internal issue within an organization. Globalization increases demands on sustainable supply chain management (SSCM). SSCM focuses on the forward supply chain (SC) (Seuring and Müller, 2008) and is complemented by closed-loop supply chain management (Guide and Van Wassenhove, 2009), including reverse logistics, remanufacturing, and product recovery. SSCM has received a lot of attention for the past two decades. Many studies in this field are based on empirical research, including field research, case study, and broad-based empirical surveys. Others may include either conceptual or quantitative models (Brandenburg et al., 2014). For more details about related research, readers may refer to three review papers conducted recently by Tang and Zhou (2012), Seuring (2013), and Brandenburg et al. (2014).

According to these reviews, only a small part of papers in SSCM applies quantitative models, many of which are quite recent in development. In addition, they all suggest that the integration of social issues into formal modeling should be a research direction that deserves further investigation. Therefore, this study will focus on developing a quantitative model to determine optimal performance levels of sustainability (social or environmental dimensions) and compensation for all the SC actors, thus maximizing the total SC profit. The equilibrium product flows are also determined in its lower-level model, in which the behavior of the individual SC actor that maximizes its own profit is well considered.

This paper tries to answer the following questions: Is it possible that the SC's profits and the individual profits can be improved by CSR collaboration? How high should the CSR performance levels be set for SC actors in collaboration? In the

* Tel.: +886 3 4581196x7507.
E-mail address: cfhsueh@uch.edu.tw

http://dx.doi.org/10.1016/j.tre.2014.11.006
1366-5545/

following, we review recent studies about formal models for SSCM in Section 2. Section 3 describes the problem and presents the model formulation. The solution algorithm is proposed in Section 4, and numerical examples are provided in Section 5 for illustration. Conclusions are made in Section 6.

2. Literature review

Managing supply chains in a sustainable manner has become an increasing concern for many company managers and researchers Seuring and Müller (2008) reviewed 191 papers published from 1994 to 2007, and defined SSCM as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements." Studies about SSCM have been growing for the past two decades. More than 300 papers were published by the end of 2010, while only 36 papers apply quantitative models. In these papers, it is evident that the social side of sustainability is not taken into account (Seuring, 2013). Recently, Brandenburg et al. (2014) also present a content analysis of 134 papers on quantitative, formal models that address sustainability aspects in the forward SC. They found that most of these studies are analytically based with a focus on multiple criteria decision making, such as the analytical hierarchy process or the analytical network process.

While different kinds of models are applied, Seuring (2013) groups them into four categories: life-cycle assessment models, equilibrium models, multiple criteria decision making and analytical hierarchy process. Our paper falls into the category of equilibrium models. Therefore in the following, we focus on the review of equilibrium models.

Nagurney and Toyasaki (2003) develop a framework for the modeling and analysis of supply chain networks with electronic commerce in which the decision makers are faced with multiple criteria, including environmental ones. In addition to profits maximization, emissions generated are also considered as weighted functions in the objective functions. They provide a variational inequality formulation to derive the equilibrium shipment and price pattern in the SC. Similar formulation methods are found in several papers, in which social responsibility activity costs, emissions, and risks are also considered in the objective functions (Cruz, 2008, 2009, 2013; Cruz and Liu, 2011; Cruz and Matsypura, 2009). In these studies, the social responsibility activity cost, emissions, and risks are assumed as convex functions of the level of social responsibility activities, which takes on a value lying in the range [0,1]. These studies are related to our paper, because in our paper: (1) the lower-level model also uses variational inequality formulation, and (2) CSR performance level also takes on a value lying in the range [0,1]. For better understanding of variational inequality and its solution algorithm, readers may refer to Nagurney (1999) and Noor et al. (2013). Readers may also refer to Tobin and Friesz (1988), Chiou (2005), and Josefsson and Patriksson (2007) for the sensitivity analysis of variational inequality.

Taking a different methodology, Ni et al. (2010) adopt game-theoretical analyses to investigate corporate social responsibility (CSR) allocation in a two-echelon SC that is bound by a wholesale price contract. They assume wholesale price is a linear function of CSR performance, which is also included in the supplier's cost function and the demand function. The optimal social responsibility allocation is determined based on both economic and CSR performance criteria. Liu et al. (2012) also use two-stage Stackelberg game models to investigate the impact of competition and consumers' environmental awareness on SC players. The unit cost function of the manufacturer is defined as a quadratic function of the eco-friendly level of the product, which is also considered in linear demand functions.

Goering (2012) also considers a two-stage game in which the retailer makes its quantity-setting decision in stage two, given the two-part tariff (wholesale price and fixed franchise fee) set by the stage-one producer. Either firm is socially concerned in terms of its desire to enhance its end-customers' welfare, i.e., consumer surplus of its stakeholders, in addition to the traditional profit motive. It is found that the optimal channel-coordinating tariff is very different from the standard pure profit-maximizing two-part tariff. Similarly, Swami and Shah (2012) also propose a two-part tariff contract to coordinate a green SC, which consists of a manufacturer and a retailer. Both of them put in efforts for "greening" their operations.

All the above studies assume that the SC actors compete in a noncooperative manner, and only investigate the equilibrium status of the SC. No further SC collaboration is considered to improve the whole SC performance. The following studies, however, have taken collaboration in SSCM into consideration. Hsueh and Chang (2008) use variational inequality to investigate the equilibrium status in a SC, and demonstrate that system-wide optimization of a SC can be achieved by appropriately allocating investments in CSR among manufacturers. They define a perceived production cost function and require the manufacturers agree on sharing information and investing in CSR activities in order to achieve a system-optimal solution. Ni and Li (2012) conduct game-theoretical analyses to obtain equilibria for both simultaneous-move and sequential-move CSR games, in which CSR is embedded in a wholesale price contract. Under certain assumptions and critical thresholds of parameters, it is concluded that a win-win performance in terms of both CSR and profitability can be achieved.

Recently, Hsueh (2014) proposes a new revenue sharing contract, in which CSR performance level is characterized by a function of unit investment in CSR and will affect market demands. A mathematical model is proposed to determine the optimal CSR investment, the wholesale price, and the revenue sharing ratio such that channel coordination and win-win situation are achieved. It is shown that the contract can simultaneously achieve the following objectives under proper parameter settings: (1) improve CSR performance; (2) improve total SC profits; (3) ensure that each SC partner in the SC can benefit from the contract. Xie (2014) investigates the impact of regulations imposed by policy makers on energy saving level and price of environmentally friendly products in green supply chains with both vertical integration and a decentralized setting. He also investigates the coordination of a decentralized supply chain by using a common wholesale pricing and profit