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Assessing the economic performance of an environmental sustainable supply chain in reducing environmental externalities

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ABSTRACT

This study investigates the mechanism that motivates supply chain firms to reduce environmental externalities while balancing the economic feasibility of the supply chain system under environmentally constrained circumstances in a competitive market. Taking government policy incentives into account, a quantitative model of an integrated supply chain that incorporates sustainable constraints is formulated to optimize supply chain firms' operational strategies of producing environmental friendly products (EFPs). This study contributes to the literature with a better understanding the interplay and interrelation of multiple sustainable constraints and their impact on supply chain firms' collaborative decisions. Our findings suggest that the decisions of operating EFPs are subject to sustainable constraints and that the government policy incentives play a dominant role overseeing supply chain firms' environmental behaviors toward sustainability.

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1. Introduction

Over the past few decades, economic development has caused many environmental issues that our society currently faces, including climate change, ozone decline, nuclear radiation, industrial toxins, widespread air and water pollutions (Cohen & Winn, 2007). Similar to climate change, most negative externalities can be traced back to market failure (Coase, 1960). To a large extent, environmental pollution and damage caused by firms' production processes and the use of their products are not directly captured in the market; i.e., they are "external" to private sectors and are therefore potential sources of market inefficiency. Since the costs of repairing the environment and/or removing the damages are not recognized or accounted for by the supply chain firms, the real problem created in the free-market economy is that they do not have to subtract these costs from their overall revenues. Consequently, private costs of production tend to be lower than related social costs, which can lead to inefficiency in the resource allocation. The question of how to resolve these issues of environmental externalities has become the subject of worldwide debate. Thus, the purpose of this research is twofold: (1) to investigate the mechanism of economic feasibility that reduces environmental externalities in the context of the supply chain system while tak-

ing stakeholders' environmental interests as sustainable constraints and (2) to gain insight into the balance between economic development and environmental protection.

With increasing awareness of the need for environmental protection and sustainability as well as pressures from governments, customers, and various stakeholder groups, companies are being urged to effectively incorporate sustainability issues into their supply chain management (SCM) schemes (Gold, Seuring, & Beske, 2010). In addition, the issue of supply chain sustainability combining sustainable development and supply chain management has been receiving increased attention (Dyllick & Hockers, 2002).

Sustainable development is often described as a combination of environmental, social, and economic issues involved in human development (Zailani, Jeyaraman, Vengadasan, & Premkumar, 2012). As corporations attempt to move toward environmental sustainability, management must extend their efforts to improve environmental practices across their supply chains (Vachon & Klassen, 2008). One of the most important issues in green logistics is how to identify preferred solutions that balance environmental and business concerns (Quariguasi Frota Neto, Walther, Bloemhof, van Nunen, & Spengler, 2009). Previous studies have addressed sustainability in SCM from different perspectives, including green product design (Mallidis, Dekker, & Vlachos, 2012), green purchasing and supplier selection (Bai & Sarkis, 2010; Kumar, Jain, & Kumar, 2014; Rao, 2002), manufacturing (Ilgin & Gupta, 2010), remanufacturing (Mitra & Webster, 2008), reverse logistics (Barker & Zabinsky, 2011), closed-loop logistics (Devika, Jafarian, & Nourbakhsh, 2014),

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and supply chain design (Chaabane, Ramudhin, & Paquet, 2011). Although the literature regarding environmental management in the supply chain context has been growing in recent years (Tseng & Hung, 2014), the interplay effects that incorporate environmental externalities, government policy incentives, and stakeholders' environmental interests (as sustainable constraints in this domain) have not been given sufficient attention. Since they are important for both environmental and economic sustainability, they require theoretical and empirical investigations.

Negative externalities resulting from the poor environmental performance of supply chain firms can have a destructive impact on environmental sustainability (Delucchi, 2000). Thus, firms have been increasingly under pressure to achieve a balance between profitability and sustainability. Maintaining such a balance in the long run requires firms to take a holistic approach toward sustaining financial flow (profit), resource flow (planet), and development flow (people) (Tang & Zhou, 2012). In this study, we refer to "reducing environmental externalities" as the efforts that firms make (under government enforcement and incentives) to reduce environmental pollution through improvements in their production processes or product usage. In other words, it involves transformation processes that attempt to effectively control and prevent pollution from the manufacturing source. In doing so, environmental externalities can be internalized by the development of a sustainable supply chain among partner firms not only for economic development but also for environmental and socially sustainable development (Erol, Sencer, & Sari, 2011; Seuring & Müller, 2008).

The internalization (reduction) of externalities is one of the necessary paths for achieving sustainability (Bithas, 2011). However, reducing externalities comes with financial burdens (attributed as additional expenses) when attempting to manufacture products that ensure ecological sustainability. This includes additional investments incurred because of greening and the penalties levied for not meeting certain standards (Barari, Agarwal, Zhang, Mahanty, & Tiwari, 2012). With a profit-driven nature that favors their own interests, firms inevitably seek trade-offs by balancing conflicting pressures that are often connected with sustainable development, i.e., firm-level economic performance versus environmental degradation and social disruption (Matos & Hall, 2007). Moreover, firms are compelled to reduce their impact on the environment by both regulatory and non-regulatory pressures from the government, market, and community (Hall, 2000).

The environmental behaviors of partner firms may have influences on the supply chain's value transformation process (Klassen & Vachon, 2003). Changes in value transformation represent opportunities for supply chain members' reconsideration of collaborative relationships. Contracts and supply chain cooperation should be further understood so that sustainability issues are not simply viewed as trade-offs (Seuring, 2013). These issues raise the following questions:

How can supply chain firms manageably deal with the complex and dynamic nature of reducing environmental externalities?

Which trade-offs occur between the environmental impacts of supply chain firms' economic activities and their costs, and what are the best solutions that balance ecological and economic concerns (Dekker, Bloemhof, & Mallidis, 2012)?

What factors influence supply chain members' collaborative relationships when they face the challenge of improving their environmental performance?

What are the sustainable constraints that represent environmental externalities and stakeholders' environmental interests, and how do they affect supply chain firms' decision behaviors?

Would government policy incentives help motivate supply chain firms to make environmental technology investments in the competitive market?

The present study seeks to address these issues by introducing multiple sustainable constraints in a quantitative model of an integrated supply chain that reflects stakeholders' environmental interests, analyzing the joint effects of the multiple sustainable constraints and their interrelation on supply chain firms' decision behaviors, and explicating the environmental and economic performance of the supply chain system. By constructing an integrated supply chain model while considering government policies, our research investigates a supply chain system's evolving path towards environmental sustainability.

The remainder of this paper is organized as follows. Section 2 reviews the existing literature. Section 3 describes the sustainable constraints while taking stakeholders' environmental interests into account. Section 4 formulates an integrated environmental sustainable supply chain model with multiple sustainable constraints and analyzes the solution structure. Section 5 provides the results and discussion. The final section draws the conclusions and presents future research directions.

2. Literature review

There have been numerous literature reviews on green or sustainable supply chain research (e.g., Bloemhof-Ruwaard, van Beek, Hordijk, & van Wassenhove, 1995; Brandenburg, Govindan, Sarkis, & Seuring, 2014; Dekker et al., 2012; Fahimnia, Sarkis, & Davarzani, 2015; Gold et al., 2010; Ilgin & Gupta, 2010; Quariguasi Frota Neto et al., 2009; Reed, 2008; Seuring, 2013; Seuring & Müller, 2008). Bloemhof-Ruwaard et al. (1995) observed the earliest studies on the application of operational research (OR) optimization models to environmental management (e.g., Batta & Chiu, 1988; Böttcher & Rembold, 1977; Bouzaher, Braden, & Johnson, 1990; Das & Haimes, 1979; Ellis, 1988). Brandenburg et al. (2014) observed that, among the extant research related to the SCM perspective, sustainability is often externally motivated by the government, the customers or stakeholders (e.g., Gold et al., 2010; Seuring & Müller, 2008), and a vertical coordination for improving environmental performance among supply chain firms is required (Carter & Rogers, 2008). Fahimnia et al. (2015) presented an excellent structured review of green SCM literature and stated the following:

"Sustainable and green supply chain management is necessarily globalized. Broadening the number and location of countries where green supply chain management is investigated is required. Without the voices of less-developed countries amongst the researchers portends a major weakness and belies a multi-culturally and globally relevant viewpoint."

They also observed that conceptual and empirical studies represent the most influential works, and prescriptive, normative, and quantitative modeling have begun to take on greater importance. In particular, opportunities abound for additional research in the formal modeling of green SCM with practical applications (Fahimnia et al., 2015). As environmental issues become a worldwide concern, within the field of OR, research combining environmental issues and OR models has been growing rapidly.

Through our literature survey, we found that the related literature may be classified as two different schools: (1) the study of supply chain firms' decision-making processes interrelated with environmental responsibility (i.e., eliminating pollution at its source), from the perspective of stakeholders' environmental interests; and (2) the integration of environmental issues in supply chain optimization through a quantitative model-based approach, which can be found in the studies on green/sustainable/reverse/closed-loop supply chains.

Externality costs occur when the private calculation of costs differs from (usually much less than) society's valuation of costs (Griffin & Steele, 1980). The school of stakeholders' environmental

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