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A strategic decision-making model considering the social costs of carbon dioxide emissions for sustainable supply chain management

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ABSTRACT

Incorporating sustainability into supply chain management has become a critical issue driven by pressures from governments, customers, and various stakeholder groups over the past decade. This study proposes a strategic decision-making model considering both the operational costs and social costs caused by the carbon dioxide emissions from operating such a supply chain network for sustainable supply chain management. This model was used to evaluate carbon dioxide emissions and operational costs under different scenarios in an apparel manufacturing supply chain network. The results showed that the higher the social cost rate of carbon dioxide emissions, the lower the amount of the emission of carbon dioxide. The results also suggested that a legislation that forces the enterprises to bear the social costs of carbon dioxide emissions resulting from their economic activities is an effective approach to reducing carbon dioxide emissions.

1. Introduction

In the past decade, supply chain management (SCM) has received a great deal of attention from practitioners and scholars because of globalization. Mentzer et al. (2001) have defined SCM as the systemic, strategic coordination of traditional business functions with the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. Usually, studies of SCM have concentrated on economic issues (Goetschalcks and Fleischmann, 2008), such as finding ways to minimize the operational costs (Nagurney, 2010a) or to maximize profits (Nagurney, 2010b).

However, with increasing awareness of the need for environmental protection and sustainability, companies are urged to effectively incorporate sustainability issues into their SCM schemes, prompted by the pressures from governments, customers, and various stakeholder groups (Gold et al., 2010). Carter and Rogers (2008) defined sustainable supply chain management (SSCM) as the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of an individual company and its supply chain. Many approaches have been observed for addressing sustainability issues in supply chain management, including green design (Lin, 2013), green purchasing (Bai and Sarkis, 2010), green manufacturing (Lin, 2013; Shang et al., 2010), reverse logistics (Eltayeb et al., 2011), etc.

Nevertheless, what previous studies have neglected to consider are the environmental, social, and economic threats resulting from climate changes (Marchant, 2010). The direct effects of climate changes include changes in temperature, precipitation, soil moisture, and sea level. The main cause of climate changes is global warming, which is mainly brought on by greenhouse gas emissions, with carbon dioxide (CO_2) as the main man-made greenhouse gas (Karl and Trenberth, 2003; Lashof and Ahuja, 1990). Damages caused by the CO_2 emissions are spread across time and space (Anthoff et al., 2009a). Thus, the reduction of CO_2 emissions has become an urgent global issue in the last decade for mitigating global warming (Morath, 2010). Several approaches, such as emission trading scheme, agreed emissions targets, and carbon tax have been proposed for reducing CO_2 emissions (Forster et al., 2006; Zhang and Folmer, 1998). Emission trading scheme has been applied in the European Union, but have failed because of the unequal access to information and market inefficiency (Andrew, 2008). The Kyoto Protocol provided for agreed emissions targets, but the evidence available to date indicates that most countries will not meet its targets. This is because of the need to sustain and grow economic activities (Andrew, 2008). Compared to emission trading scheme and agreed emissions targets, carbon tax is considered to be more transparent and visible, and hence harder to evade or

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avoid (Andrew, 2008). The carbon tax levy has been considered as one of the most common market-based approaches from the aspect of economic incentives in carbon emission regulation (Oreskes, 2011). The optimal carbon tax is the tax on carbon emissions that balances the incremental costs of reducing carbon emissions with the incremental benefits of reducing climate damages. In an optimal regime, the carbon tax could equal the social costs resulting from carbon emissions (Nordhaus, 2007).

As mentioned above, many unrecoverable damages caused by CO_2 emissions could result in tremendous social costs. Yet, most producers of CO_2 emissions do not pay attention to these social costs while societies pay for them. CO_2 emissions adversely affect everyone, regardless of their location and source, whether or not people are willing to pay to avoid the resulting costs. To mitigate the damages caused by CO_2 emissions, it is necessary to take the social costs of CO_2 emissions into consideration for all economic activities. In this study, the authors propose a model considering both the operational costs and social costs of CO_2 emissions in SCM. The objective of this study is to provide a useful model for decision-makers of SCM for planning a sustainable supply chain. This study was organized as follows: first, a literature review regarding SSCM, as well as the estimation of the social costs caused by CO_2 emissions, was offered. Second, the research problem of this study was provided. Third, a mathematical model with an illustrative case was developed. Finally, the conclusion, discussion, recommendations, and limitations for this study were presented.

2. Literature review

In this section, the authors of the present study review past literature related to SSCM and the estimation of the social costs of CO_2 emissions. The authors also aim to demonstrate the significance of incorporating the social costs of CO_2 emissions into SSCM.

2.1. Sustainable supply chain management (SSCM)

The literature about SCM has increasingly focused on issues relating to sustainability, driven by governments and both profit and nonprofit organizations in the past decades (Ageron et al., 2012). SSCM is seen as the integration of environmental, social, and economic goals in the systematic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its chains for sustainable development (Carter and Rogers, 2008). Previous studies have addressed sustainability in supply chain management from various perspectives, including product design, materials purchasing, supplier selection, manufacturing, remanufacturing, reverse logistics, waste management, etc.

For example, Alves et al. (2009) developed a sustainable design procedure for employing green materials in product design procedure. Zsidisin and Siferd (2001) concentrated on green purchasing for addressing the sustainability issue in SCM. Bai and Sarkis (2010) introduced a multi-stage, multi-method approach considering economic, environmental, and social factors for selecting sustainable suppliers. Govindan et al. (2013) applied a fuzzy multi criteria approach for measuring sustainability performance of a supplier based on the triple bottom line approach. Manzini and Accorsi (2013) proposed an integrated approach to control quality, safety, sustainability, and logistics efficiency of food products and processes along the whole food supply chain, from farm to fork simultaneously. Michelsen et al. (2006) applied eco-efficiency as an instrument to measure sustainability of furniture production supply chains. Zhu et al. (2010) used empirical research to examine if different types of manufacturing enterprises with environmental-oriented supply chain cooperation (ESCC) exist. Mancini et al. (2012) used the MIPS (Material Input per Service Unit) methodology to assess the sustainability along the supply chains of three Italian foodstuffs. Liu et al. (2012) proposed a new hub-and-spoke integration model to integrate green marketing and sustainable supply chain management from six dimensions: product, promotion, planning, process, people, and project. Gold et al. (2013) used three case studies to address the question of how sustainable supply chain management (SSCM) applied to BoP (Base of the Pyramid) projects can help multinational corporations achieve their sustainability goals. Caniato et al. (2012) used a multiple case study methodology to analyze different kinds of companies tackling the environmental sustainability issue. Shaverdi et al. (2013) applied the fuzzy AHP approach for evaluating supply chain management sustainability in the publishing industry. Srivastava (2007) made a much wider attempt to address SSCM, including product design, material source and selection, manufacturing process, delivery of the final product to the consumer, and end-of-life management of the product after its useful life.

In recent years, several studies addressed the CO_2 emission issue in SCM. For example, Sundarakani et al. (2010) employed the Eulerian and Lagrangian transport models to estimate carbon emissions across the supply chain, including emissions from material processing, manufacturing, warehousing, inbound logistics, and outbound logistics. They suggested that carbon emissions across stages in a supply chain can constitute a significant threat that requires careful attention in the design phase of supply chains. Lee (2011) integrated carbon emission as an indicator for automobile supply chain management. Chaabane et al. (2012) proposed a model to design a sustainable supply chain under the carbon emission trading scheme. However, the carbon emission trading scheme has been applied in the European Union, but has failed because of its serious shortcomings in design (Andrew, 2008; Sovacool, 2011). Emissions credits were distributed for free as a rough function of past emissions, yet such a concession provided enterprises an incentive to emit more during the early years of the program to receive a larger allocation in the future (Hepburn, 2007). Furthermore, most European countries allow their enterprises to determine their own baselines and to set their own abatement cost curves, so most enterprises have a tendency to revise their estimates upward to obtain more generous allowances (Sovacool, 2011).

Compared to the emission trading scheme, carbon tax is considered to be more transparent and visible, and thus harder to evade or avoid (Andrew, 2008). The optimal carbon tax is equal to the social costs of carbon emissions (Nordhaus, 2007). Thus, in this study, the authors developed a mathematical model through integrating social costs of CO_2 emissions into supply chain management to reduce CO_2 emissions for sustainability.

2.2. The social costs of CO_2 emission

Kapp (1963) defined social costs as all direct and indirect losses sustained by third persons or the general public as a result of unrestrained economic activities. These social losses may take the form of damages to human health, the destruction of property values, and the premature depletion of ecosystems. The social costs of CO_2 emissions might be defined as the monetary value of the damage made by the emission of one extra ton of CO_2 at some point of time (Etchart et al., 2012; Guo et al., 2006; Pearce, 2003).

Owing to a great number of negative impacts in physical, biological, and human systems caused by CO_2 emissions, many studies have tried to estimate the social costs of CO_2 emissions. Existing studies that have attempted to place a value on the social costs of emitting CO_2 have employed one of two alternative approaches. They are the cost-benefit analysis (CBA) approach and the marginal cost (MC) approach (Clarkson and Deyes, 2002).