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Managing green house gas emission cost and pricing policies in a two-echelon supply chain

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ABSTRACT

Reduction of green house gas (GHG) emission is becoming a vital issue to protect our environment. In this point of view, industrial firms' managers have to consider the cost of emissions trading in their policies to control GHG emission as almost all developed and developing countries of the world are now implementing some norms and penalty for GHG emission. The present article deals with a manufacturer–retailer supply chain model where cost of GHG emission during manufacturing process is taken into account. The profit functions of decentralized and centralized models are analyzed and compared considering emissions trading schemes. This study suggests to the manager of manufacturing firm who may apply two policies, shortages and adjustment of wholesale price, to reduce GHG emission. Although both policies are beneficial for GHG trading, the manufacturer prefers to allow shortages while the retailer prefers the other. Revenue sharing contract and asymmetric Nash bargaining strategy are used to resolve channel conflict and to share surplus profit between the channel members. Finally, a numerical example is presented to validate the proposed model.

Introduction

The green house gas (GHG) is increasing day by day and the bad effect of GHG is the biggest threat to the earth's ecological system and human race. The emission of CO_2 in human civilization is the combustion of fossil fuels such as coal, natural gas, and oil for energy and transportation although huge percentage of CO_2 is emitted from many industrial processes and land-use changes. In 2002, the main component CO_2 of GHG emissions was estimated at 40 billion tons and expected to reach 58 billion tons by 2030 [41]. In 2005, the European Union Emission Trading System (EU-ETS) has initiated steps to restrict carbon emissions by implementing a mandatory 'cap-and-trade' system in the 27 European Union countries. Recently, carbon emission trading is well accepted and applied in United Nation and many governments of European Union. Interestingly, in response to the cap-and-trade system, a firm can optimize its operational decisions to reduce carbon emission. A recent report of National Academies of Science (NRC 2009) have pointed out that any assessment will suffer from uncertainty, speculation, and lack of information about the following facts: (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the impact of changes in climate on the physical and biological environment and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change would raise serious questions of science, economics, and ethics and it should be viewed as provisional. Most federal regulatory actions can be expected to have marginal impacts on global emissions [38].

In the current global business scenario, a firm must have to provide serious attention on green house gas emissions due to its activities. To controlling GHG emission most developed and developing countries are implemented governmental norms and penalty for GHG emissions. So, firm managers have to consider the cost of emissions trading in their policies. In practice, the researchers as well as practitioners have also showed keen interest to include the issues like GHG emission, government regulations, 'cap-and-trade' system in business modeling [6,40,37]. In this proposed study, we develop a two echelons supply chain model considering cost of GHG emissions from the manufacturing/

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production process. It is assumed that demand of the product depends on selling price. GHG emission of the manufacturing process depends on production and demand rates. Quite often, it is observed that there exist some pre-specified yearly limit slabs of total emission and different penalty costs corresponding to the different slabs. In this situation, the firm maximizes its profit under the circumstances of paying penalty corresponding to total GHG emission of the manufacturing process per year. Thus, the firm has to analyzed carefully its business strategies due to penalty for GHG emission. Now, the objective of the manufacturing firm is to control its yearly GHG emissions in a certain slab. To prevent higher penalty cost of GHG emission, the manufacturer and retailer consider two ways to control yearly GHG emission: first one considers adjustment of pricing policy to control demand rate without allowing any shortage while the second one imposes some restriction in the production rate by allowing shortage associated with some cost of shortage. Under the decentralized and centralized decision making context, the present study aims to address how best possible profits can be achieved controlling cost of GHG emission in a two-level supply chain. The main objective of this article is to maximize of the channel members' individual profits in decentralized scenario and maximization of the integrated channel profit for centralized scenario under the circumstance of GHG emission penalty. To cut off channel conflicts of the decentralized decision, this article also investigates a suitable contract mechanism to coordinate the channel. Finally, the present study provides idea for win–win profits of the channel members.

Literature review

Studies dealing with environmental issues in inventory systems are urgent and progressively increasing day by day in a large number. In this context, [15] studied the EU-ETS system in a supply chain and operations management context by two-level (vendor–buyer) supply chain model with a coordination mechanism taking into account the effect of greenhouse gas (GHG) emission of manufacturing processes. In [2] analyzed two models in which the first model considered a classical coordination policy, while the second considered a vendor-managed inventory with consignment agreement of stock policy. In [39] developed a joint economic lot size model for coordinated inventory replenishment decisions under the vendor-managed inventory with consignment stock agreement considering an emissions-trading scheme. They assumed a single product that transferred along a two-level supply chain system with a single vendor and a single buyer. In [7] considered carbon footprint and low-carbon preference to determine manufacturer's optimal decision in single-period setting. They analyzed the effect of low-carbon preference, emission cap and emission price on profit and production policies. In another work, [8] considered issues like additional cost for low carbon production, low-carbon premium and carbon price to determine the manufacturer's multi-product joint pricing and production decisions. They showed that carbon cap-and-trade regulation and government's financial incentive had significant affect on firm's low-carbon decisions. Gurtu et al. [1] analyzed the impact of changes in fuel prices and the imposition of a carbon tax on emission from transport on shipment of lot sizes and supply chain costs. They developed a function of fuel prices which is also used to calculate transportation cost in the future. They also showed that increases in fuel prices should be dealt with differently than other costs. In [3] discussed a new "Sustainable EOQ model" in which all sustainability factors linked to the material lot size were analyzed from the beginning of the purchasing order to the end of its life inside the buyer plant. As a result, the environmental impact of transportation and inventory was incorporated in the model and investigated by an economic point of view. [4] suggested that performance measures should encourage the positive aspects of holding inventory to provide inventory planning. In their model, the performance encouraged the 'environmentally good' activities and discouraged the 'environmentally bad' activities. [9] depicted two segments of the consumers in the market: one segment acknowledged green product and other segment not keen to pay for green product. Using big data technology, this study examined the affect of consumer's green segmentation on firm's decision of green production. [33] developed an integrated vendor–buyer model considering the setup cost reduction for vendor and affect of carbon emission during transporting items from vendor to buyer.

Based on the above environment, an appropriate coordination of supply chain is needed for improving its performance. In decentralized scenario, best output of a supply chain can be achieved through proper channel coordination. Mainly, quantity discount [28,27], Two part tariff [19–21], consignment contract [11], revenue sharing [10,5,22], compensation on disposal cost [26], mail-in-rebate [30] so forth had been studied as tools for supply chain coordination. Revenue sharing contract has been extensively studied as possible coordination contract to achieve optimal supply chain profit. Although revenue sharing contract may take many different forms but their conceptual purpose is consistent. Revenue sharing has become an essential tool within corporate governance to endorse partnerships and increase sales or sharing costs. Both the U.S. and Canadian governments have used taxation revenue sharing between different levels of government. This contract is also familiar in videocassette industry, Hydro carbon industry [13], and software industry [14]. In revenue sharing contract, manufacturer receives some of the retailer's created revenue plus a wholesale price per unit of product those the retailer buys. Performance of revenue sharing contract has been examined on standard newsvendor problem and it has been found that it eliminates channel conflict and arbitrarily divides profits when price is exogenous. In price-setting, retailer's revenue sharing contract coordinates the system for a particular profit split [5]. [10] developed a revenue sharing model to coordinate a three-echelon supply chain. [35] used revenue sharing contract as coordination tool for videocassette industry, where demand varies with time. Outline of revenue sharing contract on supply chains with retailers facing newsvendor problem was found in the work of [5] where the authors discussed extensively the strengths and limitations of revenue sharing contract in comparison to other coordination contracts.

There exists several research on inventory and supply chain management considering emission trading. But, limited researches among them explored pricing policy for profit maximization. [7] discussed pricing policy to maximize monopoly manufacturer's profit in cap-and trade system. In another work [8] examined pricing policy of low carbon products as well as ordinary product to maximize the manufacturer's profit. Differing from these studies, the present article firstly considers a two levels manufacturer–retailer supply chain to analyze the effect of emissions trading on pricing policy of different members in supply chain. Secondly, interactions between the manufacturer and the retailer are examined through some game theoretical aspects such as non-cooperative game, cooperative game, Stackelberg game, asymmetric Nash bargaining etc. Thirdly, this work contributes a detailed analysis on channel coordination to improve its performance and surplus profit distribution for win–win outcome. Finally, main contribution of this work is the flexible decision making due to pre-specified emissions trading slabs announced by the government. Two policies, viz, allowing shortages and adjusting the wholesale price are adopted to control GHG emission and hence it reduces the penalty cost. This study shows how

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