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Low-carbon production with low-carbon premium in cap-and-trade regulation

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ABSTRACT

Manufacturers face a choice of whether to reduce their carbon emissions through employing low-carbon technologies. Though many carbon regulations are set up to curb carbon emissions, some firms choose not to take low-carbon production because the additional cost of low-carbon progressing is high. However, low-carbon production would be a better alternative when we consider consumer's low-carbon premium in the cap-and-trade system. In this work, we solve the manufacturer's multi-product joint pricing and production problem when consumers value the low-carbon product higher than the ordinary product. Our findings provide firms with conditions where low-carbon production is profitable. Furthermore, we find that the cap-and-trade would constrain the total carbon emissions and promote low-carbon production simultaneously under certain conditions.

1. Introduction

Greenhouse gases (GHGs) concentration in our planet results in global warmness and the climate change will present challenges to our society and environment. The latest report by the Intergovernmental Panel on Climate Change (IPCC) shows that global emissions of GHGs have risen to unprecedented levels, despite a growing number of policies to reduce climate change. Reported by IPCC, between 2000 and 2010, annual anthropogenic GHG emissions have increased by 10 billion metric tonnes of carbon dioxide equivalent (CO_2 e or CDE).

Governments worldwide are developing regulatory instruments to reduce GHG emissions, as well as bridging support for low-carbon technologies. A typical carbon policy is the Europe Emissions Trading System (EU ETS) which works on the 'cap and trade' principle. A 'cap', or limit, is set on the total amount of GHGs that can be emitted by the factories in the system. Each year if a company' emissions exceed the 'cap', he would buy some allowances from another company. Conversely, if a firm's emissions are less than the 'cap', he would sell the surplus allowances and benefit from the trade. Thus, emissions have a financial value which would promote low-carbon production.

Unfortunately from an environmental perspective, most companies do not adopt the low-carbon production option mainly driven by one concern: cost. Companies face higher construction and operating costs due to the additional low-carbon progressing. The research community of Carbon Capture and Sequestration (CCS) Research at MIT find that the CCS and similar low-carbon technologies are currently not economical in the private market (Eidea et al., 2013). Such as the two major CCS demonstration projects: ZeroGen in Australia and the Kemper Country in the USA.

It is encouraging that there is growing environmental consciousness from the consumer part. Polls suggest that as many as 83% of individuals are concerned about the environment (Nielson, 2011). As consumers become aware of the impacts related to environment, they place greater importance on environmental-friendly purchases. The U.S. Environmental Protection Agency (EPA) are advising consumers to buy green products and provides online carbon footprint calculator for individuals. Some environmental-labels are introduced to guide consumer's greener purchase. Such as the carbon label which was introduced in the UK in 2006 by the Carbon Trust. Another example is the dolphin-safe label. The canned tuna gets a significant market share increment after the labeling because consumers shift their purchase options towards the eco-labeled cans (Teisl et al., 2002).

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Some companies take it an important marketing opportunity when the additional low-carbon costs could be passed on to consumers. In this paper, we develop models to support decision making concerning low-carbon production with consumers' environmental consciousness and cap-and-trade. In particular, we provide insights to the following questions: (1) Considering consumers' low-carbon premium, is it profitable to take low-carbon production? If yes, how to position (the price and the quantity) the low-carbon product? (2) What is the impact of cap-and-trade on low-carbon production? Will cap-and-trade promote low-carbon production and curb carbon emissions?

The rest of this paper is organized as follows: Section 2 positions the relevant literature on consumers' low-carbon premium and low-carbon production. Section 3 gives the important assumptions and notation. Section 4 presents the benefit model with consumers' low-carbon premium in the market. This analysis compares the low-carbon scenario to one where no low-carbon production is considered. Section 5 considers a cap-and-trade setting and combines the two factors. Section 6 analyzes the impacts of carbon related incentives on the manufacturer's optimal decisions and the environment. Section 7 gives a further discussion to conclude the paper.

2. Literature review

This paper is mainly related to two streams of literature, the research on low-carbon management and consumers environmental consciousness. There are clear evidences that consumers state a preference for eco-friendly products (Chitra, 2007). Recently, the existence of low-carbon premium is examined in various markets. Aguilar and Vlosky (2007) and Roheim et al. (2011) tried to find whether or not consumers are actually paying a price premium for eco-friendly products in the retail market and, at least a 5% premium was found and the highest premium was about 25%. Along with the introduction of Kyoto protocol, governments begin to care more about the energy and emissions of the cities and countries. Such as Bentzen (2004); Worrell et al. (2001); Marland et al. (2003), they presented the analyzation of global and regional carbon emissions. Wang et al. (2012); Zhang (2003); Zhang and Wang (2014); Wang and Feng (2015); Wang and Yang (2015) takes a serious research on China's energy efficiency and carbon emissions.

Pressures from both the government and public have promoted also urged firms and researchers seriously take the environmental management into consideration. Sundarakani et al. (2010) and Benjaafar et al. (2013) characterized and measured product's 'carbon footprints' in the product life cycle from production to disposition or recycle. In production period, low-carbon construct on the operations and supply chain network is more and more emphasized. Bhattacharya et al. (2014) and Dey et al. (2014) provided effective integrated analytical approach to measure and evaluate a supplier' performance incorporating the environmental performance. They gave the CDM-based GrBSc approach which helps firms in deciding if supplier's performance meet both industry and environment standards. Validi et al. (2015, 2014a,b, 2012) modeled CO_2 emission-concerned supply chain from transportation and distribution perspectives. They optimised the green supply chain facing multi-objective: low-carbon emissions and low costs. The solution methods in their research have been valuated and implemented in realistic cases and proved effective in minimising the total carbon emissions at optimal costs. Other literature on operational issues in production period are progressing rapidly. Such as low-carbon inventory management (Chen et al., 2013; Suh and Huppes, 2005; Hua et al., 2011), supply chain design and management (Cachon, 2014; Benjaafar et al., 2013; Lee, 2011). Tseng and Hung (2014) also take the social costs of carbon emissions into account when design a sustainable supply chain. Bhattacharya et al. (2015) gives comprehensive reviews on the very recent developments on the environment management in green supply chain operations and management.

In the field of carbon regulations, Zakeri et al. (2015) presented an analytical model to examine the supply chain performance at two carbon regulations: carbon pricing (tax) and carbon emissions trading schemes. Fahimnia et al. (2013) analysed the impact of a fixed carbon price regulatory on a closed-loop supply chain. This study evaluate both the forward and reverse supply chain influences on the carbon footprint. Later, Fahimnia et al. (2015) considered a bi-objective model in a carbon tax policy scheme. The impact of carbon policies on supply chain is significant (Jin et al., 2014; Chaabane et al., 2012). The carbon policies has arose much discussion and comprehensive reviews of the economics and carbon politics can be found in Helm and Hepburn (2009), Stern (2007) and Colby (2000).

In the steam of these literature, product's demand and price are usually assumed exogenous because environmental conscious consumers are not considered. The majority of the literature has focused on the cost-minimizing operating decisions or supply chain design constraint by various carbon regulations. In this paper, we consider a multi-product decision making faced by the manufacturer who provides the low-carbon product as well as the ordinary (traditional) product to the same market. The literature on multi-product production are abound and prominent, but rare of them consider both carbon emission regulations and corresponding consumer's low-carbon premium. Chang et al. (2015) studied the remanufacturing problem considering a carbon cap-and-trade regulation but not consumer's carbon related premium. Zhang and Xu (2013) analyzed a multi-item production problem with the carbon cap-and-trade did not take a carbon-related demand into consideration either. Even though there have been so many significant researches on low-carbon production, the majority has ignored the demand aspects.

We contribute to the literature by bringing a marketing perspective to the low-carbon production problem through a focus on demand aspects related to consumers' low-carbon premium and carbon price. Our results confirm that the two factors mentioned above have a significant direct impact on low-carbon production decisions. Furthermore, the effects are intimately linked and exhibit strong interactions that may provide policy makers some new insights into their carbon pricing system.

3. Assumptions and notation

This paper models a manufacture's multi-product: the ordinary and the low-carbon product optimization problem which incorporates both consumers' environmental consciousness and carbon regulation. The low-carbon product is different from the ordinary product on production cost and consumer valuation. Thus, before the analytical model, we state our key assumptions specific to cost and consumer's low-carbon premium.

Assumption 1. *Low-carbon production incurs a higher cost per unit product than the ordinary production.*

For the sake of simplicity, the performance difference between low-carbon and ordinary products is neglected without loss of generality. They just differ in carbon emissions for distinct low-carbon effort. It can be construed that the traditional production has already been conducted in the most cost-efficient way. Without deterioration in product quality, the cost increment of low carbon product seems unavoidable for the better environmental performance.