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Consumer environmental awareness and channel coordination with two substitutable products

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ABSTRACT

This paper focuses on the impact of consumer environmental awareness (*CEA*) on order quantities and channel coordination within a one-manufacturer and one-retailer supply chain. The manufacturer produces two types of products: the environmental and the traditional products. These two products differ in their price and environmental quality. Based on the multi-product newsvendor model, this study compares three decision scenarios: the centralized model (M1), the decentralized model (M2), and the decentralized model with the coordination of a return contract (M3). The closed-form expressions of optimal order quantities, wholesale prices and return credits are derived for each scenario. Extending these models, we incorporate a production capacity constraint of the manufacturer. Finally, sensitivity analyses on model parameters are performed and numerical examples are provided.

Our study suggests (1) the retailer's profit monotonically increases while the manufacturer's profit is convex with respect to *CEA*; (2) a return contract can help both parties to achieve the profit they could expect in the centralized model; (3) order quantity of the environmental product increases with *CEA*; (4) the production capacity constraint of the manufacturer does not impact order quantities of the two products if it is sufficiently large (when it is larger than two critical points); otherwise, production capacity constraint negatively changes the channel profit and order quantities; (5) our simulation study and sensitivity analyses indicate that the difference of environmental quality between the traditional and the environmental products determines whether order quantity of the traditional product increases or remains constant with respect to *CEA*. The firms will benefit from product customization and consumer segmentation based on the distribution of *CEA* in the market.

1. Introduction

The rise of environmental awareness changes consumer behavior. The BBMG Conscious Consumer Report shows that 51% of Americans are willing to pay more for products with high environmental quality and 67% agree it is important to buy products with environmental benefits (Bemporad & Baranowski, 2007). OECD (2002a) points out that 27% of consumers in OECD countries can be labeled "green consumers" due to their strong willingness-to-pay for environmental products and strong environmental activism. A study carried out by European Commission in 2008 shows that 75% of Europeans are 'ready to buy environmentally friendly products even if they cost a little bit more compared to 31% in 2005 (European Commission, 2008).

Considering the impact of consumer environmental awareness (*CEA*), researchers started to introduce environmental quality as a demand enhancement factor in the product demand function (Liu, Anderson, & Cruz, 2012). Often the traditional and the environmental products are considered to be substitutable (Brécard, 2013; Conrad, 2005; Liu et al., 2012; Reinhardt, 1998; Rodriguez-Ibeas, 2007). The environmental product provides greater environmental benefits (or imposes smaller environmental costs) than the traditional product but has a higher price. This is known as environmental product differentiation (Reinhardt, 1998). Hybrid vehicles may be considered as an example of the environmental product. Such vehicles contribute to reducing carbon dioxide by approximately 3.5 million tons as of April 2007, but they are more expensive than traditional vehicles with similar functionalities (Yakita, 2009).

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Given the important role of *CEA* (Bemporad & Baranowski, 2007; Mawson, 2007; OECD, 2002b), most studies in this area have been focused on product design and market competitiveness, and government environmental policies. Studies regarding its effects on supply chain management still remain sparse to our knowledge. We consider a one-manufacturer and one-retailer supply chain following the previous modeling approaches (e.g. Chen & Xiao, 2011; Lee & Rhee, 2007; Pasternack, 1985; Taylor, 2001). The manufacturer produces two types of products: the traditional and environmental (or green) products. We assume environmental quality of the products is given. One retailer sells the two substitutable products. Automobile dealership management may be considered as such an example. An automobile manufacturer (say, Ford) produces hybrid vehicles (i.e., an environmentally friendly product) and traditional gasoline vehicles (i.e., a traditional product that is less environmentally friendly). In each region (which may be defined based on the geographical distance), there is usually one and only one dealership for the manufacturer that sells both products.[1] The automobile manufacturer and the dealership constitute one manufacturer and one retailer supply chain in a region.

We assume that the demand function of a product is the common knowledge of both parties. The retailer needs to determine order quantity and the manufacturer needs to decide wholesale price (and return credit in the case of introducing a return contract) for each product to maximize their profits. We investigate the following questions:

1. How *CEA* impacts both parties' profits and the retailer's order quantities for the traditional and the environmental products, respectively?
2. Whether a return policy can effectively coordinate the manufacturer and the retailer?
3. Will production capacity of the manufacturer change the results?

Based on the multi-product newsvendor model, our study compares three decision scenarios: the centralized model (M1), the decentralized model (M2), and the decentralized model with the coordination of a return contract (M3). We derive the closed-form expressions of optimal order quantities, wholesale prices, and return credits. Extending these models, we further incorporate a production capacity constraint of the manufacturer. Finally, sensitivity analyses on model parameters are performed and numerical examples are provided.

This study contributes to the literature by investigating how *CEA* impacts supply chain management. We show that a return contract can effectively coordinate the manufacturer and the retailer to achieve the profit that they can expect in the centralized model. Order quantity of the environmental product increases with *CEA*. The retailer's profit monotonically increases while the manufacturer's profit is convex with respect to *CEA*. The production capacity of the manufacturer does not impact order quantities of the two products if it is sufficiently large. Otherwise, order quantities and profits decrease with the production capacity. Further, based on our simulation and sensitivity analyses, if environmental quality of the traditional product is sufficiently smaller than that of the environmental product, order quantity of the traditional product will remain constant with *CEA*. Otherwise it will increases with *CEA*. Both parties will benefit from product customization and consumer segmentation based on the distribution of *CEA* in the market.

[1] Our results will remain the same even if there are two dealerships for the manufacture in a region but they sell different type of products (one for the environmental product, and one for the traditional product).

This paper is organized as follows. Section 2 provides a review of relevant literature. Section 3 presents the basic assumptions and definitions. Section 4 first analyzes the centralized and the decentralized model. Then it discusses the channel coordination with a return contract. Section 5 extends the models with a production capacity constraint. Section 6 describes sensitivity analyses and numerical examples. Section 7 summarizes our main findings and concludes the paper by providing some directions for future research. All proofs are relegated to Appendix A.

2. Literature review

Our work is closely related to the growing focus on *CEA* in operations management. There are two main streams of literature on *CEA*. The first stream focuses on how firms improve environmental quality of their products to increase their competitiveness and capture additional market share. The common methods to improve product environmental quality include increasing technology investment (e.g. clean-up level, emission level), improving social responsibility, introducing eco-labeling and so on. For example, Amacher, Koskela, and Ollikainen (2004) showed that incentives for firms to invest in green technologies depend on their relative cost structure. Chung and Wee (2008) explored how green product design new technology and remanufacturing affect the production inventory policy. Su, Wang, and Ho (2012) suggested how the two technologies, Zero-Sum and Synergy, impact the market structure strategy for environmental products. In two-echelon supply chain, Ni, Li, and Tang (2010) addressed how to allocate corporate social responsibility between a supplier and a retailer under wholesale price contracts. Liu et al. (2012) investigated the impact among the supply chain players considering consumers' environmental awareness and manufacturer competition.

The second stream focuses on how the government set environmental policies (e.g. environmental standard, subsidy and tax policy) by encouraging the manufacturers to improve environmental quality of their products. For example, Chen (2001) showed that stricter environmental standards might not necessarily benefit the environment. Gonzalez and Fumero (2002) demonstrated how frequently-used environmental policies influences the social welfare. Tian (2003) presented how a regulatory increase in the minimum required level of environmental friendliness of imported good impacts home firm and consumer gain. Bansal and Gangopadhyay (2003) investigated how subsidy policies and tax policies influence total pollution and aggregate welfare in the presence of environmentally aware consumers. Lombardini-Riipinen (2005) studied how governments set the socially optimal emission and commodity tax policies when consumers are willing to pay a price-premium for green variants of a product. Yakita and Yamauchi (2011) explored the welfare effects of environmental R&D strategies of firms. Zhang, Xu, and He (2012) examined how subsidy policies affect firms' design strategies of environmental products.

Most studies on *CEA* have primarily focused on product design and market competitiveness, and government environmental policy. In this paper, we focus on how *CEA* impacts supply chain management and coordination, a topic on which studies remain sparse to our knowledge.

3. Problem assumptions and model description

We consider two substitutable products: the environmental (or green) and the traditional products, namely, products 1 and 2. We assume that each product have two attributes, price (denoted as p) and environmental quality (denoted as e), influencing consumer demand. Both price and environmental quality of the