International Journal of Production Economics (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

An integrated revenue management framework for a firm's greening, pricing and inventory decisions

Syed Asif Raza[a,*], Sivakumar Rathinam[b], Mihaela Turiac[c], Laoucine Kerbache[d]

[a] College of Business and Economics, Qatar University, Doha, Qatar
[b] Texas A & M University, College Station, USA
[c] Economic Cybernetics and Statistics Doctoral School, The Bucharest University of Economic Studies, Romania
[d] HEC Paris, France

ARTICLE INFO

Keywords:
Environment
Newsvendor problem
Pricing
Market segmentation
Distribution-free approach

ABSTRACT

There is a growing interest on developing efficient ways of incorporating environmental considerations into business practices in order to meet both consumers' demand for green products/services, and the firms' sustainable profitability. The main contribution of this article is in developing an integrated revenue management framework to address a firm's greening (investment) effort, pricing and inventory decisions. It is assumed that the firm inaugurates a green product along with its existing product. Even though the firm offers both the green and regular product at differentiated prices, the market segmentation as a result of this price differentiation is regarded as imperfect. This imperfect market segmentation causes a demand leakage mainly due to the heterogeneity among the customers' willingness-to-pay. These effects are included in our proposed model and simplified analytical solutions are developed to solve the same. Additional scenarios where a firm experiences a price-dependent stochastic demand with an unknown distribution is also modeled. This scenario is addressed using a distribution-free approach based on Scarf' s rule. The performance of the proposed methods and the significance of the modeling framework are finally corroborated through several simulations. This analysis provides a sustainable environment, production and retailing framework while still augmenting profitability using fundamental tools from revenue management.

1. Introduction:

Sustainable development is increasingly required for environmental well-being and for general prosperity of a society. The newly developed applications for Operational Research (OR) in decision making are also expected to reflect a balance between social, economic, and environmental factors (White and Lee, 2009). In the recent years, the social responsibility has been intensively emphasized through public events and social campaigns, and by this a society is motivated to contribute more in the sustainable development and environment protection. Studies have provided clear evidences that the *consumers' concern and awareness about the environmental impact of products* can positively influence their buying behavior (Laroche et al., 2001). Consumption of green (environment friendly) products is widely observed in edible food such as organic products (Angood et al., 2007; Zander et al., 2013). Other consumer items such as textile, apparel, fashion and wood related products have also seen a similar consumer behavior (see (Angood et al., 2007; Bonini and Oppenheim, 2008; Zander et al., 2013; Chan and Wong, 2012; Aguilar and Vlosky, 2007)). Numerous organizations have perceived the worldwide trend of green consumerism and have incorporated this trend in their business practices. Organizations are more often calibrated on green performance and recognized by international agencies, research centers on environment, and institutes for standards of ethical business practices. In particular, manufacturers and retailers are facing not only the ethical challenges of complying with laws and regulations related to environmental protection, but also there is an increasing pressure from environmentally aware consumers to have more and more green products in the markets, which sustains the growing competition observed nowadays among eco-labelling. Recently, many research studies examined the impact of ecolabels such as fair trade, fair life, fair labor, organic, green or recyclable on the consumers' attitudes and willingness-to-pay (WTP) and showed that it can influence the *consumers' behavior in their purchasing decisions* (Caswell and Mojduszka, 2001; Mai, 2014). In many situations, the consumers' WTP increases after a production process innovation which enables the firm to charge a premium on green products (Swami and Shah, 2013). Drozdenko et al. (2011) have notified that an innovation can lead the customers to pay a price

* Corresponding author.
E-mail addresses: syedar@qu.edu.qa (S.A. Raza), srathinam@tamu.edu (S. Rathinam), kerbache@hec.fr (L. Kerbache).

http://dx.doi.org/10.1016/j.ijpe.2016.11.014
Received 23 May 2015; Received in revised form 6 August 2016; Accepted 22 November 2016

premium. Similarly, a greening innovation gives the firm rights for claims involving green products and thus enables it to lead the customers to pay a price premium for the green products. This price premium can be interpreted as the customers' demand for environmental quality. Apart from the external drives imposed through legislation and regulation, two important motivation factors for greening are still anticipated cost reduction effect and higher profitability outcomes (Srivastava, 2007).

Despite an increased awareness on environment and greening, a society contains customers from various backgrounds who have significant differences in their WTP (Keane and Wasi, 2013; Fiebig et al., 2010). Earlier studies (Chen et al., 2004) have reported that pricing is a paramount factor that often impacts the purchasing behavior. Currently, there is a growing interest on developing efficient ways of incorporating environmental considerations into business practices in order to meet both consumers' demand for green products/services, and the firms' sustainable profitability. To address this concern, Revenue Management (RM) (also referred to as yield management) offers a set of tools to improve profitability for its users (Phillips, 2005; Talluri and Ryzin, 2004). Price differentiation is a proven tool that enables a firm selling products to a group of people with distinct WTP.

The main contribution of this article is in developing an integrated RM framework to address a firm's greening (investment) effort, pricing and inventory decisions. It is assumed that the firm inaugurates a green product along with its existing product. Even though the firm offers both the green and regular product at differentiated prices, the market segmentation as a result of this price differentiation is regarded as imperfect. This imperfect market segmentation causes a demand leakage mainly due to the heterogeneity among the customers' WTP. These effects are included in our proposed model and simplified analytical solutions are developed to solve the same. Additional scenarios where a firm experiences a price-dependent stochastic demand with an unknown distribution is also modeled. This scenario is addressed using a distribution-free approach based on Scarf (1958)'s rule. The performance of the proposed methods and the significance of the modeling framework are finally corroborated through several simulations. This analysis provides a sustainable environment friendly production and retailing framework while still augmenting profitability using fundamental tools from RM.

The rest of this paper is organized as follows: In Section 2, a brief literature review is presented and the contribution of this article is highlighted in comparison to the existing studies. Section 3 formulates a mathematical model for a firm's RM with greening effort. Sections 4–6 detail the solution methodologies and lower bounds developed using the distribution-free approach. In Section 7, a numerical experimentation of the model is discussed and the effects of various parameters on the expected optimal revenue of a firm and the benefits of greening are highlighted. Finally, in Section 8 the findings are summarized, and future research directions are provided.

2. Literature review

There are several studies focusing on related areas of sustainability, environmental friendly manufacturing, re-manufacturing, recycling, reverse logistics, waste management, carbon emission reduction, tax incentives, etc. These topics although correlated are vast enough that a coverage of each of these topics is out of the scope of this paper. However, few relevant recent studies are briefly discussed here. Barbier (1987) presented earlier concepts of sustainable economic development. Bloemhof-Ruwaard et al. (1995) pointed out that Operational Research (OR) tools can be very useful while incorporating environmental issues in industrial supply chains. Gungor and Gupta (1999) surveyed issues in environmentally conscious manufacturing and product recovery. Fleischmann et al. (1997) reviewed quantitative models for reverse logistics. Autry (2005) laid out a strategy for managing returns from formalization of reverse logistics programs. Mutha and Pokharel (2009) proposed a strategic network design for reverse logistics and re-manufacturing. Jamshidi (2011) provided a comprehensive analysis and literature coverage in reverse logistics. Lambert et al. (2011) proposed a conceptual framework for reverse logistic decisions. Agrawal et al. (2015) provided perspectives in reverse logistics in a recent literature review. Alshamsi and Diabat (2015) studied a reverse logistic network design. Vahabzadeh et al. (2015) proposed a green decision making model in reverse logistics applying a fuzzy analysis. Bazan et al. (2016) reviewed mathematical inventory models for reverse logistics from an environmental perspective. Waste management is another area of focus. Hannan et al. (2015) reviewed technologies and their usage in solid waste management system, and identified issues and challenges. Recent advances in carbon emissions reduction: policies, technologies, monitoring, assessment and modeling are reported in Huisingh et al. (2015). Bing et al. (2016) researched recent challenges in municipal solid waste logistic management. Filho et al. (2016) explored benchmarking approaches and methodologies in the field of urban waste management. Laureri et al. (2016) developed an algorithm for an optimal collection of wet waste.

Greening supply chain has received much of the attention recently. Linton et al. (2007) introduced sustainable supply chains. Srivastava (2007) presented a literature review on green supply chains. However, prior to these studies, there was also work on sustainable and environment friendly (green) supply chains (see Rao (2002), Rao and Holt (2005) and Sarkis (2003)). Swami and Shah (2013) modeled a coordinated pricing strategy with greening (investment) effort in a manufacturer and a retailer experiencing a price-dependent deterministic demand. Later, Sang (2014) also suggested a coordination strategy of a supply chain with linear demand. Nouira et al. (2014) proposed optimization methods for manufacturing systems under environmental considerations of a greenness-dependent demand. Ghosh and Shah (2012) studied a comparative analysis of greening policies across supply chain structures. C.-T. Zhang et al. (2014) described their research on pricing and coordination strategy of green supply chains under a hybrid production mode. Ghosh and Shah (2015) later also explored supply chain analysis under green sensitive customer demand and cost sharing contract. Wang et al. (2015) suggested a framework for inventory management and pricing decisions for a supply chain with demand leakage and a return-policy contract. Li et al. (2016) formulated pricing policies of a competitive dual-channel green supply chain.

Recently, there is growing interest in the pricing decisions. Li et al. (2014) studied dual-channel supply chain pricing decisions with a risk-averse retailer. J. Zhang et al. (2014) addressed supply chain pricing decisions with price reduction during the selling season. Although pricing decisions are integrated with greening considerations, consumers' heterogeneity in WTP introduces many challenges in modeling (Keane and Wasi, 2013; Fiebig et al., 2010). Analytically tractable models are prohibitively complex to be developed, but some research studies have presented simplified approaches by using price differentiation tactics from RM. Phillips (2005) presented a numerical study of a single market demand being divided into two segments using a price-widget, referred to as the differentiation price. Later, Raza (2015a) proposed an analytical framework for the problem presented in Phillips (2005) for predetermined differentiation price for price-dependent stochastic demand with known as well as unknown distribution. In extension to this study, Raza (2015b) considered joint optimizing the differentiation price which is used for market segmentation for the price-dependent stochastic demand whose distribution could also be unknown. In contrast to this, some other recent studies (see Zhang and Bell (2007, 2010) and Zhang et al. (2010) have considered the demand leakage effect between the two pre-existing market segments, and therefore, the notion of differentiation price is not utilized. All of these research studies determine the pricing and order (production) quantity