ABSTRACT

The growing concern of consumers about eco-friendly behaviors and ethical consumption required for many firms to reassess their perspective towards the environment and to invest in greening efforts. Nowadays, the firms’ greening initiatives became an efficient tool in Revenue Management (RM) practice to generate profits and to gain competitive advantage. This paper addresses the tool of price differentiation of a firm with a greening initiative which can improve profitability through sustainable efforts. We formulate the firm’s problem to determine the optimal decisions on pricing, inventory and greening effort that maximize the revenue.

KEYWORDS: Revenue management, Greening effort, Price differentiation, Inventory control, Demand leakage

INTRODUCTION

The consumers’ concern for green consumerism is a strong stimulant for promoting green production by companies and governments. As the awareness for environmental aspects increase among customers, researchers analyzed their preference for products with organic attributes from the perspectives of nutrition and ethical consumption (Bonini & Oppeneheim, 2008, Manget et al. 2009, Zander et al. 2013). A substantial interest has focused on how to embed the environmental aspects into business practices, in order to meet both customers’ demand for environmental friendly products/services and market competition. In this concern, a growing segment in the supply chain literature approaches the environmental issues by extending the traditional supply chain design to green supply chains (Paksoy et al., 2010). Green supply chains consider several aspects that enclose the environmentally friendly concerns by performing strategies such as: green design, green operations, green manufacturing, green refurbishment, green disassembly, green returns management, product life-cycle, waste management, remanufacturing, recycling, reverse logistics systems, closed-loop supply chains (Guide & Srivastava, 1998; Srivastava, 2007). As Zhu & Sarkis (2004) suggested, green supply chain must refer to innovations in the supply chain management and in the industrial purchasing as a perspective toward environmental preservation. They confirmed that the innovation for greening the supply chain might increase the investment or operational cost at first, but the compensation of these costs can improve significantly the profitability on the
long term. From the economic perspective, the greening efforts of a firm may enhance its market share, reduce the production costs or augment the demand. The greening effort can also lead the customers to pay a price premium. Additionally to demand augmentation, the investment in greening effort could yield a reduction in the manufacturing cost of the green product via the process innovation required often in green manufacturing. As rightly noticed in Swami & Shah (2013), there is need of analytical research stream which can address the rapidly emerging phenomenon of green (environment friendly) manufacturing. The literature attested that manufacturing cost and product pricing are the main determinants in a firm’s profitability (Chen & Sheu, 2007), however, no clear practical consideration has been given on how greening effort change the manufacturing cost structures which consequently affect the pricing strategy at a firm’s level.

In RM practice, pricing is one of the most powerful tools of a firm to segment the market and to improve profitability (Talluri & Ryzin, 2004; Philips, 2005). Despite the numerous differentiation strategies applied in RM, there is a very limited focus on how does greening effort integrates into a firm’s RM decisions. The economic concern in the practice of greening initiatives motivates our research to examine to what extend the greening practice drives a firm to toward increased profitability when pricing decisions must be taken. The proposed framework includes simultaneous decisions on pricing, inventory quantities and greening effort. The problem is formulated based on the well-known newsvendor-pricing concepts and extended to demand leakage and greening efforts invested by a firm. While a firm adopts greening strategies, this directly implicates onto its market demand. The demand augmentation is observed in response to firm’s greening efforts. The green product process requires the firm a greening effort through a fixed investment which leads to an augmentation in the green product demand. The regular and green products are sold at differentiated prices, however, the market segmentation incurred due to differentiated prices is imperfect and thus the firm experiences demand leakage from green market segment into regular market segment. We investigate a firm’s problem which needs to determine the optimal pricing, inventory and greening effort decisions to maximize the revenues. This paper presents an optimization model, with a detailed analytical framework, for greening effort integration with RM tolls, which can be utilized by a firm to enhance profitability under uncertain markets with unknown stochastic demand distribution, when distribution free approach is applied.

The paper is organized as follows: in section 2 a brief literature review is presented, the mathematical model is developed in Section 3, Section 4 presents and discusses the numerical experimentation and in Section 5 the results are summarized concluding with the further directions for research.

LITERATURE REVIEW

The research in greening has focused on green design, reverse logistics, product recovery, and strategic supply chain network design. Fleischmann et al. (1997) presented a comprehensive survey of rapidly emerging field of reverse logistics. Environmentally conscious manufacturing in the context of product recovery was addressed by Gungor and Gupta (1999). Beamon (1999) discussed the development of environmental management strategies for the supply chain in the framework of product life-cycle analysis. These strategies investigate the environmental factors leading to the development of a more comprehensive environmental (green) supply chain, as an extension to the traditional supply chain. Sarkis (2003) also defined green supply chain management from the perspective of reverse logistics in combination with the activities of an environmental company. He supported that a larger number of organizations are considering the integration of environmental practices into their strategic plans and daily operations. In this support, numerous initiatives have provided incentives for organizations to become more environmentally. Jayaraman et al (2003) proposed mathematical models and solution
algorithms in remanufacturing and disposal, using heuristics to solve complex problem in design of reverse distribution networks. Linton et al (2007) highlighted the integration of sustainability and supply chains. Their study suggested that this convergence can be achieved by focusing beyond the myopic optimization of environmental factors and the supply chain traditional issues, to the entire supply chain: production, consumption, customer service, and post-disposal disposition of products. Srivastava (2007) documented a comprehensive literature review of environment and supply chain management, and a concise classification, based on the theoretical framework of different problems within green supply chain. The practice of green supply chain on the performance of supply chain and was explored in a conceptual model of their relationship in a case study of Azevedo et al. (2011). Bose & Pal (2012) investigated the impact of firms’ greening initiatives across supply chain onto their stock price. They analyzed 104 announcements related to greening initiatives across supply chain using an event study, and determined that the manufacturing firms with high R&D expenses and who were early adopters showed a strong increase in stock prices on the day of the announcement. At the same time, small firms, the firms not well-known for taking green initiatives, as well as firms that were low in growth potential considerably surprise the market when they made such announcements. From the nutrition and eating quality perspective, environmental sustainability is very desirable. Angood et al. (2008) conducted an empirical study on organic and conventional meet of British lamb from UK. The study provided statistical evidences of the perception among the consumers that the organic meat taste better. The potential cause of the taste difference was attributed due to differences in the fatty acids and the higher level of linoleic acid. Besides this, other evidences are also established in the study such as an organic meat is heavier than the conventional meat. Zander et al. (2013) presented a research report about the fact the ethical consumerism is a growing trend worldwide. Ethical consumers’ expectations are increasing and some of cornerstones concepts in the field such as fair-trade and organic farming fail to cover all the ethical concerns of consumers. Their research was the aimed to elicit consumers’ preferences regarding organic food with additional ethical attributes and their relevance at the market place. Bonini & Oppeneheim (2008) has identified in a survey conducted by McKinsey in 2007 consisting of 7751 people in Brazil, Canada, China, France, Germany, India, The United Kingdom, and United States, that 87 percent of the consumers are concern about the environmental and social impact of the purchases they make. Manget et al. (2009) on the other hand referred to Boston Consulting Group report and revealed that there ample evidences from consumers’ behavior that environmental issues impact the demand expansion. This effect is showed quite prevalent among consumers across wide cross-sections of nationalities, cultures, and geophysical location. One primary effect of going green is demand stimulation of the green products, which derives from the customers’ demand for sustainability. The process innovation effect onto demand enhancement has been also adopted by Gilbert & Cvsa (2003) in a bilateral monopoly supplier-buyer, where they analyzed the effect of strategic commitment to price by a supplier to stimulate innovation in a supply chain with demand uncertainty. The innovation effort effect with pricing decisions have been also approached by Giannakas & Fulton (2005), using a three-stage sequential game-theoretic model of a pure and a mixed oligopoly in the agriculture market with horizontal product differentiation and cooperative incentives. Unlike our study, the process innovation is considered to reduce the firms’ marginal costs of production in the second stage of each game, while the innovation cost is similarly approached through an increasing quadratic function of the innovation level. Drozdzenko et al. (2011) studied the consumer perceptions of the pricing premium of green products in three diverse categories and the demographic and situational factors that may affect their adoption. As Swami & Shah, (2013) observed, after a process innovation, the customers’ willingness to pay increases allowing a firm to charge a premium for the green products. Given the nature of the problem, the practice of RM and pricing is a natural choice to an optimal investment in greening and operations integrated framework for a firm. Among the RM tools,
pricing is one of the principal cores of yield management practice also known RM (Philips, 2005; Talluri and Ryzin, 2004). An example of price differentiation was identified by Zhang & Bell (2012) in airline industry, where tickets to passengers who are willing to pay much in advance and accept penalties for no shows or cancelations are low priced. Another industry that use the tactic of price differentiation is the hotels business, where higher prices are set for weekdays (Sunday through Thursday) room rates which are expected to be reserved by their business customers compared to weekend (Friday and Saturday) rates which are more desirable for their leisure customers. Hotels also apply several penalty rules such as cancelation restrictions, date change fee, non-refundable with lower priced room rates to restrict business customers to buy down. The integration of greening technology alters the cost structures and therefore the firm will look for the optimal price differentiation scheme. A realistic market condition assumes that and the market segmentation is imperfect and demand leakage effects are inevitable. As widely observed in most of real situations, we consider the greening investment as the strategy to expand the customer base and to differentiate the products. The analytical model presented in this research also considers the effect of demand leakage into the differentiated pricing scheme for green and regular products offered by a firm. The fundamental concept is to segment a single market into multiple market segments using a differentiation price depending upon the customers' willingness to pay for product or services at differentiated prices. A special situation in cannibalization is realized when a firm experiences demand leakage between its market segments created using a differentiation price which is the focus of this paper. This work also adopts the price differentiation from Philips (2005) which allows a firm to control the maximum perceived demand for each market segment. Using the price differentiation, the firm is able to segment its single market demand into multiple segments. In addition, a price differentiation strategy is more intuitive as a firm can decide on a price threshold as differentiation price. Therefore, the paper can be regarded as the extension of Philips (2005)’s model by integrating the greening investment decisions at a firm level.

THEORETICAL MODEL

We propose a deterministic model for the RM problem of a firm who is selling green and regular types of products and which is trying to maximize its profit by adopting an optimal price differentiation between the green and the regular products. The notations used in the model are presented in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Notations</th>
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<tr>
<td><strong>Parameters:</strong></td>
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<tr>
<td>$c_i$</td>
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<tr>
<td>$\alpha_i$</td>
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<tr>
<td>$\beta_i$</td>
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<tr>
<td>$u_i$</td>
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<tr>
<td>$y_i$</td>
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<td>$\delta$</td>
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<td>$\theta$</td>
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<tr>
<td>$i$</td>
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<tr>
<td><strong>Decision variables:</strong></td>
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<tr>
<td>$p_i$</td>
</tr>
<tr>
<td>$v$</td>
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<td>$q_i$</td>
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<td>$\tau$</td>
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</table>
The firm activates in monopoly and segments the market based through a price differentia- tion. The market segmentation resulted after the price differentiation, considers the consumers’ willingness to pay and results a green product market segment (g) and a regular product market segment (r). The assumption of deterministic demand excludes any sort-sales or leftovers in the model structure. We assume that the firm observes simultaneously the demands for the two products and we adopt a linear price-dependent form of demand, \( \forall i = \{g, r\} \), such that, 
\[
 u_i(p_i) = [\alpha_i - \beta_i p_i]^+, \text{ where } [x]^+ = \max(0, x).
\]
The linear demand curve is intensively applied in pricing research due to its simplicity and yet comprehensive structure (Zhang et al., 2010). Also, the linear demand curves follows the Increasing Price Elasticity (IPE) property in a non-strict sense so that, the demand price elasticity \( \frac{\partial \eta_i}{\partial p_i} \geq 0 \), where \( \eta_i = -\frac{p_i \frac{\partial u_i}{\partial p_i}}{u_i}, \forall i = \{g, r\} \), which implies \( \frac{\partial u_i}{\partial p_i} \leq 0 \). The firm offers a green product for price, \( p_g \), and a regular product, \( p_r \) and \( p_g > p_r \). In the price deterministic demand \( u_i \), the consumers’ price sensitivity is, \( \beta_i, \forall i = \{g, r\} \) and the maximum demand experienced by the firm in each market segment is \( \alpha_i \). In regular market segment \( \beta \) is assumed higher than in the green market segment, such that, \( \beta_g \leq \beta_r \), since the consumers from the green market segment are more willingness to pay than the consumers assigned to the regular market segment. The price differentiation, \( \nu \geq 0 \), applied by the firm allows it to control the market shares of each segment of the market, so that \( \alpha_r = \nu \beta_r \). The price differentiation was adopted initially in Phillips (2005) and later in Zhang & Bell (2007) and Zhang et al. (2010), by considering it a fixed policy rather than an optimized parameter. The green products are obtained through a green effort, \( \tau \), invested by the firm and implemented through a fixed investment. The greening effort, \( \tau \), augments the demand of the green products, which are qualitative superior products compared to the regular products. The response function of the greening effort is modelled following Swami & Shah (2013), through a linear influence into the green product demand, such that, \( u_g + \gamma \tau \). Similar approach of market response onto the demand can be found in Savaskan et al. (2004) and Savaskan & Wassenhove (2006), for supply chain problems.

Next, we assume the market segmentation has a negligible fencing cost and that the segmentation is imperfect, leading to \( \theta \) demand leakage between the market segments. The leakage effect is observed due to price differential perception into customers’ willingness to pay and therefore, it is realistic to assume that it occurs from the green (higher priced) market segment to regular (lower priced) market segment. In RM research, demand leakage was addressed intensively in the recent years (Hanks et al., 2002, Kimes, 2002, Zhang & Bell, 2007, Raza, 2014) and researchers have focused on how to mitigate the demand leakage (see Zhang & Bell (2010) and Zhang et al. (2010) for more details). Thus, the price dependent deterministic demands in the two market segment affected by demand leakage are given by:

\[
\begin{align*}
\eta_g &= (1 - \theta)(u_g + \gamma \tau) \\
\eta_r &= \theta (u_g + \gamma \tau) + u_r
\end{align*}
\]

The cost of implementing the greening effort is assumed as a fixed investment and following Savaskan et al. (2004), we model it through the cost structure, \( \delta \tau^2 \), as a function of greening effort and fixed cost, \( \delta \). Naturally, the greening investment has a diminish effect onto the firm’s revenue. The firm goal is to find the optimal price differentiation strategy, the selling prices and greening effort, which maximize its total profit. We define the firm’s RM problem of jointly determining the optimal control decisions under demand leakage as per below:

\[
P: \quad \pi = (p_g - c_g) \eta_g + (p_r - c_r)\eta_r - \delta \tau^2
\]
Subject to:

\[
p_g - v \geq 0 \\
v - p_r \geq 0
\] (4) (5)

In problem P, Equation (3) represents the firm’s total revenue from the green and the regular market segment, while Equations (4) and (5) are the pricing constraints. Thus, the firm must decide on the pricing decisions, \( p_g \) and \( p_r \), the price differentiation scheme, \( v \), and the greening level of effort, \( \tau \), when it anticipates \( \theta \) demand leakage between the market segments, \( \gamma \) market sensitivity to the greening effort and \( \delta \) cost of the greening investment. Once the prices are determined, the firm’s inventory level will be to the actual perceived demand in each market segment, \( y_i \).

**NUMERICAL EXPERIMENTATION**

**The Impact of Environmental Factors**

We provide a numerical analysis to the mathematical model for analyzing the impact of the exogenous factors, demand leakage, market sensitivity to greening effort and greening cost, onto the firm’s profitability. The numerical experimentation was conducted with the parameters values adopted from Philips (2005)’s work, assuming for simplicity the symmetry of \( \alpha = \alpha_r = \alpha_g = 10,000 \), \( \beta = \beta_g = \beta_r = 800 \), and \( c = c_g = c_r = 5 \). The assumption on the price sensitivity symmetry implies that the market segmentation results from price differentiation policy. Demand leakage is considered a discrete variable with values in \( \theta = \{0, 0.25, 0.5, 0.75, 0.9\} \). From several studies conducted with various levels of market sensitivity to greening effort and greening cost, we have selected \( \gamma = \{1, 20\} \) and \( \delta = \{1, 20\} \), respectively. Thus, the joint effect of \( \delta \) and \( \gamma \) are presented in each of the five scenarios of \( \theta \), as showed in Table 2. Figure 1 illustrates the findings obtained in Table 2.

<table>
<thead>
<tr>
<th>( \delta )</th>
<th>( \gamma )</th>
<th>( \theta )</th>
<th>( p^*_1 )</th>
<th>( p^*_2 )</th>
<th>( \tau^* )</th>
<th>( q^*_1 )</th>
<th>( q^*_2 )</th>
<th>((2)^*\pi)</th>
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<tbody>
<tr>
<td>0</td>
<td>10.00</td>
<td>7.50</td>
<td>2.50</td>
<td>2000.88</td>
<td>2000.83</td>
<td>15006.30</td>
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<td>0.25</td>
<td>10.05</td>
<td>7.99</td>
<td>2.31</td>
<td>1385.18</td>
<td>2308.58</td>
<td>13851.50</td>
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<tr>
<td>1</td>
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<td>10.36</td>
<td>8.22</td>
<td>2.14</td>
<td>857.47</td>
<td>2572.36</td>
<td>12861.70</td>
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<tr>
<td>0.75</td>
<td>10.50</td>
<td>8.50</td>
<td>2.00</td>
<td>400.14</td>
<td>2600.96</td>
<td>12004.00</td>
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<tr>
<td>0.9</td>
<td>10.58</td>
<td>8.65</td>
<td>1.92</td>
<td>153.90</td>
<td>2924.03</td>
<td>11542.20</td>
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<td>0</td>
<td>11.00</td>
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<td>0.25</td>
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<td>20</td>
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<td>0.11</td>
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<td>3000.00</td>
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It is obvious to notice the diminishing impact of demand leakage, $\theta$, as its level increases to 90%. For instance, at $\gamma = 1$, $\delta = 1$, the revenue drops with 30% for $\theta = 0.9$ from the favorable case of $\theta = 0$. The natural reaction of the firm to the high level of demand leakage is to increase the selling prices of the products and to offer less quantity to its consumers. Also as a reaction to $\theta$, the price difference drops, in order to control the demand leakage effect. From the perspective of greening effort and cost of greening, the most favorable situation of the firm is obviously in a market with high attraction for green products and low cost of the greening investment. This study can be a good benchmarking exercise for the firm by analyzing the market awareness about the environmental issue before the greening initiative. As the results also show, targeting the right market can increase profitability of a firm, for example, a high preference for the green products can bring 20% more profits compared with a low $\gamma = 1$ market profile, when the greening cost and demand leakage are minimum, $\delta = 1$, $\theta = 0$. It is obvious to notice that, in this case the green effort invested by the firm is at highest level, $\tau = 60$, and this scenario is the most favorable, given the highest profit of $\pi = 18000$.

In Figure 1 is illustrated the impact of the environmental factor onto the firm’s revenue and on demand leakage range proposed in this numerical experimentation and also the advantage of market segmentation versus the single market segment.
The Impact of Price Differentiation Strategy

In this study we analyze the price differentiation strategy, following an earlier study of Philips (2005). Thus, we consider two strategies for price differentiation, $v$, specified by fixing an arbitrary price differentiation or by choosing to optimize it. If the price differentiation is fixed, we assume $v$ to take values of $\{7, 8, 9\}$ and we compare each of these strategies with the optimized $v$ and as well with the single market segment. Each comparison is conducted in four scenarios based on the environmental factors levels: $\gamma = 1$ and $\delta = 1$, $\gamma = 1$ and $\delta = 20$, $\gamma = 20$ and $\delta = 1$, $\gamma = 20$ and $\delta = 20$, considering the initial demand leakage range $\theta = \{0, 0.25, 0.5, 0.75, 0.9\}$. The results are illustrated for each scenario in Figures (2) – (5). The results are showing that the firm can achieve superior profitability while segmenting the market by optimizing the price differentiation strategy $v^*$ than using any fixed price differentiation, in any of the environmental scenarios. Again, it is clear the strong influence of demand leakage factor, which can diminish any market segmentation strategy over the single market segment, as its level increase.

Figure (2): Impact of price differentiation for $\gamma = 1$ and $\delta = 1$
Figure (3): Impact of price differentiation for $\gamma = 1$ and $\delta = 20$

Figure (4): Impact of price differentiation for $\gamma = 20$ and $\delta = 1$
CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This paper proposes an integrated framework for greening effort, pricing and inventory decisions for a firm in a deterministic setting. The mathematical model assumes that a firm is offering green (environment friendly) and regular products in a market as monopolist. The firm is able to produce the green product with a financial investment on greening effort implementation, while the greening effort augments the demand for green product proportional to the greening effort. The market segmentation through price differentiation is imperfect and demand leakage is expected by the firm, as the price of the green product is higher than the price of the regular product. We modeled the firm’s decisions in an RM model and we test it through a numerical application. The results showed that the price differentiation strategy can augment profitability if it is optimized rather than fixed.

There are several restriction applied to the model which can limit the problem formulated for a firm. Thus, a more realistic situation can be considered for a stochastic demand curve or a demand with probability unknown. Moreover, an interesting extension of the model can be done by using log-linear or exponential curves of demand. Later, the monopoly case can also be extended to competition. And lastly, this model considers one upfront investment for implementing the greening initiative; however, in reality the greening effort can also impact the cost of manufacturing the green products.

ACKNOWLEDGMENTS:
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REFERENCES


