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Channel Coordination in Green Supply Chain Management: The Case of Package Size and Shelf-Space Allocation

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__**Abstract**__: *Environmental consciousness has become increasingly important in present times, as evident by the examples from both everyday life and business practices. In the manufacturing sector, the efforts to reduce the impact of environmentally harmful activities have collectively been labeled as green supply chain management. Any major greening project would require efforts on the part of the entire supply chain. However, relatively few studies have addressed the issue of coordinating the green supply chain. We address the issue of vertical coordination in a green supply chain between the players at the upstream (say, a manufacturer) and downstream (say, a retailer) levels of the chain. In this paper, we focus on an interesting problem faced by manufacturer-retailer pairs (e.g., P&G, and Walmart) in the consumer products supply chains. The manufacturer has to decide on the wholesale price and the package size of its product. The manufacturer is labeled as a green manufacturer, since reducing the pack size of its product would help him save on environmentally costly transportation cost. Reduction in pack size helps the manufacturer also save on product packaging cost. Moreover, the reduced package size also results in cost savings for the retailer in terms of handling and storage.*

The retailer decides on the retail price and the shelf space to be allocated to the "green" manufacturer. The increase in allocation of shelf space has a demand expansion effect on the retail demand for the green manufacturer's products. However, the decrease in pack size has a demand reduction effect on its demand, because larger pack sizes attract more consumer attention, and therefore, act as an advertising vehicle. Further, the retailer has limited shelf-space and has to balance the space allocation for the green manufacturer against the potential profitability of allocating that space to "other" manufacturers

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In view of the above elements of complexity, it is interesting to examine the optimal prices charged, optimal reduction in size and optimal shelf-space allocation in this problem. We examine the problem for the cases of both integrated and decentralized channels. Our results show that the total profit is greater, pack sizes are smaller, and shelf-space allocation is greater in the integrated channel as compared to the decentralized channel. Retail prices can be greater or smaller in the decentralized channel as compared to the integrated channel, depending on certain values of the problem parameters. These results show that clearly there is scope for channel coordination in this problem setting for better profitability and environmental benefits. We propose a two-part tariff scheme which effectively coordinates the green supply chain in this problem setting.

[Key words: Distribution, Channel Integration, Green supply chain management, Supply chain coordination, Environment]

1 Introduction

Consider the following concerns of Unilever managers in their direct competition with P&G on Wal-Mart's shelves:

> "On my grocer's shelf are a bulky, 100-fluid-ounce, orange plastic jug of Procter & Gamble's bestselling Tide and a slim 32-ounce aqua plastic bottle of Unilever's "small and mighty" All. Both contain enough detergent for 32 loads of wash, but the smaller package, made possible by condensing All, saves energy, shipping costs, and shelf space - a big win all around, right?
>
> Not quite. Bigger packages command more shelf space, provide more surface area for advertising, and suggest to consumers that they're getting more for their money. Unilever executives voiced all those worries when they went to see Scott [the Wal Mart CEO]." (Gunther 2006).

The above quote aptly represents the dilemma faced by a manufacturer, who invests heavily in making his product more environment-friendly, only to realize later that it also has to balance this against the realities of market place (i.e., consumer behavior). Recently, such dilemmas have begun to be addressed in the broad field of green supply chain management. This is a rapidly emerging field since environmental consciousness has become intertwined with everyday life and sound business practices (Intergovernmental Panel on Climate Change 2007).

A 2003 report by U.S.-based non-profit government consulting institute, LMI Research Institute, mentions that, particularly in the manufacturing sector, there has been increased scrutiny of the items being purchased for use in various processes, the effects of processes, and the packaging and delivery of the products. The effort to reduce the impact of these activities on the environment has been labeled as green supply chain management. This report states that "Firms have generally taken two approaches to greening their supply chains. The first looks externally to its various suppliers. Suppliers are asked to provide evidence of their operations meeting relevant environmental requirements and, in some cases (Toyota and Ford for example), evidence of ISO14001 certification. The second approach is an internal examination of how a firm designs, produces, and ships its products." (LMI Report 2003, p. 2.8).

Examples have begun to emerge from practice regarding the economic benefits of the adoption of the green practices. Commonwealth Edison reported financial benefits of \$50 million annually from managing material and equipment with a life-cycle management approach. Pepsi saved \$44 million by switching from corrugated to reusable plastic shipping containers. Similar savings have been reported by Texas Instruments and Dow Corning (Wilkerson 2005). Rao and Holt (2005) specifically mention that greening different phases of a supply chain may eventually result in an integrated supply chain, which in turn would ensure better economic performance and competitiveness.

The research area of green supply chain management has opened up several interesting and challenging problems for both the practitioners and researchers. In response to these challenges, a relatively new stream of research has emerged, which is labeled as green supply chain management (Srivastava 2007). A number of research issues have been addressed such as green design (Zhang et al. 1997), reverse logistics (Flieschmann et al. 1997), product recovery (Gungor and Gupta 1999), logistics design (Jayaraman et al. 2003), solid waste management (Adamides et al. 2009) and so on. However, very few studies have addressed the issue of coordinating the green supply chain.

We address the issue of vertical coordination in a green supply chain between the players at the upstream (say, a manufacturer) and downstream (say, a retailer) levels of the chain. In this paper, we focus on the problem faced by manufacturer-retailer pairs (e.g., P&G, and Walmart) in the consumer products supply chains. The manufacturer has to decide on the wholesale price and the package size of its product. The manufacturer is labeled as a green manufacturer, since reducing the pack size of its product would help him save on environmentally costly transportation cost. Reduction in pack size helps the manufacturer also save on product packaging cost. Moreover, the reduced package size also results in cost savings for the retailer in terms of handling and storage.

The retailer decides on the retail price and the shelf space to be allocated to the "green" manufacturer. The increase in allocation of shelf space has a demand expansion effect on the retail demand for the green manufacturer's products. However, the decrease in pack size has a demand reduction effect on its demand, because larger pack sizes attract more consumer attention, and therefore, act as an advertising vehicle. Further, the retailer has limited shelf-space and has to balance the space allocation for the green manufacturer against the potential profitability of allocating that space to "other" manufacturers.

In view of the above elements of complexity, it is interesting to examine the optimal prices charged, optimal reduction in size and optimal shelf-space allocation in this problem. We examine the problem for the cases of both integrated and decentralized channels, and compare the results to examine the presence of channel conflict in this problem setting.

The rest of the paper is organized as follows. The next section provides the background literature for this paper. Section 3 discusses the model development. Section 4 provides the results of the various analyses. Section 5 concludes with the discussion and future research ideas.

2 Background Literature

2.1 Channel Coordination

Jeuland and Shugan (1983) define channel coordination as the setting of all manufacturer and retailer-related decision at the levels that would maximize total channel profits. In this context, the seminal work by McGuire and Staelin (1983) studied the impact of product substitutability on Nash equilibrium distribution structures where each manufacturer distributes its goods through an exclusive retailer. Jeuland and Shugan (1983) focused on channel coordination in the context of a single manufacturer and a single retailer structure. They find that coordination between a manufacturer and a retailer using a quantity discount schedule could lead to higher profit for channel members. Moorthy (1988) examines the effect of strategic interaction on a manufacturer's channel structure decisions.

Choi (1991) considers a channel structure consisting of two manufacturers and a single common retailer. His model addresses three types of games: the Manufacturer–Stackelberg game, the Retailer–Stackelberg game and Vertical–Nash equilibrium. Ingene and Parry (1995) took an opposite approach to Choi's (1991) and studied channel coordination by focusing on a single manufacturer using two competing retailers. They use a Stackelberg game, in which the manufacturer could apply either a two-part tariff scheme or a schedule for quantity discounts. They find that while quantity discount schedule facilitates channel coordination, the two-part tariff does not. Lee and Staelin (1997) provide a more generalized model allowing two manufacturers to interact with two retailers. Iyer (1998) analyzes how manufacturers should coordinate distribution channels when retailers compete in price as well as important non-price factors such as the provision of product information, free repair, faster check-out, or after-sales service.

Jorgensen, Taboubi, and Zaccour (2001) examine dynamic advertising and promotion strategies in a marketing channel where the retailer promotes the manufacturer product and the manufacturer spends on advertising to build a stock of goodwill. The results show that the cooperative advertising program is a coordinating mechanism in the marketing channel. More recently, Arya and Mittendorf (2006) provided a counter-intuitive result that sometimes a separated, as opposed to vertically integrated, channel that embodies a degree of discord can be helpful from a long-term viewpoint. From the applications perspective, Raut et al. (2008) provide an innovative application of channel coordination in the motion picture industry characterized by a dynamic market environment, limited shelf space, product category management, and complex contractual practices They find that simpler contracts (e.g., two-part tariff, or 50/50 split of revenues) is sufficient to coordinate the channel considered.

2.2 Shelf Space Management

A number of researchers have proposed optimization models in the area of retail shelf space allocation. Lynch (1974) considers shelf space maximization with a constrained optimization model. The author assumes a quadratic relationship between shelf space and demand. The paper is a comment on a previous paper on the relationship between shelf space and unit sales in supermarkets. Anderson (1979) assumes a logistic market share model for the relationship between shelf space and market share. The paper looks at the decision of assembling a portfolio of product brands and determining what display area should be assigned to each. Corstjens and Doyle (1981) consider the problem of allocating scarce shelf space among competing products. A geometric programming model is developed which incorporates main and cross space elasticities. The parameters of the model are estimated. The allocation rules that result are shown to provide higher profits. Yang and Chen (1999) proposed an integer programming model for the shelf-space allocation problem. Wang and Gerchak (2001) consider a manufacturer who has to supply product to a retailer. The retailer's demand is shelf space dependent. The manufacturer aims to coordinate the decentralized supply chain. The authors show that to coordinate the channel, the manufacturer needs to offer a holding cost subsidy to the retailer. Gerchak, Cho, and Ray (2001) consider the problem of channel coordination and dynamic shelf-space management of video movie rentals.

Yang (2001) proposed a heuristic method to solve the same problem. Lim et al (2004) extended Yang and Chen's (1999) model by considering non-linear profit functions and cross-elasticity effects, formulating the problem as a non-linear integer programming model. Raut, Swami and Moholkar (2009) propose heuristic and meta-heuristic approaches for multi-period shelf-space optimization problem in the area of motion picture retailing. Hansen, Raut and Swami (2010) present a comparative analysis of heuristic and meta-heuristic approaches in retail shelf allocation.

2.3 Green Supply Chain Management

Zhang et al. (1997) provide a comprehensive review of green design through a term introduced by then as "Environmentally conscious design and manufacturing (ECD&M)". Around the same time, Flieschmann et al. (1997) surveyed the then rapidly emerging field of reverse logistics. They subdivided the field into three main areas, namely distribution planning, inventory control, and production planning. For each of these, the implications of the reuse efforts, mathematical models proposed, and areas in need of further research were discussed. Beamon (1999) discusses the development of environmental management (EM) strategies for the supply chain. Her research investigates the environmental factors leading to the development of an extended environmental supply chain, describes the elemental differences between the extended supply chain and the traditional supply chain, and develops a general procedure towards achieving and maintaining the green supply chain. Sarkis (2003) posits a strategic decision framework for green supply chain management. Jayaraman et al. (2003) discuss the models and solution procedures regarding the design of reverse distribution networks.

Linton et al. (2007) provide an introduction to sustainable supply chains. They give consideration to the convergence of supply chains and sustainability. Srivastava (2007) provides a comprehensive literature review of a broad frame of reference for green supply-chain management (GrSCM). A succinct classification is aimed at helping academicians, researchers and practitioners in understanding integrated GrSCM from a wider perspective. Srivastava (2008) also provides an integrated holistic conceptual framework that combines descriptive modeling with optimization techniques for network design in reverse logistics.

2.4 Coordinating Green Supply Chains

Some research has begun to emerge in the area of the coordination of green supply chain. Vachon and Klassen (2008) mention that as corporations attempt to move toward environmental sustainability, management must extend their efforts to improve environmental practices across their supply chain. Using a survey of North American manufacturers, their paper examines the impact of environmental collaborative activities on manufacturing performance. Environmental collaboration was defined specifically to focus on inter-organizational interactions between supply chain members, including such aspects as joint environmental goal setting, shared environmental planning, and working together to reduce pollution or other environmental impacts. These practices can be directed either upstream toward suppliers or downstream toward customers.

Walton et al. (1998) consider the case of how to integrate suppliers into the environmental management processes of green supply chain. Using survey-based approach, they find that it is beneficial for purchasing companies to influence the suppliers' environment management practices. Similar results have been reported by Rao (2002) in South-East Asian context.

Kogg (2003) reports the case study of a greening a cotton-textile supply chain, which specifically considers the case when the suppliers have greater channel power. Goldbach, Seuring and Back (2003) provide a case study on the introduction of a sustainable cotton supply chain at a German mail-order business OTTO. The major difficulty arising in the chain was how to coordinate the activities of a complex network of different players involved in the chain. In the practical setting considered, the coordination required a set of hybrid approaches at different levels, ranging from market-like structures to hierarchical ones based on command-and-control mechanisms.

Vachon and Klassen (2006) consider the impact of upstream and downstream integration on extending green practices across the supply chain. It was found that technological integration with primary suppliers and major customers was positively linked to environmental monitoring and collaboration. For logistical integration, a linkage was found only with environmental monitoring of suppliers.

Simpson et al. (2007) explore the moderating impact of relationship conditions existing between a customer and its suppliers on the uptake and effectiveness of the customer's green supply chain performance requirements. In a setting of automotive supply chain, they find that suppliers were more responsive to their customers' environmental performance requirements where increasing levels of relationship-specific investment occurred. Similar issues were explored by Simpson and Power (2005).

Mitra and Webster (2008) analyze a two-period model of a manufacturer who makes and sells a new product and a remanufacturer who competes with the manufacturer in the second period. They examine the effects of government subsidies as a means to promote remanufacturing activity. They find that the introduction of subsidies increases remanufacturing activity, and that the manufacturer's profits generally decrease while the remanufacturer's profits increase when 100% of the subsidy goes to the remanufacturer.

3 Model Development

The problem considered in the current paper is of a single manufacturer who sells its products to a single retailer. The manufacturer has to decide on the wholesale price and the package size of its product. The manufacturer is labeled as a "green" manufacturer, since reducing the pack size of its product would help him save on transportation and packaging costs.

The retailer decides on the retail price and the shelf space to be allocated to the green manufacturer. The increase in allocation of shelf space has a demand expansion effect on the retail demand for the green manufacturer's products. However, the decrease in pack size has a demand reduction effect on its demand, because larger pack sizes attract more consumer attention, and therefore, act as an advertising vehicle. Further, the retailer has limited shelf-space and has to balance the space allocation for the green manufacturer against the potential profitability of allocating that space to “other” manufacturers. Moreover, the reduced package size also results in cost savings for the retailer in terms of handling and storage.

We wish to examine the effect of various parameters, such as, effectiveness of package size reduction efforts, cost of transportation, shelf-space sensitivity of demand, attractiveness of “other” goods, on different decision variables and profitability of the supply chain. The demand of the product generated at the retail end is a function of the retail price, shelf-space allocation, and package size reduction. However, as the demand effects of some of these variables are in opposite direction, *ex ante*, it cannot be said how much package size reduction or space allocation would be optimal for the supply chain. Also, given that some of these variables are controlled by manufacturer, while others by the retailer; it may be in the interest of both of them to contribute jointly to their resultant effect on profit generation.

The specific assumptions of the model structure can be summarized as given below:

- The supply chain structure (as shown in Figure 1) comprises of one (green) manufacturer and one retailer.
- The retail demand of the green manufacturer’s product is assumed to be downward sloping in retail price, upward sloping in shelf-space allocation, and downward sloping in size reduction. Further, demand is a linear function of the variables of retail price, shelf-space allocation, and size reduction.

- It is assumed that the market is homogeneous in its preference for the green product.
- The variable costs of manufacturing or retailing are assumed to be negligible, and are equal to 0.
- Market potential is sufficiently large, and significantly greater than the other parameters of the model.
- The savings in cost of transportation is a quadratic function of package size reduction. Similarly, the attractiveness of "other" products, or the opportunity cost of the shelf-space allocation to the green product is a quadratic function of shelf-space allocation to the green product.

In the proposed model, the manufacturer, as a Stackelberg leader, decides first on a wholesale price w and the amount of package size reduction, δ. Then, the retailer decides on the retail price p and shelf-space allocation to the green product, n_g.

Based on the assumptions described above, the demand at the retail end is considered as follows:

$$Q\ (p, \delta, n_g) = \theta - p + \alpha_1 n_g - \alpha_2 \delta \qquad (1)$$

In the demand equation, θ represents the base market potential, and p is price per unit. The demand effects of shelf-space allocation, and the package size reduction are represented by the respective effectiveness parameters, α_1 and α_2.

[Insert Figure 1 About Here]

The following profit functions are considered for the manufacturer and retailer, respectively.[1]

$$\pi_m = (w + c * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2 \delta) + F_1 \delta^2 - F_2 \quad (2)$$

$$\pi_r = (p - w + r * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2 \delta) - m_0 n_g^2 - F_3 \quad (3)$$

Here w represents wholesale price per unit. The packaging cost reduction effect for the manufacturer is represented by c, while the packaging cost savings for the retailer in terms of handling and storage is represented by r. The transportation cost savings for the manufacturer are represented by F_1. The attractiveness of the other products (or the opportunity cost of the current space allocation) is represented by m_0. In addition, the fixed costs for the manufacturer and retailer are shown by F_2 and F_3, respectively.

4 Results

We first present the results of vertically integrated channel, and subsequently the results of a decentralized channel.

4.1 Integrated Channel

The total channel profits in this case are given by

$$\pi^I = \pi_r + \pi_m$$

$$= (p + r * \delta + c * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2 \delta) + F_1 \delta^2 - m_0 n_g^2 - F_2 - F_3 \quad (4)$$

Assuming concavity of the respective objective functions, the first-order conditions for π^I yield the following optimal values of p, τ_r and τ_m:

$$p^* = \frac{\{2m_0 F_1 - m_0(c + r)\Delta_1\}}{\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$$

(5)

[1] The modeling structures used builds upon the earlier works by Berger et al. (2006), Savaskan and Van Wassenhove (2006), and Gurnani et al. (2007).

$$\delta^* = \frac{m_0\Delta_1}{\Delta_2 F_1 + m_0\Delta_1^2} * \theta$$

(6)

$$n_g^* = \frac{\alpha_1 F_1}{\Delta_2 F_1 + m_0\Delta_1^2} * \theta$$

(7)

where $\Delta_1 = \alpha_2 - c - r$, and $\Delta_2 = 4m_0 - \alpha_1^2$. For the feasibility of δ^* and n_g^*, the denominator of Equations 6 or 7 should be greater than 0, that is, the following condition should hold:

$(\Delta_2 F_1 + m_0\Delta_1^2) > 0$

This condition is assumed to hold through the rest of the analytical development in the paper.

4.2 Decentralized Channel

In this case, we present the result using the Stackelberg game structure. Assuming concavity of the respective objective functions, we first determine the best response functions of the retailer from the simultaneous solution of the first-order conditions of π_r. This gives n_g and p as functions of w and δ. These response functions are then used to derive an expression for π_m only in terms of the relevant decision variables at the manufacturer's level, that is, w and δ. The first-order conditions for π_m then yield the optimal values of w and τ_m. This development is shown below.

$$\pi_m = (w + c * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2\delta) + F_1\delta^2 - F_2 \quad (8)$$

$$\pi_r = (p - w + r * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2\delta) - m_0 n_g^2 - F_3 \quad (9)$$

$$\frac{\partial \pi_r}{\partial p} = 0 \quad \rightarrow \quad 2p = \theta + w + \delta * r + \alpha_1 n_g - \alpha_2\delta \quad (10)$$

$$\frac{\partial \pi_r}{\partial n_g} = 0 \quad \rightarrow \quad \alpha_1(p - w + \delta * r) - 2m_0 n_g = 0 \tag{11}$$

These response functions are then used to derive an expression for π_m only in terms of the relevant decision variables at the manufacturer's level, that is, w and δ. The first-order conditions for π_m then yield the optimal values of w and τ_m:

$$w^* = \frac{\Delta_2 F_1 - m_0 c\,\Delta_1}{2\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$$

(12)

$$\delta^* = \frac{m_0 \Delta_1}{2\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$$

(13)

When used in Equations 10 and 11, we get

$$n_g^* = \frac{\alpha_1 F_1}{2\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$$

(14)

$$p^* = \frac{\{2m_0 F_1 + \Delta_2 F_1 - m_0(c + r)\Delta_1\}}{2\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$$

(15)

After the optimal values of the above variables have been inserted in Equations 2-3, we get the values of optimal manufacturer's and retailer's profits in the decentralized channel, denoted by π_m* and π_r*, respectively. The total channel profits in the decentralized channel are given by

$$\pi^D = \pi_m* + \pi_r*$$

4.4 Comparing the Results of Vertically Integrated and Decentralized Channels

We now compare various analytical results of the vertically integrated and decentralized channels. These are presented in the form of various propositions. Throughout the results, the superscript I denotes the 'integrated' channel, while D denotes the 'decentralized' channel.

Proposition 1: The following relation holds between the profits in the integrated channel and the decentralized channel: $\pi^I > \pi^D$.

Proof of Proposition 1:

For the **integrated channel**, we get the following value of the profit:

$$\pi^I = \frac{F_1 m_0 \theta^2}{\Delta_2 F_1 + m_0 \Delta_1^2} - F_2 - F_3 \tag{16}$$

For the **decentralized channel**, the total profit is given by

$\pi^D = \pi_r + \pi_m$,

where the values of optimized variables come from Equations 12-15. Inserting these values, we get

$$\pi^D = \frac{(-4\alpha_1^4 F_1^2 F_3 + 4\alpha_1^2 F_1 F_3 m_0 (8F_1 + \Delta_1^2) - 3F_1\theta^2) - m_0^2\theta^2\{F_3(8F_1 + \Delta_1^2)^2 - F_1(12F_1 + \Delta_1^2)^2\}}{(2\Delta_2 F_1 + m_0\Delta_1^2)^2} - F_2 \tag{17}$$

Equations 16 and 17 give the following relation after simplification:

$$\pi^I - \pi^D = \frac{F_1 \Delta_2^2 m_0 \theta^2}{(\Delta_2 F_1 + m_0 \Delta_1^2) * (2\Delta_2 F_1 + m_0 \Delta_1^2)^2} \tag{18}$$

Since all the terms in the right-hand side of Equation 18 are non-negative, the conclusion in Proposition 1 follows.

Proposition 1 indicates that the total channel profits in the integrated channel will be greater than that in the decentralized channel. This result is consistent with the earlier results in the channels literature. This shows that lack of channel coordination results in loss in profitability. As we show later, the coordinated channel is able to ensure a greater amount of pack size reduction, as well as greater shelf-space. Thus, there is huge premium attached with the coordination of the green supply chain. We now present the result regarding the prices.

Proposition 2: The following results are obtained:

$p^I = p^D$, if, $m_0 = \frac{\alpha_1^2 F_1}{2F_1+\alpha_2}$

$p^I < p^D$, if $m_0 > \frac{\alpha_1^2 F_1}{2F_1+\alpha_2}$

and $p^I > p^D$, if $m_0 < \frac{\alpha_1^2 F_1}{2F_1+\alpha_2}$

Proof of Proposition 2:

From Equations 5 and 15, we have, respectively

$$p^I = \frac{\{2m_0F_1 - m_0(c+r)\Delta_1\}}{\Delta_2 F_1 + m_0\Delta_1^2} * \theta$$

$$p^D = \frac{\{2m_0F_1 + \Delta_2F_1 - m_0(c+r)\Delta_1\}}{2\Delta_2F_1 + m_0\Delta_1^2} * \theta$$

Thus, it can be shown that,

$$\frac{p^I}{p^D} = \frac{(1 + \frac{\Delta_2F_1}{\Delta_2F_1 + m_0\Delta_1^2})}{(1 + \frac{\Delta_2F_1}{2m_0F_1 - m_0(c+r)\Delta_1})}$$

Therefore,

$p^I < p^D$, if

$(1 + \frac{\Delta_2F_1}{\Delta_2F_1 + m_0\Delta_1^2}) \; < \; (1 + \frac{\Delta_2F_1}{2m_0F_1 - m_0(c+r)\Delta_1})$

This inequality can be simplified to the condition $m_0 > \frac{\alpha_1^2F_1}{2F_1+\alpha_2}$. The other conditions of Proposition 2 can be derived similarly.

Proposition 2 indicates that, if the attractiveness of the “other” competing goods is above a certain threshold, then the retail price in the decentralized channel will be greater than that in the integrated channel. Thus, if the stated conditions hold, then this result is consistent with the earlier research in the channels literature, which has been termed as the ”double marginalization” issue in the distribution channels. However, we find that if the opposite of the inequality holds, then the price in the integrated channel may be higher than that in the case of the decentralized channel. This makes sense, since if the other products are not so attractive, then the integrated channel can afford to raise its prices. At the threshold value, both the integrated and decentralized channels price their products at the same level at the retailer’s end.

Proposition 3: The ratio of the optimal pack size reduction allocation by the manufacturer in the integrated channel to that in decentralized channel is given by the following formula:

$$\frac{\delta^I}{\delta^D} = \frac{2\Delta_2 F_1 + m_0 \Delta_1^2}{\Delta_2 F_1 + m_0 \Delta_1^2}$$

Proposition 4: Similar to Proposition 3, the ratio of the optimal shelf-space allocation by the retailer in the integrated channel to that in decentralized channel is given by the following formula:

$$\frac{n_g^I}{n_g^D} = \frac{2\Delta_2 F_1 + m_0 \Delta_1^2}{\Delta_2 F_1 + m_0 \Delta_1^2}$$

Proofs of Propositions 3 and 4: The required proofs can be obtained by taking the ratio of Equations 6 and 13 (or Equations 7 and 14). By rearranging the terms, it can easily be verified that the respective ratios are greater than 1, but less than 2.

Proposition 3 implies that, in the integrated channel, the extent of manufacturer's reduction in pack size is greater than that in the decentralized channel. However, this reduction is below a threshold limit, that is, the pack size reduction in the integrated channel is never more than twice of that in the decentralized channel. A similar analysis is applicable to the case of shelf-space allocation by the retailer. That is, in the integrated channel, the retailer allocates a greater amount of shelf-space to the green manufacturer than that allocated in the decentralized channel. Further, Propositions 3 and 4 imply that the two ratios are equal, that is, the extent by which the manufacturer reduces pack size in the integrated channel, as compared to the decentralized channel, is equal to the extent by which it gets greater shelf-space exposure in the integrated channel. Thus, it can be said that the integrated channel result in "greener" channel without compromising profitability. In view of these results, therefore, the next pertinent question arises: *how to coordinate the green channel?*

4.5 Coordinating the Green Channel

In this section, we restrict our attention to the case in which both the manufacturer and the retailer put in the greening effort. In the previous literature, several approaches have been proposed for coordinating a distribution channel. These include quantity discounts (Jeuland and Shugan 1983), two-part tariff (Moorthy 1987), etc. In this paper, we propose a simple two-part pricing approach, (*F, w*), to coordinate the green channel in which there are both price and non-price variables. The procedure followed is as follows.

We assume that the per-unit wholesale price *w* charged by the manufacturer is the channel-coordinating price. In addition, the retailer makes a lump-sum payment *F* to the manufacturer. Under these assumptions, the profit functions for the manufacturer and retailer are:

$$\pi_m = (w + c * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2 \delta) + F_1 \delta^2 - F_2 + F' \tag{19}$$

$$\pi_r = (p - w + r * \delta) * (\theta - p + \alpha_1 n_g - \alpha_2 \delta) - m_0 n_g^2 - F_3 - F' \tag{20}$$

Differentiating π_r with respect to *p* and n_g, we get the first-order conditions for the retailer with expressions for *p* and n_g as a function of *w*. Now, we use the expressions of p^*, δ^*, and n_g^*, , from the vertically-integrated case to get the values of w_c and $F_c{}'$ that would coordinate the green channel. The result is summarized in the following proposition.

Proposition 5: The following two-part tariff contract between the manufacturer and retailer coordinates the channel:

$$w_c = \frac{m_0 c * (c + r - \alpha_2)}{\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$$

and

$$0 \leq F' < \left\{ \frac{F_1^2 \Delta_2 m_0 \theta^2}{(\Delta_2 F_1 + m_0 \Delta_1^2)^2} - F_3 \right\}$$

Proof of Proposition 5:

Using the profit functions for manufacturer and retailer from Equations 19 and 20, the first-order conditions are given below:

$$\frac{\partial \pi_r}{\partial p} = 0 \quad \rightarrow \quad 2p = \theta + w + r * \delta + \alpha_1 n_g - \alpha_2 \delta \tag{21}$$

$$\frac{\partial \pi_r}{\partial \tau_r} = 0 \quad \rightarrow \quad \alpha_1 (p - w + \delta * r) - 2 m_0 n_g = 0 \tag{22}$$

Putting the values of the decision variables from the vertically integrated case (Equations 5-7), and simplifying, we get:

w*= per-unit transfer price = $\frac{m_0 c * (c + r - \alpha_2)}{\Delta_2 F_1 + m_0 \Delta_1^2} * \theta$

Putting the values from Equations 5-7 and Equation 23 into Equation 20, we get

$$\pi_r = \frac{F_1^2 \Delta_2 m_0 \theta^2}{(\Delta_2 F_1 + m_0 \Delta_1^2)^2} - F_3 - F'$$

Since retailer has to make some profit, we have

$\frac{F_1^2 \Delta_2 m_0 \theta^2}{(\Delta_2 F_1 + m_0 \Delta_1^2)^2} - F_3 - F' > 0$, or $\quad F' < \left\{ \frac{F_1^2 \Delta_2 m_0 \theta^2}{(\Delta_2 F_1 + m_0 \Delta_1^2)^2} - F_3 \right\}$

This tariff structure suggests that the manufacturer would charge a wholesale price per unit which is positive if $(c + r - \alpha_2) > 0$. This implies a condition in which the packaging cost savings for manufacturer (c) and handling cost savings for the retailer (r) are together greater than the negative effect that the smaller size packs have on the product demand (α_2). However, if the opposite condition prevails, that is, if α_2 dominates

$(c + r)$, then it is interesting to note that the manufacturer would charge a wholesale price per unit which is negative This indicates a situation in which the manufacturer provides extra incentives to the retailer to stock the green product by providing it a “slotting allowance.” Of course, the manufacturer ensures that its profits are covered from the fixed-fee component, which would be a result of negotiation between the retailer and manufacturer, in the limits provided by the proposition. The final value will be determined by the relative channel power that the manufacturer commands. Since the upper limit on F' has been derived as a result of the constraint that the retailer has to make non-zero profits, this negotiation process would make sure that both the manufacturer and retailer are “sharing the pie” appropriately.

5 Conclusions and Directions for Future Research

Environmental consciousness has become increasingly important in present times, as evident by the examples from both everyday life and business practices. Any major greening project in the supply chain context necessitates efforts on the part of the entire supply chain. We address the issue of vertical coordination in a green supply chain between the players at the upstream (say, a manufacturer) and downstream (say, a retailer) levels of the chain. We focus on a problem faced by manufacturer-retailer pairs (e.g., P&G, and Walmart) in the consumer products supply chains. The manufacturer has to decide on the wholesale price and the package size of its product. This green manufacturer reduces the pack size of its product that helps it save on environmentally costly transportation cost. Reduction in pack size helps the manufacturer also save on product packaging cost. Moreover, the reduced package size also results in cost savings for the retailer in terms of handling and storage. The objective of our research was to derive equilibrium conditions for the variables considered. We assumed the manufacturer to be the leader in the Stackelberg leader-follower game setting.

We examine the effect of various parameters, such as, effectiveness of package size reduction efforts, cost of transportation, shelf-space sensitivity of demand, attractiveness of "other" goods, on the optimal pricing, packaging and shelf-space allocation decisions by the channel partners. Our results show that the total profit is greater, pack sizes are smaller, and shelf-space allocation is greater in the integrated channel as compared to the decentralized channel. Retail prices can be greater or smaller in the decentralized channel as compared to the integrated channel, depending on certain values of the problem parameters. These results show that clearly there is scope for channel coordination in this problem setting for better profitability and environmental benefits. We propose a two-part tariff scheme which effectively coordinates the green supply chain in this problem setting.

This work can be extended into several directions, which are listed below: (i) We can also model the greening effects of price premium into this framework, (ii) The consideration of multiple manufacturers and retailers, as well as inclusion of suppliers in the modeling framework, could provide additional useful insights, and (iii) The incorporation of uncertainty, unobservability of efforts, and dynamics would provide even richer results in this framework.

Further, the relaxation of some of the basic assumptions of the model can provide additional. For instance, we have assumed that the market is homogeneous in its preference for the green product. The relaxation of this assumption would consider multiple segments of consumers, some who would prefer the green product, possibly at higher price. Also, at times, manufacturers may have some stringent norms imposed on carbon emissions. Incorporation of these constraints may provide a more comprehensive framework and richer insights.

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Figure 1: Structure of the Supply Chain Considered