Impact of the Government Policies and Green-packaging on the Profitability of the Members of a Dual-Channel Supply-chain

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Abstract

The present research investigates the competition between two products without packaging and with green-packaging in a dual-channel supply-chain with government intervention. The manufacturer supplies the product to the customers at the first level without packaging, and the packaging-company supplies it at the second level with green-packaging. The profits made by the supply-chain members have been calculated under the two government policies for identification of the optimal decisions. The results indicate that the low cost of green-packaging is to the benefit of the packaging-company in both government policies, which is the case for the manufacturer only in the second. It has also been demonstrated that the difference between the sales prices of the two products increases, and the competition between them decreases with an increase in the difference between the customers' conceptions of their values.

Key words: Green-packaging, Competition, Dual-channel supply-chain

1- Introduction

To gain competitive advantage in today's business market, firms adopt strategies to positively influence customers' purchasing behavior and satisfy their expectation [1]. Investment in how products are presented can be considered as an effective strategy for attracting customers' attention in order to purchase them. An effective aspect of presenting products to customers is their packaging. Consumer trends and industry trends for packaging drive this gigantic growth rate (https://www.yorksaw.com).

There is increasing demand for packaging due to a shift in consumption behavior across the globe as a result of a growing middle class as well as a growing elderly population. Retailers are seeking similar qualities, in addition to packaging that

provides longer shelf lives. Greater demand entails greater market opportunities, and the global packaging market is poised to experience steady growth in the next five years with a highly competitive vendor landscape. Therefore, the packaging activity can change customers' behavior.

Packaging can be of a number of types. Some are produced and used to reduce environmental pollution, including green-packaging. Green-packaging, also called sustainable packaging or eco-friendly packaging, uses materials and manufacturing techniques to diminish energy use and reduce the harmful impacts of packaging on the environment. Given its advantages, sustainable packaging is turning into a higher priority for both brands and consumers—more than ever before. Slopes and Town is a Dutch brand. They sell belts, socks, and other accessories. Both their product and packaging are based on environment-friendly materials (Packhelp).

Based on what was stated above about the use of packaging, particularly green-packaging, in different companies and given the all-time government policy to protect the environment, the government can play a significant role in reduction of environmental pollution as an influential sector in any country by supporting companies and adopting appropriate policies. The environment-friendly policies adopted by many governments in recent years have increased the use of green products and even green-packaging.

Given the discussion that was made and the topic investigated in this research, we now examine the above issues as problem definition. In a supply-chain, there is always competition between members at the different levels for making profit. The manufacturer can sell products to the customer through a direct channel as well as the retailer, where the manufacturer and the retailer often compete over the price offered to the customer. The government, on the other side, can influence the competition between these two by adopting policies based on the environment. The government uses tax and subsidy as means of practicing these policies. Based on the above discussion, this paper investigates a bi-level supply-chain composed of one manufacturer and one packaging-company with government intervention. The packaging-company uses green packages for the products. It should be noted that the packaging-company is not a retailer, as it packages the goods sent by the manufacturer and then sell them to the customer. The obtained mathematical model is solved using game theory.

The key notion on which this paper is focused concerns the impact of government intervention and green product packaging on competition in the supply-chain, which has not been addressed so far in the literature on supply-chain competition. In fact, we seek to extend Jabarzare & Rasti-Barzoki's [1] work considering government intervention. They studied a dual-channel supply-chain composed of one manufacturer and one packaging-company. Therefore, we have also

investigated the impact of government intervention on competition in this supply-chain.
The presented framework and the results obtained in this paper can be used for supply-chains such as those for tea and coffee. This paper is aimed at answering the following questions.
-Given the competition between the two products, how does the greenness degree of the packaging affect their prices and the demands for them?

-Under what conditions will the government's tendency with respect to environmental impacts affect the decision variables?

-How do the government policies affect the profits gained by the chain members and their activities?
-How do the chain members best respond to the different policies adopted by the government?

The paper is organized as follows. The related literature is reviewed in Section 2. Section 3 provides the methodology and a description of the model under investigation, and the equilibrium of the model. The results provided by the model are presented in Section 4. A sensitivity analysis of the model is made in Section 5. Section 6 addresses the managerial insight, and conclusions and suggestions for future research are made in Section 7.

2- Literature review

Competition in dual-channel supply-chains has been investigated in the literature with different assumptions. Hua *et al.* [2] investigated price decisions and delivery lead time in a dual-channel (centralized and decentralized) supply-chain. Dan *et al.* [3] examined pricing decisions and retailer service level in a dual-channel supply-chain, and analyzed the effect of the degree of customer loyalty and retailer service on manufacturer and retail price level. Huang *et al.* [4] investigated a dual-channel supply-chain assuming disorder in demand, and presented a two-period model for decision-making on price and production. Ma *et al.* [5] investigated the effect of consumption subsidy on a dual-channel closed-loop supply-chain. They then studied the decisions made by the supply-chain members before and after the performance of the government-funded program. Chen [6] investigated the impacts of pricing schemes and the cooperative advertising mechanism in a dual-channel supply-chain. Liu *et al.* [7] investigated the effect of risk aversion on the optimal decisions made by the members of a dual-channel supply-chain. They analyzed the developed model under the assumption of complete, asymmetric information, and found that optimal price was lower in the risk-averse than in the risk-neutral mode.

Wang *et al.* [8] investigated decisions on the pricing and servicing of complementary products in a dual-channel supply-chain consisting of two manufacturers and a shared retailer. One of the manufacturers used both channels of conventional retail and direct sales to supply goods, while the other utilized only the conventional retail channel. Modarres and Shafiei [9] developed an approach to optimize the main decision variables of dual-channel distribution system simultaneously.

Zhang & Wang [10] investigated two strategies of dynamic pricing in a dual-channel supply-chain composed of one manufacturer and one retailer. They studied the model to analyze the impact of service value on decisions and the insight of complexity. He *et al.* [11] considered a dual-channel closed-loop supply-chain, where the manufacturer sells the new products via an independent retailer and supplies the remanufactured products via a third-party firm in presence of government subsidy. Ranjan & Jha [12] studied pricing strategies and the mechanism of coordinating the members of a dual-channel supply-chain. The manufacturer supplied the customers with a green product through a direct channel and with a replaceable non-green product through a retailer channel. Wang & Song [13] investigated the pricing policies adopted in a dual-channel supply-chain assuming nondeterministic demand. The manufacturer produced both green and non-green products, selling the former through the direct channel and the latter through the retailer channel. Jabarzare & Rasti-Barzoki [1] studied a dual-channel supply-chain composed of one manufacturer and one packaging-company. The supply-chain members competed over pricing decisions and quality. They examined for the first time how the packaging-company could affect product quality through packaging.

Pal *et al.* [14] studied a dual-channel supply-chain where selling price of each player, delivery time for direct channel and retail service dependent demand structures are considered for manufacturer and retailer.

Meng *et al.* [15] investigated cooperative product pricing policies in dual-channel green supply-chains, and compared the optimal solutions in two modes with and without government subsidy. Barman *et al.* [16] examined a dual-channel supply-chain consisting of one retailer and one manufacturer. The manufacturer manufactures the product considering a desired level of greenness, and then sells it via the retailer and the direct channel. Matsui [17] investigated the optimal timing of a manufacturer's bargaining of a wholesale price with a retailer in a dual-channel supply-chain consisting of one manufacturer and one retailer.

Mahmoudi *et al.* [18] investigated sustainable supply-chain management in presence of government intervention. In their model, they used an outsourcing strategy (through a 3PL company) in the transportation sector.
Barman *et al.* [19] developed a three-level supply-chain model in their paper, involving a dual-channel structure with one supplier. The manufacturer uses two conventional retailer channels and the direct sale channel to distribute the product.

Insert Table 1. about here

According to the above literature review and Table 1, the following research gaps can be identified.
1- While a large number of papers have investigated competition in dual-channel supply-chains, few of them have examined government intervention in this kind of competition.
2- Of the above papers, none has yet studied competition in dual-channel supply-chains with government intervention and green product packaging.
This paper is closely related to Jabarzare & Rasti-Barzoki [1] and Hadi *et al.* [20]. Hadi *et al.* [20] investigated pricing decisions in the green supply-chain with government intervention, where the government seeks to reduce environmental pollution, causing the supplier and manufacturer to use green raw materials in order to produce green products. The authors demonstrated that strategies adopted by the government to protect the environment considerably affected its income and supply-chain members' profit.
Considering a supply-chain containing one manufacturer and one packaging-company, Jabarzare & Rasti-Barzoki [1] investigated the effects of the channel structure on pricing decisions and product quality for both supply-chain members in competitive and cooperative scenarios. The packaging-company aims to invest in activities concerning product quality improvement and development. The first, second, and third scenarios investigate a competitive game between the manufacturer and packaging-company, a cooperative game via a revenue-sharing contract, and a cooperative game via a profit-sharing contract, respectively. According to the above two papers, we investigate the competition between the members of a supply-chain (including one manufacturer and one green-packaging-company) where the government is effective on their decisions and competition as a leader by adopting policies based on the environment. As well as sale via the direct channel, the manufacturer meets the customer's demand by selling the product to the packaging-company, applying green-packaging.
Thus, the innovation of this paper can be stated as follows based on the reviewed related papers. With the increase in the awareness of environmental protection among consumers and relevant government legislation, the performance and activity of the government in regard to the environment can play a significant role

in the eco-friendly activities of companies and supply-chains. One such activity that has appealed to many companies involves the use of green packages. Since it is a government strategy to support the environment, appropriate subsidy policies need to be formulated to specify how the support should be provided. For instance, the amount of subsidy that should be paid or of the received tax needs to be set so that the predetermined purposes are reasonably achieved. Therefore, the impact of the government on the supply-chain members' profits needs to be examined. This paper investigates a dual-channel supply-chain composed of one manufacturer at the first level and one packaging-company at the second. The packaging-company supplies the product to the customers in green packages to provide competitive advantage and increase sales. Although a number of researchers, such as Jabarzare & Rasti-Barzoki [1], have already extended their models using product packaging, the significance of considering green-packaging has been revealed more than before, as packaging is one of the biggest sources of waste for retailers.
This paper investigates the effect of government policies on the supply-chain members' performance, and is aimed at assessment of the profits gained by the government and supply-chain members with respect to different policies adopted by the government, considering green-packaging for the product.

3-Methodology

A dual-channel bi-level supply-chain consisting of one manufacturer at the first level and one packaging-company at the second is considered in this study. The manufacturer directly sells part of its product to the customer and leaves the rest to the packaging-company. The packaging-company considers a green package for the product, which increases the customer's conception of the product value. Therefore, the original product and the packaged one are different in terms of value on the customer's mind. In this model, the government functions as the game leader, considering particular tariffs for the products as a tool for market adjustment and environmental protection.
The policies adopted by the government include the following.
- Revenue-seeking policy (to increase social welfare) (**R-P**);
By adopting this policy, the government pursues its purpose of raising income (Its benefit from an income rise is to increase social welfare).
- Environmental protection and revenue-seeking policy (**ER-P**);
Under this policy, the government seeks to reduce unfavorable environmental effects besides raising income.

An overview of the model is shown in Figure 1.

Insert figure 1. about here

In fact, we examine the game between the government, manufacturer, and packaging-company by considering green-packaging to increase the customer's conception of the value of the goods.

The assumptions made in the model include the following.

1- The government is the game leader, and the manufacturer and packaging-company are followers. Therefore, the government seeks at first to adjust the market to meet its demand under different policies and specify the values of parameters T_1 and T_2 (government tariffs for the first and second products), in fact to maximize its income (I_G) as leader. The above parameters are added to the product price, increasing it, and functioning as tax if positive; otherwise, they function as subsidy.

2- θ_1 and θ_2 introduce the environmental effects of non-packaging and green-packaging products, assumed to be dependent on water pollution, soil, and air to allow the model to be generalized. They are measured using various factors such as utilization index, the annual carbon dioxide or nitrogen monoxide exhaustion of products, or even a mixture of different factors ([21]).

3- The manufacturer would sell the product at a lower price than the packaging-company; that is, $p_2 > p_1$.

4- Supply and demand are of the same value.

5- The retail sale price paid by the packaging-company to the manufacturer is lower than the price at which the original product is sold on the market; that is, $p_1 > w_1$, as asserted in research such as [1].

6- The government seeks to raise its income (I_G) in order to protect the environment (and thus develop social welfare), and supply-chain members are willing to maximize their profit (π_i).

7- The Stackelberg game is used for solving the problem and obtaining the optimal values of the decision variables.

8- No costs, including operating costs, are assumed to be incurred by the manufacturer.

9- The original and packaged goods can be replaced.

10- As in [22] and [20], the demand function is introduced as follows.

Provision of green-packaging involves two consequences:

i- an increase in the customer's conception of the value of the goods

ii- a cost imposed on the packaging-company.

Therefore, the customer's evaluation of the product as variable v has a uniform distribution in the range between 0 and 1. Given the ratio of the original product to that with green-packaging in terms of environment-friendliness, parameter δ is a

number between 0 and 1. Thus, the value of the goods with green-packaging is v, and that of the original goods is δv.

u_1 and u_2 are defined in the following equations as the consumer surplus from the purchase of the original and packaged goods, respectively.

$$u_1 = \delta v - p_1 - T_1 \quad (1)$$

$$u_2 = v - p_2 - T_2 \quad (2)$$

The following three actions can be considered for the customers:
(1) purchasing the original goods
(2) purchasing the packaged goods
(3) purchasing no products.

The indifference points between purchase and avoidance of purchase of the original goods ($u_1 = 0$) and between purchase of the packaged goods and of the original goods ($u_1 = u_2$) are $v_1 = \frac{p_1 + T_1}{\delta}$ and $v_2 = \frac{p_2 + T_2 - p_1 - T_1}{1-\delta}$, respectively.
Therefore, the customers whose evaluations of the product lie in range $[v_2, 1]$ purchase the goods with green-packaging, and those with product evaluations lying in range $[v_1, v_2]$ purchase the product without packaging.

Thus, the demand function for the two types of product is as follows.

$$D_1 = \frac{p_2 + T_2 - p_1 - T_1}{1-\delta} - \frac{p_1 + T_1}{\delta} \quad (3)$$

$$D_2 = 1 - \frac{p_2 + T_2 - p_1 - T_1}{1-\delta} \quad (4)$$

The government income function is as follows for its different policies:
- (R-P)

$$Max GNR = Max\{T_1 D_1 + T_2 D_2\} \quad (5)$$

- (ER-P)

$$Max U = Max\{GNR - \lambda EIS\} = Max\ \{(T_1 - \lambda\theta_1)D_1 + (T_2 - \lambda\theta_2)D_2\} \quad (6)$$

where λ indicates the tendency of the government toward environmental effects, and θ_i $(i = 1, 2)$ signify the environmental effects of the original and packaged goods, respectively.

Moreover, the profits of the manufacturer and the packaging-company are as follows, respectively:

$$Max\,\Pi_1 = (p_1 - T_1)D_1 + (w_1 - \varphi T_2)D_2 \quad (7)$$

$$Max\,\Pi_2 = (p_2 - w_1 - (1-\varphi)T_2 - C)D_2 \quad (8)$$

where φ represents the fixed parameter of tax ratio, and C is the cost of adoption of green-packaging by the packaging-company.

Figure 2 shows the method of decision-making and decision variables at each level. Recursive induction is used to solve the model.

Insert Figure2. About here

3.1. Equilibrium analysis of the model

Proposition 1) The profit of the packaging-company is concave with respect to p_2 under the above assumptions.

Proof) See Appendix.

Theorem 1) Since the profit of the packaging-company is concave, the optimal price value of the packaged product (in terms of T_1, T_2, p_1, and w_1) are as follows.

$$p_2^* = \frac{1}{2}(1 + C + p_1 + T_1 + w_1 - \delta - \mathrm{T}_2\varphi) \quad (9)$$

Proposition 2) The manufacturer's profit is concave with respect to p_1 and w_1.

Proof) See Appendix.

Theorem 2) Since the profit of the packaging-company is concave, the optimal price value of the original product and retail price (obtained through replacement of p_2^*) are as follows.

$$p_1^* = \frac{-7\delta^2 + \delta(3 + C + 2T_2 - 3T_1) + T_1}{1 - 9\delta} \quad (10)$$

$$w_1^* = \frac{1 + C - 3\delta + 6\delta^2 + 2T_1 + T_2(2 - 12\delta - \varphi + 9\delta\varphi)}{-1 + 9\delta} \quad (11)$$

Proposition 3) The profit of the government is concave with respect to T_1 and T_2.

Proof) See Appendix.

Theorem 3) Since the profits of the government are concave, the optimal tariffs in the first government policy (obtained through replacement of p_1^* and w_1^*) are as follows.

$$T_1^* = \frac{2\delta\left(1+C+4\delta\right)}{-2+18\delta} \tag{12}$$

$$T_2^* = \frac{\delta\left(-8+5C-\delta\right)}{2-18\delta} \tag{13}$$

Theorem 4) Since the profits of the government are concave, the optimal tariffs in the second government policy (obtained through replacement of p_1^* and w_1^*) are as follows.

$$T_1^* = \frac{2\delta^2 - 2\theta_1\lambda + \delta\left(-C+8\theta_1\lambda+2\theta_2\lambda\right)}{-2+18\delta} \tag{14}$$

$$T_2^* = \frac{-\delta^2 - 9\theta_1\lambda + \delta\left(7-5C+4\theta_1\lambda+3\theta_2\lambda\right)}{-2+18\delta} \tag{15}$$

Using recursive induction, the optimal price values of the original and packaged goods and retail price are obtained as follows.

R-P:

$$p_2^* = \frac{3+C-13\delta-19C\delta-3\delta^2}{4-36\delta} \tag{16}$$

$$p_1^* = \frac{3\delta\left(-2+C+5\delta\right)}{-1+9\delta} \tag{17}$$

$$w_1^* = \frac{1-\delta+15\delta^3\left(-2+\varphi\right)-16\delta\varphi+C\left(-1+\delta\left(5\varphi\right)\right)}{2-18\delta} \tag{18}$$

ER-P:

$$p_2^* = \frac{-3+3\delta^2+C\left(-1+17\delta\right)+5\theta_1\lambda+8\delta\left(2+\theta_1\lambda-2\theta_2\lambda\right)}{-4+36\delta} \tag{19}$$

$$p_1^* = \frac{7\delta^2+4\theta_1\lambda+\delta\left(-2+C+\theta_1\lambda-2\theta_2\lambda\right)}{-1+9\delta} \tag{20}$$

$$w_1^* = -1+8\theta_1\lambda-3\delta^2\left(-2+\varphi\right)-\theta_1\lambda\varphi+\delta\left(-1+7\varphi+2\theta_1\lambda\left(-1+2\varphi\right)+5\varphi\right)+C\left(1-\delta\left(2+5\varphi\right)\right)/\left(-2+18\delta\right) \tag{21}$$

See the appendix for the solution procedure.

Proposition 4) For R-P, the relationship between variables T_1 and T_2 holds under the following conditions.

$$\begin{cases} T_2 < T_1 \quad ,if \ \ \delta < \frac{1}{9} \ or \frac{1}{9} < \delta < \frac{3C-10}{9} & (A) \\ T_1 < T_2 \ , & Otherwise \end{cases}$$

Proof) See Appendix.

Proposition 5) For ER-P, the relationship between variables T_1 and T_2 holds under the following conditions.

$$\begin{cases} T_2 < T_1 \quad ,if \ \delta \left\langle \frac{1}{9} \ or \ \ \delta \right\rangle \max\left\{ \frac{1}{9}, \frac{3\delta^2}{7-4C-4\theta_1\lambda+\theta_2\lambda} \right\} & (B) \\ T_1 < T_2 \ , & Otherwise \end{cases}$$

Proof) See Appendix.

4- Results

In this section, the results are presented in two forms: parametric and numerical.

4-1- Parametric results

In this section, the changes in price, profit, or demand are examined parametrically.

4-1-1- Cost of green-packaging (C)

This subsection involves an assessment of the impacts of the changes in the cost of green-packaging on the price of the packaged goods and the demand for the two products. For this purpose, the following equations are considered.

$$\frac{dp_2}{dC} = \frac{-1+17\delta}{-4+36\delta} \tag{22}$$

$$\frac{dD_1}{dC} = \frac{-3+7\delta}{-4+40\delta-36\delta^2} \tag{23}$$

$$\frac{dD_2}{dC} = \frac{1+5\delta}{4-40\delta+36\delta^2} \tag{24}$$

Equation 22 is formulated, representing the changes in the price of the packaged goods resulting from the increase in the cost of packaging.

The equation is positive if $\delta > \frac{1}{9}$, in which case an increase in the cost of packaging results in a rise in the price of the second product. This means that the packaging-company has to increase the price of the goods to gain profit as the cost of packaging rises. Clearly, the company needs to raise the product price to

compensate for the incurred cost of packaging. Equation 23 represents the changes in the demand for the first product with respect to the cost of green-packaging. The fraction is positive if the $\delta > \frac{1}{9}$ condition holds and negative otherwise. In other words, the price of the second product increases in the above case as the cost of packaging rises, resulting in an increase in the demand for the first product. The two products are regarded as competitors, so a rise in the price of one raises the demand for the other. Equation 24 assesses the changes in the demand for the second product as a result of an increase in the cost of packaging.

The third equation is negative if $\delta > \frac{1}{9}$. That is, demand decreases if cost increases, due to the increase in price.

4-1-2- Parameter δ

As parameter δ changes, the following changes occur in the prices of the products and the demand for them.

$$\frac{d(p_1)}{d\delta} = \frac{2 - C - 12\delta + 54\delta^2}{(1-9\delta)^2} \tag{25}$$

$$\frac{dD_2}{d\delta} = \frac{6(-1+\delta)^2 - C(-5+18\delta-45\delta^2)}{4(1-10\delta+9\delta^2)^2} \tag{26}$$

$$\frac{dD_1}{d\delta} = \frac{-30(-1+\delta)^2 + C(23-54\delta+63\delta^2)}{4(1-10\delta+9\delta^2)^2} \tag{27}$$

$$\frac{d(p_2-p_1)}{d\delta} = \frac{10+2C+114\delta+513\delta^2}{4(1-9\delta)^2} \tag{28}$$

Equation 25 is always positive if $C < 2 - 12\delta + 54\delta^2$. That is, an increase is observed in the price of the first product as δ increases if the above condition holds. Otherwise, a higher difference between the two products in terms of environment-friendliness denotes a lower price for the first product. The second product is extremely environment-friendly, which affects the customers' purchase behavior, where the completion between the two products reduces the first product price.

Equation 26 is negative if the $C > \frac{6(\delta-1)^2}{-5+18\delta-45\delta^2}$ condition holds, *i.e.* if C and δ are thus related to each other. An increase in δ denotes a rise in the ratio of the two products in terms of environment-friendliness, which requires the packaging-company to pay for a high cost of green-packaging for the product to raise the ratio

of the two products in terms of environment-friendliness, leading to an increase in price and a decrease in demand. In other words, parameter δ has a negative impact on the demand for the packaged goods if the above condition holds; otherwise, demand increases as a result of a rise in δ. The observation shows that the increase in demand results from the subsidy allocated by the government to the goods, which compensates for the increased cost of packaging.

Equation 27 is negative if $C < \frac{30(\delta-1)^2}{23-54\delta+63\delta^2}$, in which case the demand for the first product decreases as δ increases. In other words, parameter δ has a negative effect in that case on the demand for the non-packaged goods.

Equation 28 is always positive, which means that the difference between the sales prices of the two products increases as δ rises, lowering in turn the level of competition between them. This also causes an increase in the ratio of the products in terms of environment-friendliness and therefore a longer distance between the customers' conceptions of the product values, thereby increasing the difference between the goods in terms of sales price.

4-1-3- Parameter λ

Changes in parameter λ induce the following changes.

$$\frac{dp_2}{d\lambda} = \frac{2(\theta 1 + \delta\theta 1 - 2\delta\theta 2)}{-1+9\delta} \quad (29)$$

$$\frac{dD_2}{d\lambda} = \frac{(\theta 1 + \delta\theta 1 - 2\delta\theta 2)}{1-10\delta+9\delta^2} \quad (30)$$

$$\frac{dD_1}{d\lambda} = \frac{(6-4\delta)\theta 1 - (1+\delta)\theta 2}{1-10\delta+9\delta^2} \quad (31)$$

Equation 29 is positive if $\frac{1}{9} < \delta < \frac{\theta_1}{2\theta_2 - \theta_1}$. As suggested by the definition of λ, the government provides environmentalist activities with greater support as the parameter value increases, which can increase the price of the second product.

Equation 30 is positive if $\delta \left\langle \frac{1}{9} \right.$ *or* $\left. \delta \right\rangle \frac{\theta_1}{2\theta_2 - \theta_1}$. As λ increases, the demand for the second product rises once the above condition holds, which can be due to an increase in the environment-related policies adopted by the government. If $\frac{1}{9} < \delta < \frac{\theta_1}{2\theta_2 - \theta_1}$, therefore, the policies adopted by the government to mitigate environmental hazards will raise the price of the second product and, therefore,

reduce the demand for it. If $\delta \left\langle \frac{1}{9} \; or \; \delta \right\rangle \frac{\theta_1}{2\theta_2 - \theta_1}$, however, the government's policies will raise demand, which can be in part due to the price decrease.

Equation 31 is positive if $\delta \left\langle \min\left\{\frac{1}{9}, \frac{6\theta_1 - \theta_2}{4\theta_1 + \theta_2}\right\} or \, \delta \right\rangle \max\left\{\frac{1}{9}, \frac{6\theta_1 - \theta_2}{4\theta_1 + \theta_2}\right\}$. As λ increases, the demand for the first product decreases once the above conditions hold. It should be noted that the expressions imposed on C and δ, obtained for Equations 25 to 31, will hold in all cases where the conditions and assumptions of our model are met.

4-2- Numerical results

This section involves a numerical example, solved for a better understanding of the performance of the model.

Insert Table 2. about here

The model has been solved for the parameter values given in Table 2 (These numbers have been taken from [20]), and the results appear in Table 3.

Insert Table 3. about here

As clear from the above table, the value of p_1 is less than that of p_2 (in accordance with the assumption made in the model).

In both policies, the government gains the greatest incomes as the leader. In the first policy, it obtains taxes from the manufacturer, while granting subsidy to the packaging-company. The same procedure is adopted in the second policy, where both amounts of tax and subsidy are higher, since the government is concerned there not only with income but also with environmental considerations. This accounts for the observation that the price of the first product has increased in the second policy, while that of the packaged product has decreased. Furthermore, the difference between p_1 and p_2 is smaller in the second policy than in the first, because twice as much subsidy is granted there to the packaging-company, while less than twice as much tax is obtained from the manufacturer. This causes p_1 to increase less and p_2 to decrease more than in the first policy, leading to their closer values in the second policy.

In the first policy, the packaging-company gains the least profit, while it gains greater profit than the manufacturer in the second policy due to the greater subsidy

granted by the government. In the second policy, the profits gained by the packaging-company and the government increase with respect to those in the first policy, which is not the case for the manufacturer. That is, if the government adopts its first policy, the absence of product packaging will result in greater profit. If the second government policy is adopted, however, the green product packaging will lead to the same advantage. Therefore, the manufacturer had better refrain from selling its product to the customer and supply its goods to the market only via the packaging-company. The procedure through which the members gain profit in the government policies can be found explicitly from the numerical results. In fact, the values obtained for the two policies have thus been compared, obtaining numerical results used to assess the correct behavior of the model.

5- Sensitivity analysis

This section reports a sensitivity analysis made for a better understanding of the changes in price and profit with respect to the parameters of the model.

6-1. Sensitivity analysis with respect to δ

Insert Figure3. about here

Insert Figure4. About here

Figure 3 shows the changes in price in terms of δ. It is observed that price decreases in both government policies as δ increases. In fact, this reduces the value of the original goods, *i.e.* δv. According to the demand equations, therefore, the demand for both products decreases, which can be accounted for by the increase in the product prices. Figure 4 shows the changes in the government tariffs in terms of δ. The upward trend in the tariffs as δ increases can be observed in the figure. As can be observed, price rises as δ increases, in part due to the tariffs allocated by the government to the goods, leading to a decrease in demand. Thus, an increase in δ raises the tariffs and prices, and finally reduces demand. It can be concluded that the closer the values of the products (in terms of environment-friendliness) from the customers' perspective, the lower the prices and the higher the demand, which is also more preferable by the customers.

Insert Figure 5. About here

Figure 5 shows the changes in profit with respect to δ in the second government policy. As δ increases, the demand for both products decreases, which in turn reduces their profits. This is not the case with the government, however. Since the government tariffs rise as δ increases, the income gained by the government

increases. It should be noted that the government gains the greatest income for $\delta > 0.8$. Moreover, the profit gained by the packaging-company surpasses that of the manufacturer for $\delta > 0.65$. It can be concluded that the government benefits from a greater difference between the product values from the customers' perspective, which is of course unfavorable for the manufacturer and the packaging-company.

Insert Figure 6. about here

Figure 6 shows that wholesale price rises in both government policies as δ increases. Wholesale price is higher in the first policy than in the second. The increase in δ indicates a decrease in product demand, which can be caused by an increase in price.

Insert Figure 7. about here

6-2. Sensitivity analysis with respect to θ_1 and θ_2

Figure 7 examines the simultaneous effect of parameters θ_1 and θ_2 on the profits gained by the manufacturer, packaging-company, and government. As clear from the figure, they all gain their greatest profits as the above parameters simultaneously increase. A rise in θ_1 reduces the profit gained by the manufacturer and increases that of the packaging-company, while a rise in θ_2 increases the profit gained by the manufacturer, and reduces that of the packaging-company. For $\theta_1 > 1$ and $\theta_2 > 2$, the manufacturer gains less profit than the government and the packaging-company, as it takes no measure in regard to the environment, while they do. The manufacturer can also raise its profit by doing environment-friendly activities (such as use of green-packaging). Moreover, the government gains the greatest income for $\theta_1 > 3$ and $\theta_2 > 2$.

Less profit is gained by the manufacturer than by the government and the packaging-company. Furthermore, the profit gained by the government surpasses and grows more than that of the packaging-company as θ_1 and θ_2 increase ($\theta_1 > 2$ and $\theta_2 > 1$).

Insert Figure 8. about here

6-3. Sensitivity analysis with respect to λ and C

Figure 8 shows the changes in government tariffs with respect to λ. It can be understood from the figure that the government grants greater subsidy to the

packaging-company as λ increases, and obtains greater tax from the manufacturer instead. That is, it provides the packaging-company with greater support since it considers environmental effects as well as income.

Insert Figure 9. about here

Figure 9 shows the changes in profit with respect to λ. The profits (income) gained by the government, manufacturer, and packaging-company increase as λ rises. While the manufacturer obtains the greatest profit for $\lambda < 1.6$, the government, packaging-company, and manufacturer acquire the greatest profits in that order for larger values of λ. Consequently, the manufacturer can perform environment-friendly activity to increase its profit in order to obtain greater subsidy from the government.

Insert Figure 10. about here

Figure 10 shows the changes in the income gained by the government with respect to the cost of green-packaging. As the cost increases, the profit decreases. For $C < 9.5$, the income gained by the government is greater in the first policy than in the second. The government gains maximal income in the first policy for small values of cost, where it can therefore better adopt that policy. For values of cost greater than 9.5, therefore, the government gains greater income in the second policy than in the first. As a consequence, the government can adopt its first policy for small values of C to gain greater income.

Insert Figure 11. about here

It is clear from Figure 11 that the profit gained by the packaging-company decreases as the cost of green-packaging increases. However, the company gains greater profit in the second government policy than in the first. Consequently, it can be stated that the packaging-company should consider a kind of green-packaging with a low corresponding cost to be able to obtain the greatest profit in each government policy.

Insert Figure 12. about here

Figure 12 shows the changes in the profit gained by the manufacturer with respect to the cost of green-packaging. As packaging cost rises, manufacturer profit increases in the first policy and decreases in the second. Therefore, the first

government policy is found more profitable for the manufacturer as the cost of green-packaging increases. Furthermore, profit decreases in the second policy, where the government supports the environment, with which it is concerned as well as its income.

Insert Figure 13. about here

Figure 13 shows the changes in demand with respect to the cost of green-packaging in the first government policy. On that basis, the first government policy is found more profitable for the manufacturer due to the increase in demand as the cost of green-packaging rises, while it is not reasonable for the packaging-company.

Insert Figure 14. about here

Figure 14 shows the simultaneous changes in the demand for the first product with respect to the cost of green-packaging and λ. As clear from the figure, the demand for the first product increases as cost rises, whereas demand decreases as λ increases. In the second policy, the government functions as an environmentalist. Therefore, the demand for the first product decreases as the government becomes more concerned with the environment. Consequently, greater support provided by the government to the environment denotes more profitability for the manufacturer to perform environment-friendly activity.

Insert Figure 15. about here

Figure 15 provides an examination of the changes in the demand for the second product with respect to simultaneous changes in the cost of green-packaging and government attitude toward the environment. The demand for packaged goods decreases as the cost of green-packaging increases but increases as the value of λ rises. In fact, the packaging-company has won government support in the second policy by providing its products with green-packaging, as the government also supports the environment there. Consequently, the packaging-company gains more profit as government support for the environment increases.

6- Managerial insight

In this paper, we have investigated the competition between a green-packaging-company and a manufacturer under intervention from the government, adopting two policies: maximization of income and maximization of income considering

environment-related issues. The following managerial insights can be proposed using the obtained results.

- We have found with a parametric analysis with respect to the cost of green-packaging that an increase in the cost while $\delta < \frac{1}{9}$ will benefit the packaging-company but not the manufacturer. In such a case, the following solution can be proposed to the manufacturer to increase demand: to utilize support packages or incentives for the customers and to perform environment-friendly activities to win government support.
- If condition A (B) is met in the government's first (second) policy, the tariff allocated by the government to the second product will be lower than that attributed to the first. It can therefore be stated that the tariff allocated to a product depend on the value of δ, *i.e.* the greenness level of its packaging. A solution for the packaging-company could be to raise the tariff received from the government by increasing the greenness degree of the packaging. In these conditions, the manufacturer will need to adopt one of the approaches mentioned in the previous case.
- If the government adopts its first policy, the packaging-company had better consider low-cost packaging for its product, since the company and the government will gain greater incomes. However, a decrease in the cost of packaging will not be profitable for the manufacturer. Therefore, it can utilize the special offers or discounts for the customers as a competitor to increase its profit.
- If the government adopts its second policy, it will be more profitable for the government, manufacturer, and packaging-company itself to assume a small value for the cost of green-packaging. Moreover, the government had better be more concerned with the environment to obtain greater profits for all the three parties.
- It can be found from the *Sensitivity analysis* section that if the ratio of the original product and that with green-packaging in terms of environment-friendliness increases, the manufacturer will need to perform environment-friendly activities due to the competition between the two products to gain greater profit and continue competition on the market with the packaged product. This is also true of the case where the tendency of the government toward environmental effects rises.

7- Conclusion

In this research, we have addressed the competition within a dual-channel supply-chain involving government intervention and composed of one manufacturer and one packaging-company. The manufacturer sells its goods directly and indirectly (via the packaging-company). Once the goods are sold to the packaging-company, green-packaging is considered for them to be sold then to the customers. As the game leader, the government considers tariffs for the manufacturer and the

packaging-company, which then specify the sales prices for the customers as followers. In this paper, two policies have been considered for the government. The results obtained from the model demonstrate that the government grants greater subsidy to the packaging-company in its second policy, and obtains greater tax from the manufacturer instead. Therefore, the first policy is more profitable from the manufacturer's perspective, while the government and the packaging-company prefer the second policy. It has also been indicated that a low cost of green-packaging benefits both the government and the packaging-company in both government policies, whereas the manufacturer gains greater profit for a high cost of packaging. The greater the environmental effects of a product, the less the profit gained from it and the greater the demand for the rival product instead. However, the income gained by the government rises as the environmental effects of both products increase. An increase in the ratio of the two products in terms of environment-friendliness reduces the competition between them.

This research has been conducted under specific assumptions. The following items can be considered for extension of the model. The game between the government, manufacturer, and packaging-company is one with full information. A game with incomplete information can be assumed as an extension. Alternatively, perishable goods can be considered for that purpose. Another option can involve an investigation of a government policy aimed only at supporting the environment and a comparison of its results to those of the other two policies. Uncertainty can also be considered for extension of the model. The model has been developed with the assumption that both subsidy and tax have fixed rates. In the real world, however, this is hardly the case; therefore, multiplying rates can be considered in future research for the above factors.

In a section of the paper, use of incentives and discounts has been proposed for the manufacturer to increase product demand. An important relevant line of research is to model the problem considering incentives (such as price discounts and installments).

Appendix

Proof for Proposition 1.

To prove the concavity of the profit of the packaging-company with respect to p_2, we consider the following equation.

$$\frac{\partial \Pi_2}{\partial p_2} = 1 - \frac{-\mathrm{p}_1 + \mathrm{p}_2 - \mathrm{T}_1 + \mathrm{T}_2}{1-\delta} - \frac{-C + \mathrm{p}_2 - w_1 - \mathrm{T}_2(1-\varphi)}{1-\delta}$$

Therefore,

$$\frac{\partial^2 \Pi_2}{\partial (p_2)^2} = -\frac{2}{1-\delta}.$$

Since $0<\delta<1$, $\frac{\partial^2 \Pi_2}{\partial (p_2)^2}<0$.

Proof for Proposition 2.

The Hessian matrix of the profit of the manufacturer is as follows.

$$H=\begin{pmatrix} -\frac{-2+\delta}{(-1+\delta)\delta} & -\frac{1}{-1+\delta} \\ -\frac{1}{-1+\delta} & \frac{1}{-1+\delta} \end{pmatrix}$$

Since $0<\delta<1$, $|H_{1\times1}|<0$. Moreover, $|H_{2\times2}|=\frac{2}{\delta-\delta^2}$, which is always positive. Therefore, the profit of the manufacturer is concave with respect to p_1 and w_1.

Proof for Proposition 3.

For both government policies, the following equation holds.

$$H=\begin{pmatrix} \frac{3-2\delta}{(-1+\delta)\delta} & \frac{1+\delta}{2\delta-2\delta^2} \\ \frac{1+\delta}{2\delta-2\delta^2} & \frac{1}{-1+\delta} \end{pmatrix}$$

Since $0<\delta<1$, $|H_{1\times1}|<0$. The following equation also holds for $|H_{2\times2}|$.

$$|H_{2\times2}|=\frac{1-9\delta}{4(-1+\delta)\delta^2}$$

$|H_{2\times2}|$ is also always positive under the condition $\delta>\frac{1}{9}$ (It is a mild assumption). Therefore, the profit of the government is concave under both its policies.

Proof for Proposition 4.

The following equation holds.

$$T_1-T_2=\frac{10\delta+9\delta^2-3C\delta}{2-18\delta}$$

For the above fraction to be positive, the numerator and denominator must be of the same sign. The numerator and denominator will always be positive if and only if

$$\delta<\frac{1}{9}.$$

The numerator and denominator will always be negative if and only if

$$\frac{1}{9}<\delta<\frac{3C-10}{9}.$$

Therefore, the above fraction will be positive if and only if

$$\delta < \frac{1}{9} \text{ or } \frac{1}{9} < \delta < \frac{3C-10}{9}.$$

Proof for Proposition 5.

$$T_1 - T_2 = \frac{3\delta^2 + 7\theta_1\lambda + \delta\left(-7 + 4C + 4\theta_1\lambda - \theta_2\lambda\right)}{-2 + 18\delta}$$

The above fraction will be positive if the numerator and denominator are of the same sign. The numerator will be positive if and only if

$$3\delta^2 + 7\theta_1\lambda + \delta\left(-7 + 4C + 4\theta_1\lambda - \theta_2\lambda\right) > 0$$

$$\delta > \frac{3\delta^2}{7 - 4C - 4\theta_1\lambda + \theta_2\lambda}.$$

The numerator and denominator will be positive if

$$\delta > \max\left\{\frac{1}{9}, \frac{3\delta^2}{7 - 4C - 4\theta_1\lambda + \theta_2\lambda}\right\}.$$

Moreover, the numerator and denominator will be negative if

$$\delta < \frac{1}{9}.$$

Therefore, the fraction will be positive if and only if

$$\delta > \max\left\{\frac{1}{9}, \frac{3\delta^2}{7 - 4C - 4\theta_1\lambda + \theta_2\lambda}\right\} or\ \delta < \frac{1}{9}.$$

Solution procedure

To solve the Stackelberg game between the supply-chain members and the government, we use recursive induction. Therefore, the packaging-company first decides on the price set for selling the product to the customer. For that purpose, a derivative is taken of the profit with respect to p_2, the value of which is then specified through solution of the $\frac{\partial \Pi_2}{\partial p_2} = 0$ equation as in Equation 9.

$$\frac{\partial \Pi_2}{\partial p_2} = 1 - \frac{-p_1 + p_2 - T_1 + T_2}{1 - \delta} - \frac{-C + p_2 - w_1 - T_2\left(1 - \varphi_2\right)}{1 - \delta}$$

In the following step, the manufacturer decides on its decision variables. For that purpose, p_2 is first replaced in the manufacturer's profit by the value obtained in Equation 9, leading to the following equation.

$$\Pi_1 = \frac{1}{2\left(-1 + \delta\right)\delta}\begin{pmatrix} -p_1^2\left(-2 + \delta\right) + T_1^2\left(-2 + \delta\right) + T_1\left(1 + C + 3T_2 - \delta\right)\delta \\ + p_1\delta\left(-1 - C - T_2 - 2w_1 + \delta\right) - \left(T_2 - w_1\right)\delta\left(-1 + C + 2T_2 + w_1 + \delta\right) \end{pmatrix}$$

Then, we take derivatives from the above function with respect to the variables p_1 and w_1 at the same time.

$$\frac{\partial \Pi_1}{\partial p_1} = \frac{-2p_1(-2+\delta)+\delta(-1-C-T_2-2w_1+\delta)}{2(-1+\delta)\delta}$$

$$\frac{\partial \Pi_1}{\partial w_1} = \frac{-2p_1\delta-(T_2-w_1)\delta+\delta(-1+C+2T_2+w_1+\delta)}{2(-1+\delta)\delta}$$

Next, Equations 10 and 11 are obtained through solution of the following system of equations.

$$\begin{cases} \frac{\partial \Pi_1}{\partial p_1} = 0 \\ \frac{\partial \Pi_1}{\partial w_1} = 0 \end{cases}$$

Hence, the profit will look as follows once p_1 and w_1 are replaced by their obtained values in the government income (the first policy).

$$GNR = \frac{T_2\delta(-1+C+2T_2+\delta)+T_1^2(2(2+\varphi_1)-\delta(3+\varphi_1))-T_1((1+C-\delta)\delta+T_2(2+\delta+\delta\varphi_1))}{4(-1+\delta)\delta}$$

Given that the government decision variables at this level include T_1 and T_2, derivatives are first taken of the above equation with respect to these two variables.

$$\frac{\partial GNR}{\partial T_1} = \frac{-(1+C-\delta)\delta-T_2(2+\delta+\delta\varphi_1)+2T_1(2(2+\varphi_1)-\delta(3+\varphi_1))}{4(-1+\delta)\delta}$$

$$\frac{\partial GNR}{\partial T_2} = \frac{2T_2\delta+\delta(-1+C+2T_2+\delta)-T_1(2+\delta+\delta\varphi_1)}{4(-1+\delta)\delta}$$

Equations 12 and 13 are obtained through solution of the following system of equations.

$$\begin{cases} \frac{\partial GNR}{\partial T_1} = 0 \\ \frac{\partial GNR}{\partial T_2} = 0 \end{cases}$$

Hence, the profit will look as follows once p_1 and w_1 are replaced by their obtained values in the government profit (the second policy).

$$U = \frac{\begin{array}{l} 2T_2^2\delta + \delta\left(\left(1+C-\delta\right)\theta_1 - \left(-1+C+\delta\right)\theta_2\right)\lambda + T_2(\delta^2 + 2\theta_1\lambda + \delta \\ \left(-1+C-2\theta_2\lambda\right)) + T_1^2\left(2\left(2+\varphi_1\right) - \delta\left(3+\varphi_1\right)\right) - T_1(-\delta^2 + 2\theta_1\lambda\left(2+\varphi_1\right) \\ +T_2\left(2+\delta+\delta\varphi_1\right) + \delta\left(1+C-\theta_2\lambda-\theta_2\lambda\varphi_1-\theta_1\lambda\left(3+\varphi_1\right)\right)) \end{array}}{4\left(-1+\delta\right)\delta}$$

Therefore, the following equation holds.

$$\frac{\partial U}{\partial T_1} = \frac{\begin{array}{c} \delta^2 - 2\theta_1\lambda\left(2+\varphi_1\right) - T_2\left(2+\delta+\delta\varphi_1\right) + 2T_1\left(2\left(2+\varphi_1\right) - \delta\left(3+\varphi_1\right)\right) \\ -\delta\left(1+C-\theta_2\lambda-\theta_2\lambda\varphi_1-\theta_1\lambda\left(3+\varphi_1\right)\right) \end{array}}{4\left(-1+\delta\right)\delta}$$

$$\frac{\partial U}{\partial T_2} = \frac{4T_2\delta + \delta^2 + 2\theta_1\lambda + \delta\left(-1+C-2\theta_2\lambda\right) - T_1\left(2+\delta+\delta\varphi_1\right)}{4\left(-1+\delta\right)\delta}$$

Equations 14 and 15 are obtained through solution of the following system of equations.

$$\begin{cases} \dfrac{\partial U}{\partial T_1} = 0 \\ \dfrac{\partial U}{\partial T_2} = 0 \end{cases}$$

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Biographies

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List of figures caption

Figure 1. Structure of the dual-channel supply-chain

Figure 2. Process of decision-making in the model

Figure 3. Effect of δ on prices in R-P and ER-P

Figure 4. Effect of δ on tariffs in R-P and ER-P

Figure 5. Effect of δ on profit in ER-P

Figure 6. Effect of δ on wholesale prices in R-P and ER-P

Figure 7. Effect of θ_1 and θ_2 on profit in ER-P

Figure 8. Effect of λ on tariffs in ER-P

Figure 9. Effect of λ on profit in ER-P

Figure 10. Effect of C on the incomes gained by the government in R-P and ER-P

Figure 11. Effect of C on the profit gained by the packaging-company in R-P and ER-P

Figure 12. Effect of C on the profit gained by the manufacturer in R-P and ER-P

Figure 13. Effect of C on demand in R-P

Figure 14. Effect of C. and λ on the demand for the first product in ER-P

Figure 15. Effect of C and λ on the demand for the second product in ER-P

List of tables caption

Table 1. Summary of the literature review (dual-channel supply-chain)

Table 2. Parameter data

Table 3. Results of solving the model

Figure 1. Structure of the dual-channel supply-chain

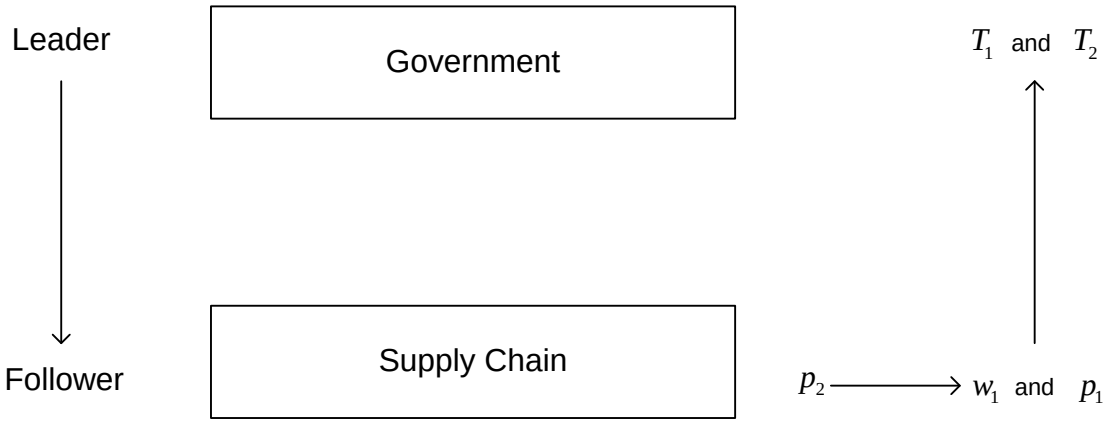


Figure 2. Process of decision-making in the model

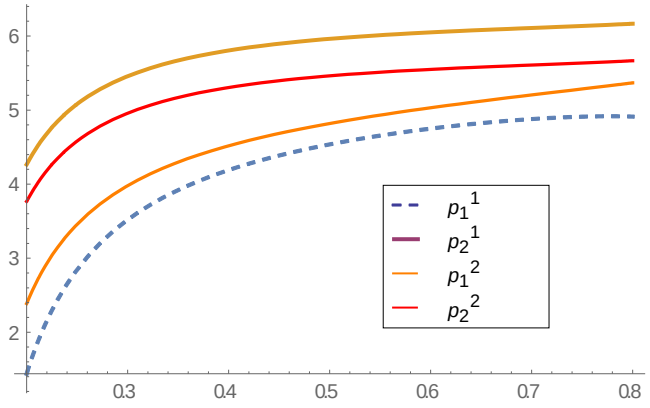
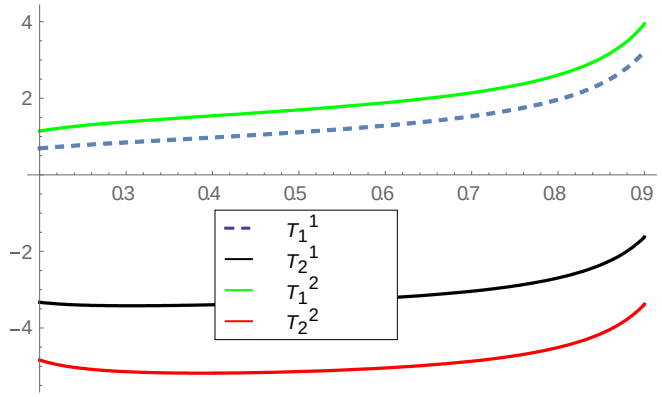


Figure 3. Effect of δ on prices in R-P and ER-P



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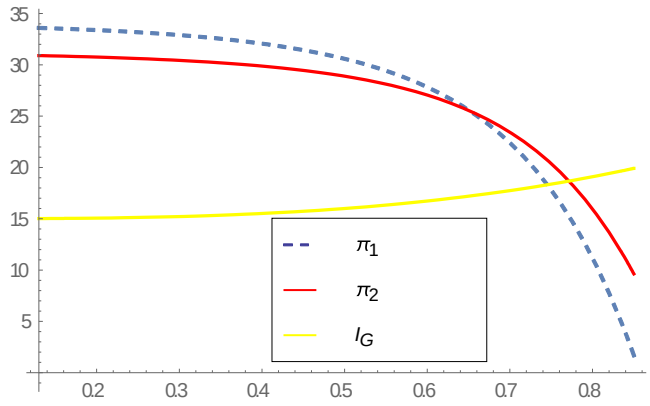

Figure 5. Effect of δ on profit in ER-P

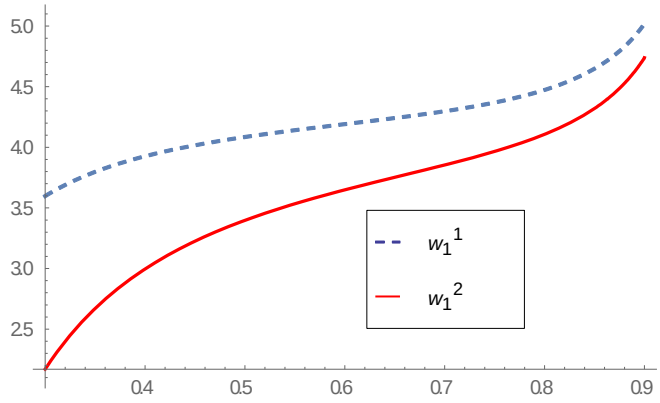

Figure 6. Effect of δ on wholesale prices in R-P and ER-P

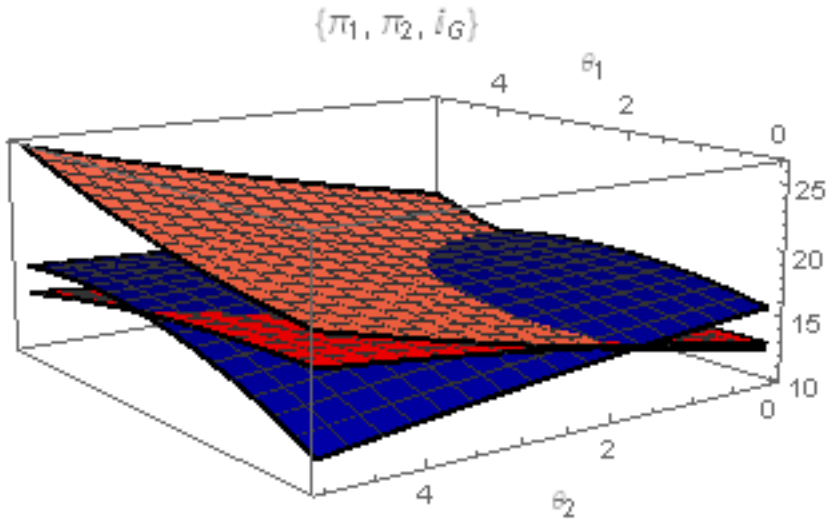

Figure 7. Effect of θ_1 and θ_2 on profit in ER-P

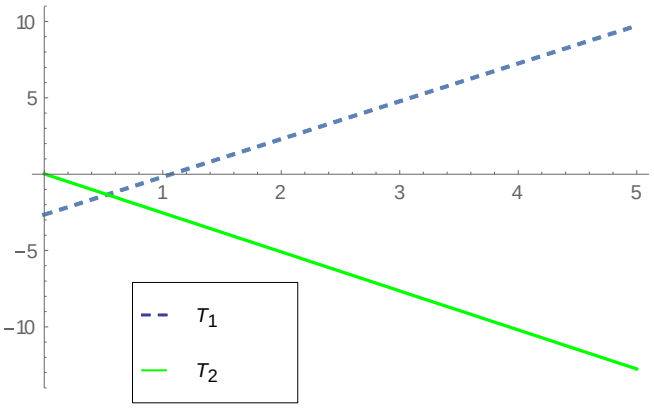

Figure 8. Effect of λ on tariffs in ER-P

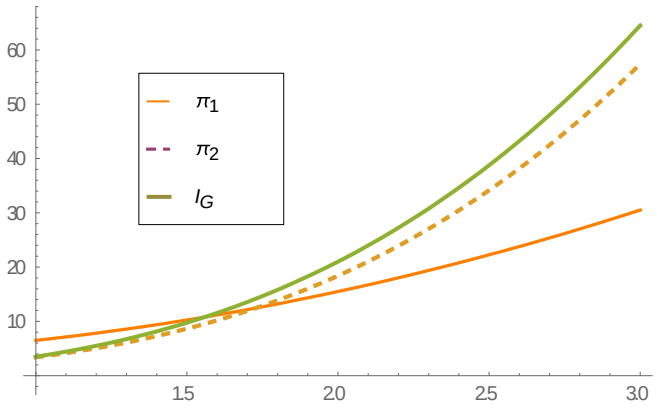

Figure 9. Effect of λ on profit in ER-P

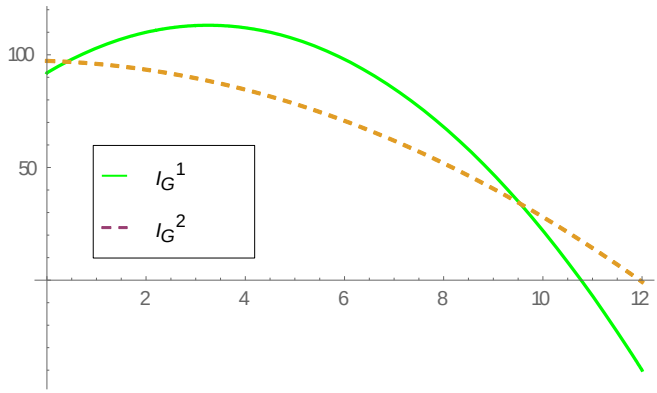

Figure 10. Effect of C on the incomes gained by the government in R-P and ER-P

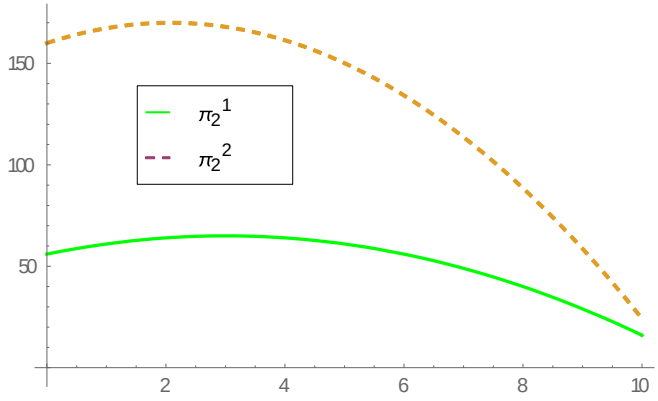

Figure 11. Effect of C on the profit gained by the packaging-company in R-P and ER-P

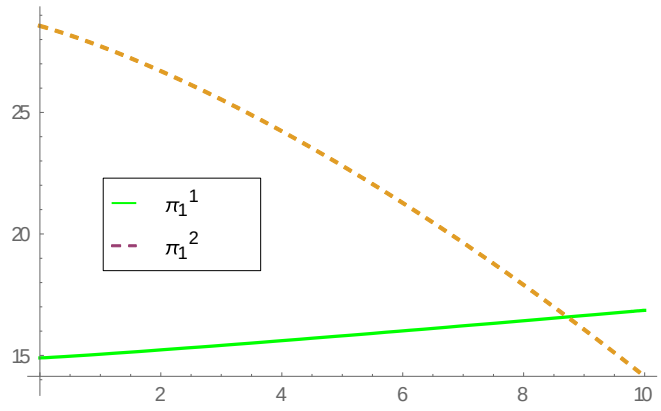

Figure 12. Effect of C on the profit gained by the manufacturer in R-P and ER-P

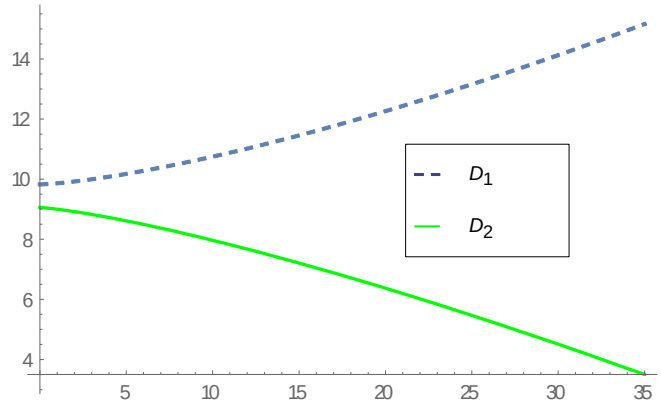

Figure 13. Effect of C on demand in R-P

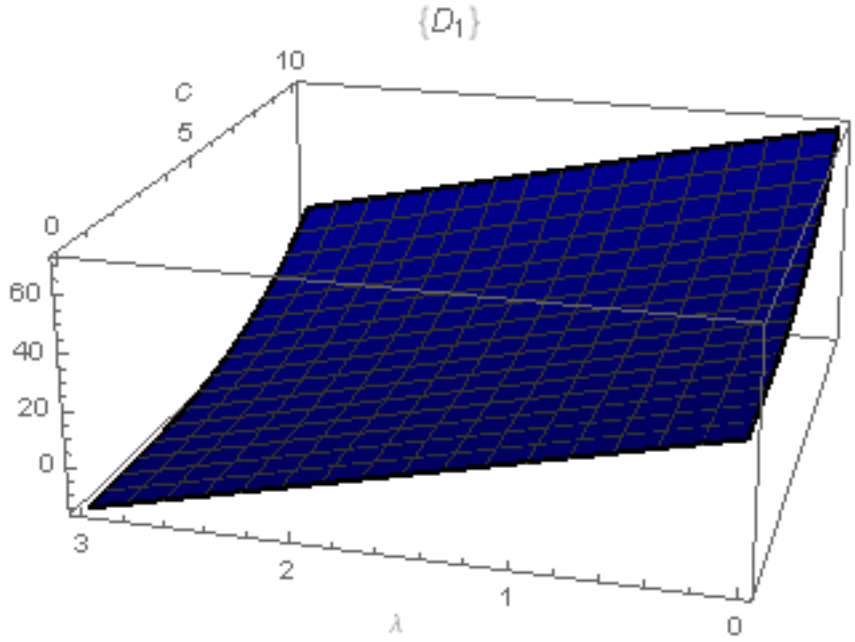

Figure 14. Effect of C and λ on the demand for the first product in ER-P

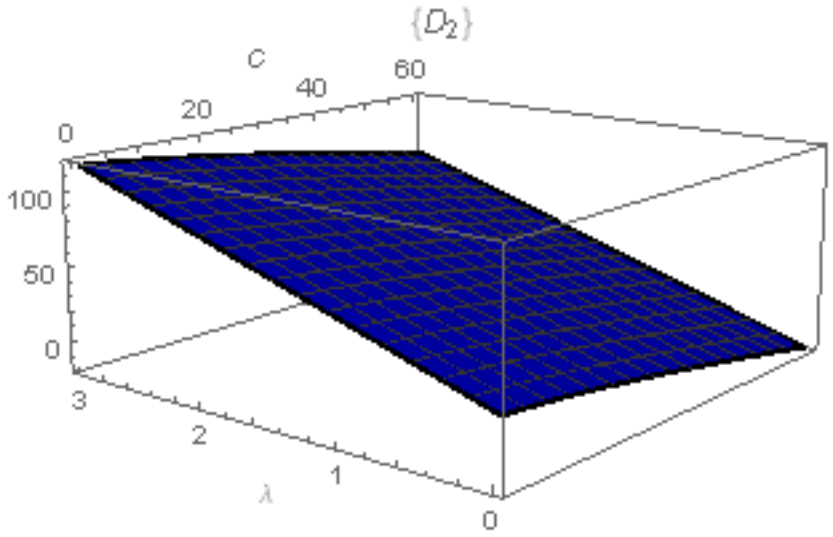

Figure 15. Effect of C and λ on the demand for the second product in ER-P

Table 1. Summary of the literature review (dual-channel supply-chain)

Paper	Government intervention	Packaging	Sale structure of the chain	Type of the dual-channel supply-	Decision variables

				chain	
[2]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, Delivery lead time
[3]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, service level
[4]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, production
[5]	Yes	No	Manufacturer(online)-retailer	**CLDCSC**	price
[6]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, investment for promoting, level of local advertising
[7]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, value added to the product
[8]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, service
[9]	No	No	Manufacturer-retailer	**DCSC**	Price, Confidence level and Effort level
[10]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, service value
[11]	Yes	No	Manufacturer(online)-retailer And Manufacturer (third party firm)-retailer	**CLDCSC**	price
[12]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, green quality level, sales effort level
[13]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, sales effort level
[1]	No	Yes	Manufacturer(online)-packaging-company	**DCSC**	price
[17]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, quantity
[15]	Yes	No	Manufacturer(online)-retailer	**GDCSC**	Price
[16]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, green level of the product
[14]	No	No	Manufacturer(online)-retailer	**DCSC**	Price, Delivery time, Service
[18]	Yes	No	First retailer (with 3pl)-second retailer (without 3pl)	**GDCSC, DCSC**	Price, subsidy
[19]	Yes	No		**GDCSC**	Price, subsidy
This study	Yes	Yes	Manufacturer(online)-packaging-company	**DCSC**	Price, tax, subsidy
DCSC: Dual-channel supply-chain, GDCSC: Green dual-channel supply-chain CLDCSC: Closed loop Dual-channel supply-chain					

Table 2. Parameter data

δ	θ_1	θ_2	λ	φ	C
0.8	3	3	2	0.5	10

Table 3. Results of solving the model

Variables	R-P	ER-P
w_1	4.33	3.78
p_1	4.64	4.85
p_2	6.1	5.21
π_1	16.02	15.54
π_2	15.57	17.18
I_G	17.99	18.93

T_1	1.83	2.36
T_2	-2.65	-4.47