PRICING MODEL FOR COMPETING ONLINE AND RETAIL CHANNEL WITH ONLINE BUYING RISK

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Abstract

This research studies the dual-channel supply chain under decentralized setting where there are two competing firms offering customers the same products. One firm sells through a traditional retailer store while the other firm sells through the Internet. The objective of this paper is to analyze how to improve the total supply chain profit with the competing traditional retail channel and online retail channel. Generally these two channels will compete against each other to get the sales. To study the effects, we have developed the decentralized model where customers will make purchasing decision with the channel that gives them the highest utility. However, the customers buying online are exposed to the risk that the products are not as expected due to lack of the opportunity to try or inspect the products. In this model, each channel tries to maximize the total supply chain profits by adjusting the price on each channel. The analytical expressions for the optimal prices and Nash equilibrium are found. The numerical result shows the analytical expressions toward the price, demand, and profit of each channel. Additionally, we found that in the case when the product has high penalty cost, there is a great difference in the price and profit between the two channels. On the other hand, there is a great difference between demands of the two channels when the product has low penalty cost.

Keywords: Supply chain, Online, Retail, Online Risk, Nash equilibrium, Game theory

1. MOTIVATION AND LITERATURE REVIEW

With more Internet users everyday, many firms have realized that selling through the Internet is another way to do the business and create more profits besides selling through a traditional physical store. In 2011, U.S. online retail sales increased 16.1% from 2010 and e-commerce was accounted for 8.6% of total retail sales, increasing from 7.6% in 2010 (Enright, 2012). We can see that the importance of e-commerce has got a significant portion of overall retail sales in the United States over time.

The benefits of shopping online are such as convenience, time and effort savings, accessibility, search capabilities, and lack of lines, salespeople and crowds (Wolfinbarger and Gilly, 2001). According to the research, 78% of Internet users agree that shopping online is convenient (Horrigan, 2008). However, the drawbacks of shopping online are unreliability, lack of the opportunity to inspect the products at the point of purchase, and delivery lags (Lieber and Syverson, 2011). While having direct interpersonal communication and the ability to examine the products are the upside of shopping from traditional retail stores. The downsides are such as expensive price due to higher cost, having exact operating hours, more time and effort used, and sometimes shortage of merchandise.

In reality, consumers may use the two channels differently. Some may prefer buying from physical stores and some may prefer the online stores. Consequently, when the two channels, offline and online, compete against each other, some total supply chain profits will be lost.

This paper provides the understandings of how to solve such problem when the traditional retail firm and online retail firm compete with each other and still get the maximized total supply chain profit. To accomplish this study, we have established the decentralized model based on the customers purchasing decision. Then, we have developed the optimal solution expression and done the numerical experiment to see the model response. Finally, we concluded the key findings of this study and provided some managerial insights for retail marketers and future researchers.

Most of the researches related to this area have studied about the two channels' consumer response and pricing strategies/competition. One research has found that the different Internet users based on income earnings, education, age, and race have a significant impact on the number of Internet usage while gender does not (Lieber and Syverson, 2011). Another research points out that high-share brands enjoy greater brand loyalty in the online store than small-share brands (Danaher, Wilson, and Davis, 2003). Also, one study has found that online customers are less price sensitive because customers place more importance on convenience, and prefer buying products in larger sizes to reduce the number of orders (Andrews and Currim, 2004). One research has indicated that the increased in competition would result in the lower pricing and less price dispersion (Gruber, 2008). Moreover, another research suggested that online retailers charge lower prices than offline retailers. Offline retailers will find it increasingly difficult to compete on price. Also, online retailers make price changes in smaller increments than offline retailers because the competition in the online market is higher (Bynjolfsson and Smith, 2000).

Purchasing online often comes with risks according to previous papers. Perceived risks from shopping online are suggested to have 6 dimensions: performance, financial, opportunity/time, safety risk, social risk and psychological risks (Cunningham, 1967). For example, performance risk refers to the probability that the purchased product does not meet the buyer expectation due to its function failure.

The main contribution of our research is that while most related papers discussed on consumer behavior, brand competition, pricing strategies or the risk of purchasing from online channel, our research would rather focus on how to obtain the optimal solution on the conflicts between offline and online channels with online purchasing risk.

After this section, the remaining part of this paper is divided as follows. Section 2 introduces the assumptions and model of the problem we discuss. Section 3 represents the outcomes of the numerical experiment. And conclusion and guidance for future researches are included in section 4.

2. MODEL

In this section, we will discuss the decentralized model where the offline and online channels focus on maximizing its own profits. First, we present the model and explain the relationship between each party. After that, we declare the related variables used in the functions. Finally we develop the optimal price function that gives the highest total supply chain profit.

2.1 Decentralized Supply Chain Model

The decentralized model presents two firms, retailer and online, offering the same products from the same suppliers. Each channel tries to maximize the profit individually. Customers can purchase either from the retailer or online channel. The decentralized supply chain consists of suppliers, retailer channel, online channel, and customers.

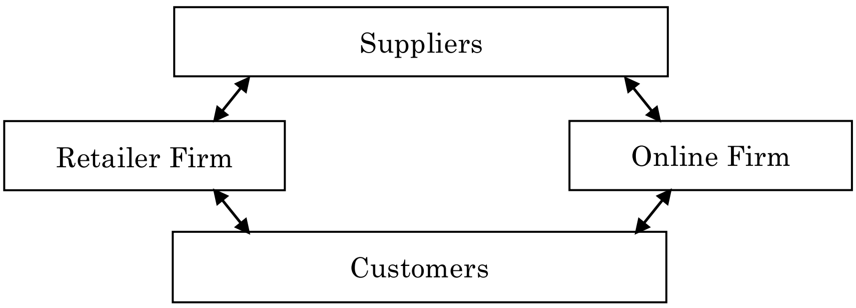

Figure 1: The relationship of supply in decentralized model

2.2 Member in the Model

There are mainly 4 members in the decentralized model. They are suppliers, retailer firm, online firm, and customers. The description of each member is expressed below.

2.2.1 Supplier

The suppliers are the party that provides the products in a supply chain. The suppliers sell it to the next link in the chain, which are the retailer firm and the online firm. There is no decision variable at the supplier.

2.2.2 Retailer Firm

The retailer firm purchases the products from suppliers in wholesale price, then sell to customers in the retailer price (P_r). The retailer price refers to the amount of money customers have to give up to acquire the products in the retailer channel. The retailer channel is a direct competitor with the online channel. The cost of the retailer channel is notated as C_r while the profit of the retailer channel is notated as π_r.

2.2.3 Online Firm

Similar to the retailer firm, the online firm purchases products from suppliers in the wholesale price and sell to customers in online price (P_d). The online price refers to the amount of money customers have to give up to acquire a product in the online channel. The online channel is a direct competitor with the retailer channel. The cost of the online channel is notated as C_d while the profit of the online channel is notated as π_d.

2.2.4 Customers

Customers decide which channel to purchase the products by comparing the utility gained between the retailer (U_r) and online (U_d) firms. When customers decide to buy a product, they will set the value of that particular product in their minds (v). If customers are not fully satisfied with that product after buying from online channel, the v value will be decreased by the proportion β.

2.3 Function

2.3.1 Notation

r	=	Retailer channel
d	=	Online channel
v	=	The customer's valuation of the product
α	=	Probability of bad incident happened ($0 \le \alpha < 1$)
β	=	The proportion of v the customer receives after mishap happens ($0 \le \beta < 1$)
P_r	=	Retailer price
P_d	=	Online price
U_r	=	Utility gained from purchasing the retailer channel

U_d	=	A utility gained from purchasing the online channel
D_r	=	Demand in the retailer channel
D_d	=	Demand in the online channel
π_r	=	Retailer profit
π_d	=	Online profit
C_r	=	Retailer cost
C_d	=	Online cost

2.3.2 Utility Function

Utility function is used to calculate the utility that customers will gain from their selected channel. The utility function is developed based on the customers purchasing decisions. The customer can decide either to purchase from the retailer channel or the online channel.

Utility function of retailer channel

$$U_r = v - P_r \tag{1}$$

From (1), the utility gained from purchasing in the retailer channel comes from the difference between the customer's valuation of the product and the retailer price. We assume that P_r must be less than v because if the retailer sets the price of their products more than what customers have thought in their minds, then customers will not purchase that products.

Since purchasing from the online channel is considered to have some perceived risks (i.e. financial risk, safety risk,), α and β are used to represent these risks. A customer has a self-estimate probability of bad incident, α, and when the bad incident happened, the value of product reduces from perceived value v to only βv where $0 \leq \beta < 1$. For example, the quality or product characteristics might not be as expected because the customer cannot examine the product before buying. The customers differ in value of self-estimate probability of bad incident α. We assume that self-estimate probability of bad incident α is uniformly distributed between 0 and 1. If the bad incident happens, the customer will perceive the gained utility of $(\beta \times v - P_d)$ with probability α. If the bad incident does not happen, the customer will perceive the gained utility of $(v - P_d)$ with probability $1-\alpha$. The expected utility gained is then $U_d = \alpha(\beta \times v - P_d) + (1-\alpha)(v - P_d)$. The utility when purchasing from the online channel is shown in (2).

Utility function of online channel

$$U_d = \alpha(\beta \times v - P_d) + (1-\alpha)(v - P_d) \qquad (2)$$

Customers will always buy from the channel that gives them the highest utility. Therefore, if $U_r > U_d$, customers will buy from the retailer channel. But if $U_d > U_r$, customers will buy from the online channel.

In order to illustrate the situation when customers will choose the retailer channel, we have to set up the equation as following:

$U_r > U_d$

$$v - P_r > \alpha(\beta \times v - P_d) + (1-\alpha)(v - P_d) \qquad (3)$$

After solving (3), we will get (4).

$$\alpha > \frac{P_r - P_d}{v(1-\beta)} = \alpha^* \qquad (4)$$

In (4), we set α^* as if the probability of the mishap that customers can take is more than α^*, customers will purchase from the retailer channel. Similarly, to illustrate the situation when customers will choose the online channel, we have to set up the equation as following:

$U_d > U_r$

$$\alpha(\beta \times v - P_d) + (1-\alpha)(v - P_d) > v - P_r \qquad (5)$$

Also, as α increases, U_d decreases. To ensure that all customers buying from online channel gets positive utility, we add another condition that $U_d > 0$ and that is equivalent to

$$\frac{v-P_d}{v(1-\beta)} > \alpha = \alpha' \tag{6}$$

Using (4), we can split the online and retailer demands at α^* where all customers with $\alpha < \alpha^*$ buying from online channel and all customers with $\alpha \geq \alpha^*$ buying from retailer channel. Please note that from (4) and (6), $\alpha' > \alpha^*$, as a result, all customer buying from online channel has positive utility and enforcing $U_d > 0$ does not change the demand function.

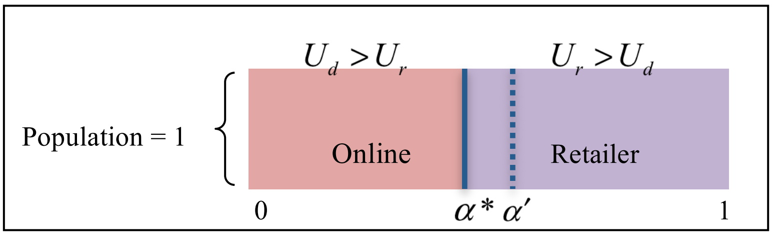

Figure 2: The utility between online and retailer channels

2.3.3 Demand Function

Demand function is elaborated from the customer buying behavior. According to Figure 2, demand functions of the retailer and online channels are as follows:

$$\begin{aligned} D_r &= 1 \times (1-\alpha^*) \\ &= 1-\alpha^* \end{aligned} \tag{7}$$

$$\begin{aligned} D_d &= 1 \times (\alpha^* - 0) \\ &= \alpha^* \end{aligned} \tag{8}$$

Proposition 1: Demand function of retailer and online channels

$$D_r = 1 - \frac{P_r - P_d}{v(1-\beta)} \tag{9}$$

$$D_d = \frac{P_r - P_d}{v\left(1-\beta\right)} \tag{10}$$

When substituting the value of α^* from (4) into the demand function (7) and (8), the result of the demand function is as in (9) and (10).

2.3.4 Profit Function

The profit of retailer and online channels are as shown in (11) and (12). Please note that $C_r > C_d$ due to setup cost and cost of hiring employees.

$$\begin{aligned}\pi_r &= (P_r - C_r) \times D_r \\ &= (P_r - C_r) \times (1 - \alpha^*)\end{aligned} \tag{11}$$

$$\begin{aligned}\pi_d &= (P_d - C_d) \times D_d \\ &= (P_d - C_d) \times \alpha^*\end{aligned} \tag{12}$$

Proposition 2: Profit function of retailer and online channels

$$\pi_r = (P_r - C_r) \times \left(1 - \frac{P_r - P_d}{v - (1 - \beta)}\right) \tag{13}$$

$$\pi_d = (P_d - C_d) \times \left(\frac{P_r - P_d}{v - (1 - \beta)}\right) \tag{14}$$

The supply chain profit function gives the maximum profit for each channel. After we substitute (9) into (11), we can get (13). After we substitute (10) into (12), we can get (14).

2.3.5 Retailer Price and Online Price Development

We can find the candidates of optimal retailer and online prices by applying the first order condition, $\frac{\partial \pi_r}{\partial P_r} = 0$ and $\frac{\partial \pi_d}{\partial P_d} = 0$, we can solve for the optimal price function as follows:

Proposition 3: Optimal price of retailer and online channels

$$P_r = \frac{1}{2}\left(v - v\beta + C_r + P_d\right) \tag{15}$$

$$P_d = \frac{1}{2}\left(C_d + P_r\right) \tag{16}$$

The first derivative function of the retailer and online profits are as in (15) and (16). Then, we determine the second order condition of profit with respect to the price function and get the following:

$$\frac{\partial^2 \pi_r}{\partial P_r} = -\frac{2}{v - v\beta} \tag{17}$$

$$\frac{\partial^2 \pi_d}{\partial P_d} = -\frac{2}{v - v\beta} \tag{18}$$

From (17) and (18), it can be concluded that $\frac{\partial^2 \pi_r}{\partial P_r} < 0$ and $\frac{\partial^2 \pi_d}{\partial P_d} < 0$ because $0 \le \beta < 1$. As a result, the profit function is strictly concave in the two prices. The second order conditions of global maximum point for both retail and online profits are satisfied and (15) and (16) leads to the unique maximum profit in each channel given the decision of the other player. (15) and (16) can be called the best response function for retail channel and online channel respectively. By solving (15) and (16) simultaneously, we get:

$$P_r = \frac{1}{3}(C_d + 2(v - v\beta + C_r) \quad (19)$$

$$P_d = \frac{1}{3}\left(v - v\beta + 2C_d + C_r\right) \quad (20)$$

The function (19) and (20) determines the outcome of the retailer and online prices that can attain the maximum profit given that both players try to maximize their profit. Using only the parameters of model, function (19) and (20) provides the predicted outcome of the game or Nash equilibrium.

3. NUMERICAL EXPERIMENT

In this section, we use the functions obtained from the previous section to analyze the model response. We use the data in the following table to illustrate the graph of the price competition between the retailer and online channels. Also, the Nash equilibrium and the impacts toward each channel's price, demand, and profit are analytically proved.

Table 1: The input data for the numerical experiment

v	β	C_r	C_d
1	0.2	0.3	0.2

3.1 Price Competition

From Figure 3, the best response of the retailer channel depends upon the online channel while the best response of the online channel depends upon the retailer channel according to the optimal price function obtained from the previous section. Therefore, if one channel adjusts the price, the other channel will have to adjust the price linearly. In game theory, the concept of Nash equilibrium can describe the method of predicting the outcome of the price setting interaction between these two channels. The online channel is making the best decision it can, taking into account the retailer channel's decision, and vice versa. In this case, we can predict the outcome of the competition from both channels when the two function lines intersect at a certain point (0.4, 0.3).

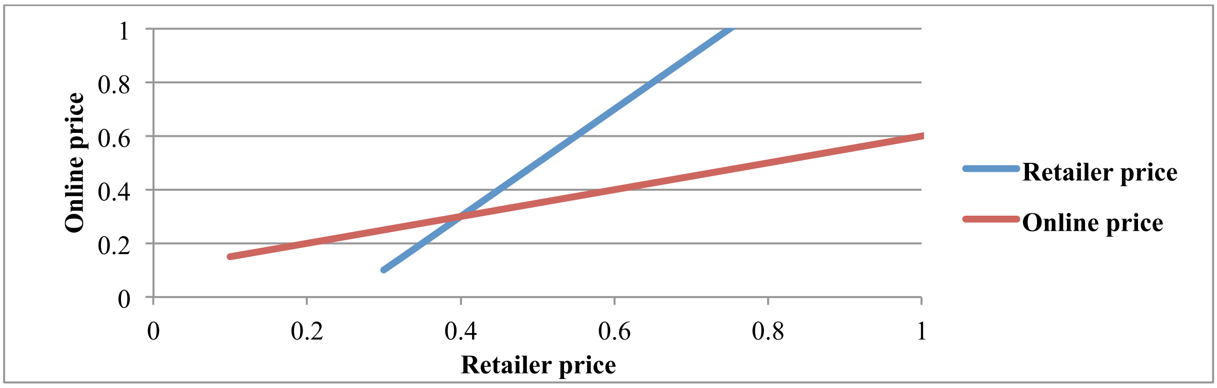

Figure 3: Price competition between retailer and online channels

3.2 The Effects When Changing β

In Figure 4, when β is low (the product has high penalty cost; ex. fashion apparels or shoes (unpredictable actual size), the difference in price between the two channels is high. This is because the value of the product will remain very low after the mishap happens. But with high β (the product has low penalty cost; ex. books etc.), both channels cannot set the price so differently. The demand from Figure 5 is resulted from the price in Figure 4. When β is low, the demand in the retailer channel is higher than the online channel. But with high β, the demand of in the online channel will be higher than the retailer channel. In Figure 6 the profit is resulted from the demand in Figure 5. The profit of the retailer channel is higher than the online channel when β is low. As β increases, the profit of the online channel will get higher, and ultimately beat the retailer channel.

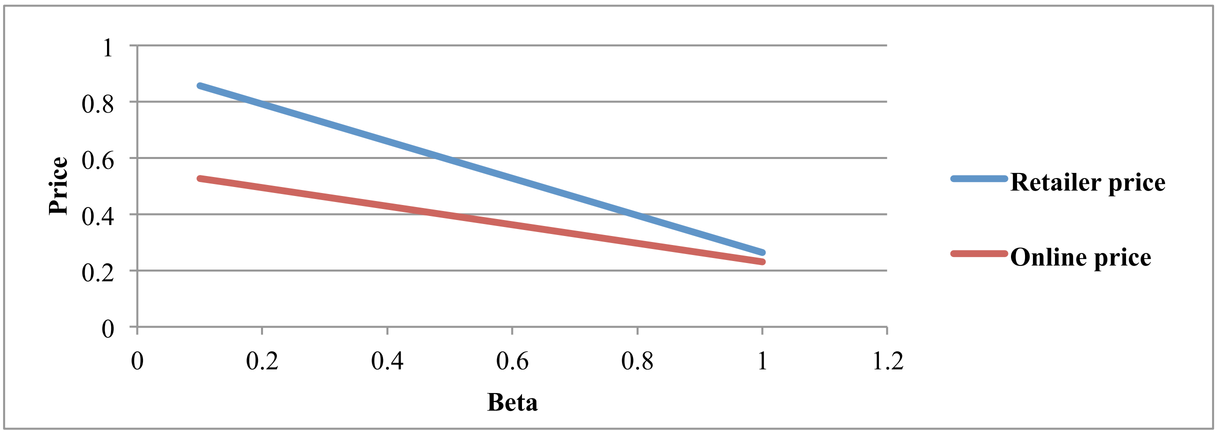

Figure 4: Price (when the β value is changed)

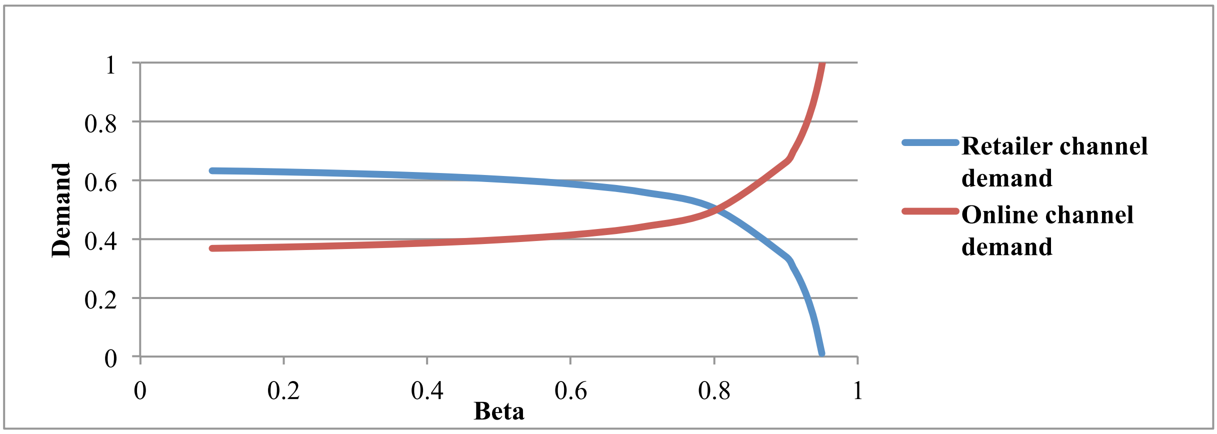

Figure 5: Demand (when the β value is changed)

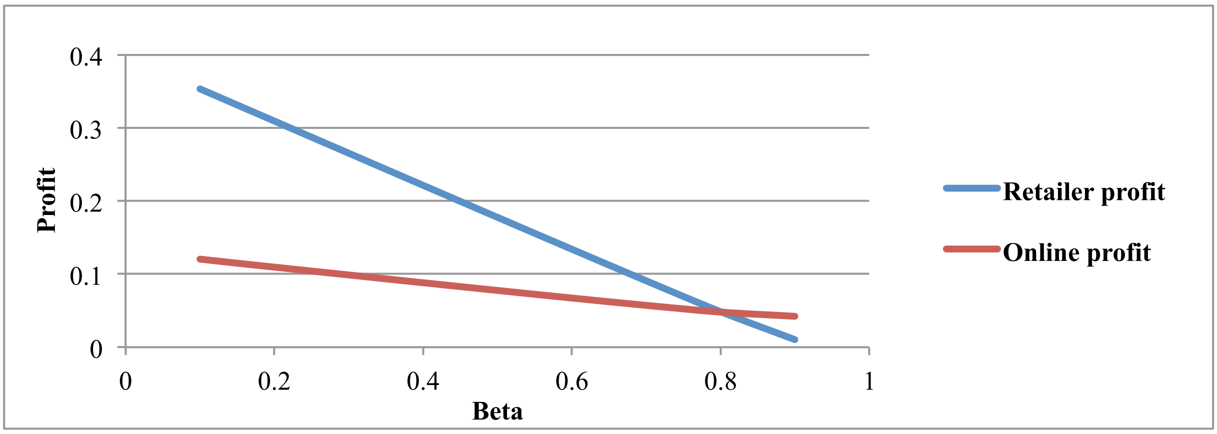

Figure 6: Profit (when the β value is changed)

4. CONCLUSION

In this paper, we study the dual-channel supply chain under decentralized setting. The objective of the research is to find the optimal pricing decisions on both channels to maximize the total supply chain profit and to gain managerial insights from the model. In this model, the retailer firm and online firm offer customers the same product. A customer decides to buy the product from the channel giving them the highest utility. The two firms try to maximize the total supply chain profits by adjusting the price on each channel. By the research, we found the optimal price of retailer channel and online channel in the decentralized model. The Nash equilibrium is also found. The analytical expressions for the optimal prices are proved analytically. The numerical result shows the effects in price, demand, and profit of the retailer and online channels. We found that when the product has high penalty cost, the retailer and online channels can set the price very differently and there is a great difference between the retailer and online profit. But when the product has low penalty cost, the demand in retailer and online channels will be very different.

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