World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:6, No:5, 2012

Optimal Prices under Revenue Sharing Contract in a Supply Chain with Direct Channel

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***Abstract*—**Westudy a dual-channel supply chain under decentralized setting in which manufacturer sells to retailer and to customers directly usingan online channel. A customer chooses the purchase-channel based on price and service quality. Also, to buy product from the retail store, the customer incurs a transportation cost influenced by the fluctuating gasoline cost. Both companies are under the revenue sharing contract. In this contract the retailer share a portion of the revenue to the manufacturer while the manufacturer will charge the lower wholesales price. The numerical result shows that the effects of gasoline costs, the revenue sharing ratio and the wholesale price play an important role in determining optimal prices. The result shows that when the gasoline price fluctuatesthe optimal on-line priceis relatively stable while the optimal retail price moves in the opposite direction of the gasoline prices.

***Keywords*—**direct-channel, e-business, pricing model, dual-channel supply chain, gasoline cost, revenue sharing

I. Introduction

THE growth of electronic commerce in recent years has provided firms with a very attractive marketing opportunity. Internet has become an important retail channel. Although traditional retailers vastly outsell Internet retailers in most product categories, the researches inInternet retailing have largely neglected this fundamental dimension of competition. Internet retailers face fierce competition from brick-and-mortar retailers when selling mainstream products, but are virtually immune from the competition when selling niche products. The online retail sales reached $165.4 billion in 2010, up 14.8% from 144.1 billion 2009 according to non-adjusted estimates released today by the U.S. Commerce Department[1]. In the long run, online stores are expected to enjoy a significant cost advantage over their brick and mortar counterparts primarily due to lower overhead and infrastructure costs [2]. The rapid development of commerce on the Internet has made it attractive for retailers to engage in direct online sales. According to Forrester Research, “E-commerce continues its double-digit year-over-year growth rate, in part because the sales are shifting away from stores and in part because on-lineshoppers are less sensitive to adverse economic conditions than the average U.S. consumer [3]. Moreover, on-line retail sites don't suffer as much as brick-and-mortar stores during economicdownturns, because on-line shoppers tend to have more money than those who shop in physical stores.”

The dual-channel dynamics in the presence of direct channel, with the rapid development of the Internet, manufacturers today are increasingly adopting a dual channel to sell their products dual-channelsupplychain where a manufacturer sells products directly to the customer and also through an independent retailer [4].

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Therefore web-based channels are fast becoming an integral part of the channel strategy of traditional off-line retailer [5]. The mix of retailing with a direct channel adds a new dimension of competition and complementsexisting distribution channels. Among online shoppers, consumers living close to physical store favor shopping at retailers because they can access traditional retail service from physical stores. However, consumers who live far away from physical stores find web-only retailer more attractive. Therefore, nowadays most firms adopt a multi-channel strategy that includes both web-based channels and pre-existing off-line channels [5]. However, traditionally off-line sellers can preempt competition from on-line channels by improving such features as convenience, personalized after-sale service, and trust.

The organization of this paper is as the following. In section 2, we briefly review the related literature.In section 3, we develop the consumer model and the game theoretic model to analyze the situation. In section 4, the numerical experimentis conducted to gain managerial insight under various situations. Section 5 concludes the research and provides the direction of future research.

II. Literature Review

A key challenge is to the price mechanism allowing the retailerto charge higher price in the face of lowered search costs in Internet markets. The effect of consumer’s online purchase cost on the profits of both online and traditional retailers is then further moderated by the traditional retail transaction cost and the product web-fit. Economic theories of consumer demand and retailer pricing suggest that product prices are a function of both the characteristics of the retailers and the competition.

It is found that prices were 9–16% lower in online stores than in conventional stores [6]. There is also the evidence that online prices for digital products were lower than prices in brick and mortar locations [7]. There are two types of channel pricing strategies: consistent pricing and inconsistent pricing. About two thirds of dual-channel companies utilize consistent pricing, whereas the remaining companies use inconsistent pricing. In a dual-channel supply chains, the manufacturer sells not only through a retailer, but also through a direct sales channel, which makes the manufacturer both a supplier to and a competitor of the retailer [8]. In any supply chain, the assortment and pricing decisions are crucial not only for the retailer, but also for its supplier. These decisions require even more scrutiny in a two-echelon, dual-channel supply chain, given the complicated nature of the relationship between the manufacturer and the retailer. Since different products have different degrees of customer acceptance of the direct channel, the product type has a great impact on the lead time and pricing decisions as well [9].

Since an online retailer competes directly with the traditional retailer and nowadays the dual-channel competition is becoming more and more intense. More and more retailers become accustomed to the coexistence of their own retail channels and supplier-own online direct channels [10]. We thus use a model to study the situation that there are two channels, the online channel of manufacturer (supplier) and the traditional retailer. The manufacturer supplies products to retailer and also has online channel for direct sell to customer.

Our study aims to develop models to capture pricing strategy to maximize the channel profits in supply chain. For this research we include the customer transportation costaffected by the fluctuating gasoline price.The increasing gasoline price will affect the customer behavior wanting to purchase from a traditional retailer. There is evidence that only major gasoline price changes have immediate impact on attitudes and behavior [11]. The important managerial implications are that when the online retailer sells the same product in a competitive market, it can effectively profit from the reduced consumer's online purchase cost [12]. The relative stability of gasoline price over time affects behavior. Periods characterized by slight but steady increases in gasoline price permit consumers to engage in compensatory behavior (e.g., decrease in mileage driven). However, in periods of rapid and substantial increases, the consumer's compensatory capability is diminished (i.e., the impact on the household budget is great and provides minimal time to adjust other spending practices) and more drastic adjustments in auto-related behavior are necessary [13]. For a retailer store, a consumer might be reluctant to buy a product if the distance to the retailer store is far away or the travel cost is too high and might choose to buy from the on-line channel instead. Because of a small number of studies of gasoline price effect to the consumer decision, we would like to incorporate gasoline price into our model and would like to capture the effect of gasoline price to channel selection at the same time. In effect, our model will incorporate the effects from travel cost.

III. Model

We start with the consumer model of consumers. The retailer owns a traditional retail store. At the same time the manufacturer also offers on-line sales channel as an alternative to sell the same product (with different services provided). Having two channels to sell a product, the both players face the pricing decisions of each channel so that each of their profit is maximized. At the same time, a consumer faces channel selection decision whether to purchase from on-line channel, retailer channel or do not buy at all. We consider a single period, single product model with a retailer. Retailer sells its product via on-line and traditional channel. The demand of on-line consumer is called "Direct Demand" or D_d while we represent the demand of retailer channel using D_r.

Both players determine the price of product in each channel simultaneously. We allow the price of each channel to be different. Let P_d denote the unit price of product sold via on-line Web site to consumers (including the shipping costs charged for delivery) and P_r denote the unit price of products sold at the brick-and-mortar retailer. In addition, we allow the level of service quality offered at each channel to be different. Studies have found that availabilities of product varieties and product information. Social interactions gained from shopping,shopping as a recreational experience and the desirability of immediate possession are important factors that influence a consumer's channel choice decision [14]. The service consumers received from buying via on-line channel has the valuation ofS_d while the service valuation of retail store is S_r. Different consumers have different service sensitivity by θ. We assume that θ is uniformly distribution between $[\underline{\theta}, \bar{\theta}]$. For example, some consumers with higher service sensitive θ may highly appreciate the service offered by retailer such as the guidance from salesperson, the ability to physically experience the product before buying and the ability to get the product right away than the other. This model closely follows model done in [15].We assume that the consumer's valuation of the product is the same between on-line and traditional consumers. We use V to denote the valuation of both on-line and traditional consumers. We also assume that $S_r > S_d$. The service at retailer is higher because it provides consumers better experience such as desire for immediate gratification. For traditional retailer channel, we assume that consumer has to incur a transportation cost to travel to the store. The travel cost depends on the gasoline price and the distance between the closet store of the firm and customer location. Because the customer location cannot be predicted in advance and it is independent to other consumer parameters, we can assume that a particular consumer with given values of other parameters, has a random value of transportation cost or the transportation cost could be anything unable to predict from other parameters of consumer incorporated in our model. We use ε to denote the transportation cost of each consumer and assume uniformly distribution between $[\underline{\varepsilon}, \bar{\varepsilon}]$. We also assume for each channel to sell a product the firm incurs variable costs c_r, c_d. The retailer incurs unit transportation cost, c_t, to buy product from manufacturer. The manufacturer incurs the production cost, c_p, to produce one unit of product. The parameters and variables discussed are summarized by group of consumers as shown below

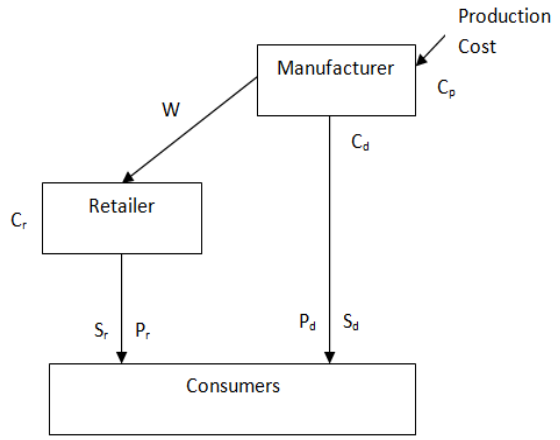

Fig. 1 Dual channel supply chain

We then present the development of demand functions based on consumer choice model in the following section.

A. Demand Model ForBoth Traditional And On-Line Consumers

A consumer will buy only when he or she gains some utility on the purchase. When a consumer purchase a product, the utility gained from the product is V but the utility gained from the service offered is θS_d depending on how the consumer appreciates the service. If the consumer does not need the service, the offered service has value 0 or θ is zero. Thus the total utility gained from the product and service is $V + \theta S_d$. However, the consumer has to pay the price P and thus the total utility gained from purchasing from this channel is $U_d = V + \theta S_d - p_d$ or $U_d = V - (p_d - \theta S_d)$. Similarly, the total utility gained from buying from traditional retailer is U_r or $V - (p_r - \theta S_r) - \varepsilon$. Since an on-line customer has to choose between these two channels, the customer choosesa traditional retailer channel when $U_r > U_d$ and chooses online channel otherwise.

The detailed derivation of the demand functions is omitted in this abridged version of the research. The result of derived demand function is summarized as follows:
The result can be further simplified as a result,

$$D_r = \frac{\alpha}{\Delta\theta}\int_{\theta^*}^{\overline{\theta}} \frac{1}{\Delta\varepsilon}[V + \theta S_r - p_r - (V + \theta S_d - p_d) - \underline{\varepsilon}]d\theta$$

$$D_d = \frac{\alpha}{\Delta\theta}(\theta^* - \theta')$$

$$+\frac{\alpha}{\Delta\theta}\int_{\theta^*}^{\overline{\theta}} 1 - \frac{1}{\Delta\varepsilon}[(V + \theta S_r - p_r - (V + \theta S_d - p_d) - \underline{\varepsilon})]d\theta$$

B. Profit Maximization

Based on our demand model, the retailer and manufacturer will maximize each channel profit. The retailer and manufacturer are under the revenue sharing contract. In this contract, the manufacturer will sell the product to retailer a low wholesale price w. In return, the retailer will keep ϕ portion of his revenue and share $1-\phi$ portion of his revenue to the manufacturer to compensate for the loss of manufacturer's profitwhere $0 < \phi < 1$. In this research, we assume that the wholesale price w and the revenue sharing ratio ϕ are given. In the full paper, the parameters will be optimized so that the total supply chain profit is maximized. The profit functions of both players are shown below:

Retailer's profit=

$$\Pi_r(p_r, p_d) = \phi p_r D_r(p_r, p_d) - (c_r + w + c_t)D_r(p_r, p_d)$$

Manufacturer's profit =

$$\Pi_m(p_r, p_d) = (p_d - c_d - c_p)D_d(p_r, p_d) + (w - c_p)D_r(p_r, p_d)$$
$$+((1-\phi)p_r D_r(p_r, p_d)$$

By using the first order condition $\frac{\partial\Pi}{\partial p_r} = 0$, we can solve for two retail prices as follows:

$$p_{r1} = \frac{w + c_r + c_t + 2\phi(p_d + \overline{\theta}(-s_d + s_r) - \underline{\varepsilon})}{3\phi} + \frac{\left((w + c_r + c_t - \phi(p_d + \overline{\theta}(-s_d + s_r)))^2 + 2\phi(w + c_r + c_t - \phi(p_d + \overline{\theta}(-s_d + s_r)))\underline{\varepsilon} + 4\phi^2\underline{\varepsilon}^2\right)^{0.5}}{3\phi} \quad (1)$$

$$p_{r2} = \frac{w + c_r + c_t + 2\phi(p_d + \overline{\theta}(-s_d + s_r) - \underline{\varepsilon})}{3\phi} - \frac{\left((w + c_r + c_t - \phi(p_d + \overline{\theta}(-s_d + s_r)))^2 + 2\phi(w + c_r + c_t - \phi(p_d + \overline{\theta}(-s_d + s_r)))\underline{\varepsilon} + 4\phi^2\underline{\varepsilon}^2\right)^{0.5}}{3\phi} \quad (2)$$

The first derivative function of the total profit provides two equations of retailer price was represented by p_{r1} and p_{r2}. Next, we evaluate the second derivatives of profit with respect to retailer price and get the following:

$$\frac{d^2\Pi_r}{dp_r} = \frac{\alpha(c_r + c_t + w + 2p_d\phi - 3p_r\phi - 2\phi((s_d - s_r)\overline{\theta} + \underline{\varepsilon}))}{(s_d - s_r)(\overline{\varepsilon} - \underline{\varepsilon})(\overline{\theta} - \underline{\theta})} \quad (3)$$

By substitute the retail channel prices in (1) and (2) into (3) and checking one of second order conditions, $\frac{d^2\Pi_r}{dp_r} < 0$, the optimal retail price is now p_{r2}.

Similarly, by using the first order condition $\frac{d\Pi_m}{dp_d} = 0$, we can solve for two retail prices as follows:

$$p_{d1} =$$
$$\frac{1}{3s_d}(2\overline{\theta}s_d^2 + s_d(w + 2\overline{\varepsilon} + c_d - (-3+\phi)p_r - 2\overline{\theta}s_r) + 2s_r(-\overline{\varepsilon} + \underline{\varepsilon})$$
$$-(\overline{\theta}^2 s_d^4 - 2\overline{\theta}s_d^3(w - \overline{\varepsilon} + c_d - \phi p_r + \overline{\theta}s_r) + 2s_d s_r(3v - 2w - 4\overline{\varepsilon} \quad (4)$$
$$+c_d + 3c_p + 2(-3+\phi)p_r + 4\overline{\theta}s_r)(\overline{\varepsilon} - \underline{\varepsilon}) + 4s_r^2(\overline{\varepsilon} - \underline{\varepsilon})^2 + s_d^2(4\overline{\varepsilon}^2$$
$$+(w + c_d - \phi p_r + \overline{\theta}s_r)^2 - 2\overline{\varepsilon}(3v - 2w + c_d + 3c_p + 2(-3+\phi)p_r$$
$$+5\overline{\theta}s_r) + 2(3(v - w + c_p + (-2+\phi)p_r) + 4\overline{\theta}s_r)\underline{\varepsilon})))^{0.5}$$

$$p_{d2} = \frac{1}{3s_d}(2\overline{\theta}s_d^2 + s_d(w + 2\overline{\varepsilon} + c_d - (-3+\phi)p_r - 2\overline{\theta}s_r)$$
$$+2s_r(-\overline{\varepsilon} + \underline{\varepsilon}) + (\overline{\theta}^2 s_d^4 - 2\overline{\theta}s_d^3(w - \overline{\varepsilon} + c_d - \phi p_r + \overline{\theta}s_r)$$
$$+2s_d s_r(3v - 2w - 4\overline{\varepsilon} + c_d + 3c_p + 2(-3+\phi)p_r + 4\overline{\theta}s_r) \quad (5)$$
$$(\overline{\varepsilon} - \underline{\varepsilon}) + 4s_r^2(\overline{\varepsilon} - \underline{\varepsilon})^2 + s_d^2(4\overline{\varepsilon}^2 + (w + c_d - \phi p_r + \overline{\theta}s_r)^2$$
$$-2\overline{\varepsilon}(3v - 2w + c_d + 3c_p + 2(-3+\phi)p_r + 5\overline{\theta}s_r)$$
$$+2(3(v - w + c_p + (-2+\phi)p_r) + 4\overline{\theta}s_r)\underline{\varepsilon})))^{0.5}$$

Then, we determine the second derivative of profit with respect to manufacturer price and it is shown as follows:

$$\frac{\partial^2\Pi}{\partial p_d} = -\frac{\alpha(2\overline{\theta}s_d^2 + s_d(w + 2\overline{\varepsilon} + c_d - 3p_d - (-3+\phi)p_r - 2\overline{\theta}s_r) + 2s_r(-\overline{\varepsilon} + \underline{\varepsilon}))}{s_d(s_d - s_r)(\overline{\varepsilon} - \underline{\varepsilon})(\overline{\theta} - \underline{\theta})} \quad (6)$$

Similarly, by plugging the online price in (4) and (5) into (6) and checking one of second order conditions, $\frac{\partial^2\Pi}{\partial p_d} < 0$, p_{d2} is the only optimal online price. We can summarize the result as shown in proposition 1.

Proposition 1: The optimal prices for both channels given the price of the other channel are as follows:

$$p_r = \frac{w + c_r + c_t + 2\phi(p_d + \bar{\theta}(-s_d + s_r) - \underline{\varepsilon})}{3\phi} - \frac{\begin{pmatrix}(w + c_r + c_t - \phi(p_d + \bar{\theta}(-s_d + s_r)))^2 + \\ 2\phi(w + c_r + c_t - \phi(p_d + \bar{\theta}(-s_d + s_r)))\underline{\varepsilon} + 4\phi^2\underline{\varepsilon}^2\end{pmatrix}^{0.5}}{3\phi}$$

$$\begin{aligned} p_d = \frac{1}{3s_d}&(2\bar{\theta}s_d^2 + s_d(w + 2\bar{\varepsilon} + c_d - (-3+\phi)p_r - 2\bar{\theta}s_r) \\ &+2s_r(-\bar{\varepsilon} + \underline{\varepsilon}) + (\bar{\theta}^2 s_d^4 - 2\bar{\theta}s_d^3(w - \bar{\varepsilon} + c_d - \phi p_r + \bar{\theta}s_r) \\ &+2s_d s_r(3v - 2w - 4\bar{\varepsilon} + c_d + 3c_p + 2(-3+\phi)p_r + 4\bar{\theta}s_r) \\ &(\bar{\varepsilon} - \underline{\varepsilon}) + 4s_r^2(\bar{\varepsilon} - \underline{\varepsilon})^2 + s_d^2(4\bar{\varepsilon}^2 + (w + c_d - \phi p_r + \bar{\theta}s_r)^2 \\ &-2\bar{\varepsilon}(3v - 2w + c_d + 3c_p + 2(-3+\phi)p_r + 5\bar{\theta}s_r) \\ &+2(3(v - w + c_p + (-2+\phi)p_r) + 4\bar{\theta}s_r)\underline{\varepsilon})))^{0.5} \end{aligned}$$

The Fig. 2 illustrates the shapes of best response functions of prices in both channels. The shapes of the best response functions are approximately linear and therefore the unique Nash equilibrium is expected even though it is not proved mathematically.

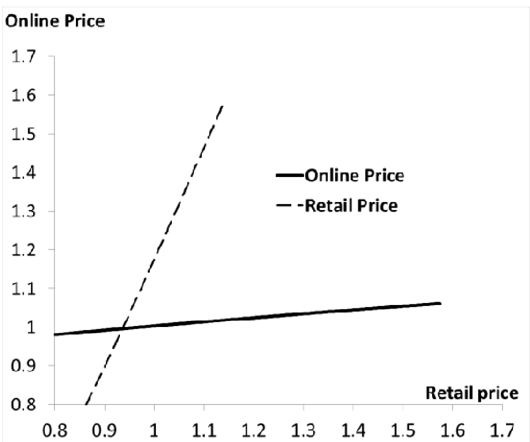

Fig. 2 Example of The best response functions of both prices

IV. Numerical Results

We collected a historical data of gasoline price in the United States during 2008 to 2011 to determine the effect of changing gasoline price. In the numerical experiment, we also calculate the centralized prices to compare against the decentralized prices. From Fig. 3, as the gasoline price fluctuates, online channel price stays approximately at the same while retail channel price in decentralization and centralization change but retail price in centralization is at higher level due to the collaborative between both parties.

Fig.3 shows the overall effect in supply chain from fluctuating gasoline price. In Fig.4, the retail prices move in the opposite direction of gasoline prices. However, the centralized price is set higher due to less price-cut between the two channels.

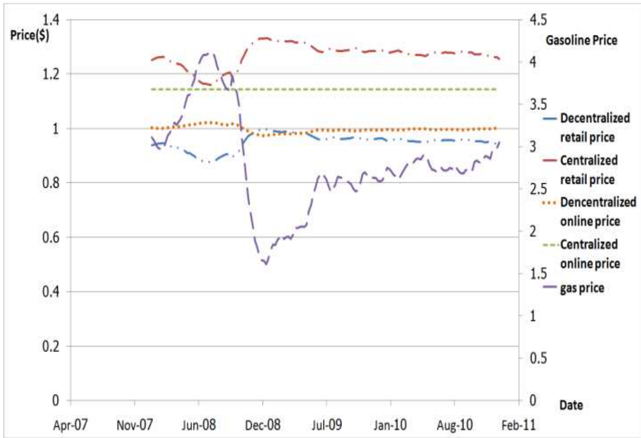

Fig. 3The effect of gasoline price to supply chain price

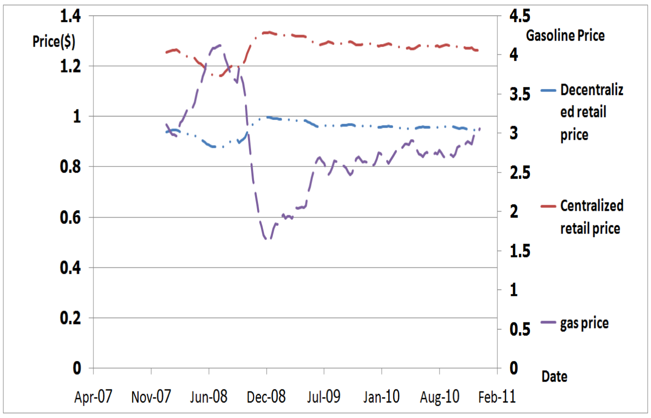

Fig. 4The effect of gasoline price to retail price

From Fig.5, in the gasoline price increases, the online price in decentralized decrease slightly because the manufacturer has to attract customers due to fierce retail price reduction to maintain online profit.However, the online price in centralized is stable because in centralized situation the loss of online profit from retail price reduction is less important because they are under the same company.

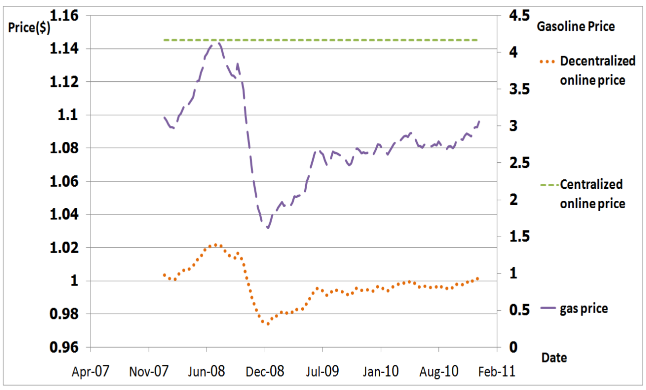

Fig. 5 The effect of gasoline price to online price

In Fig.6, the customer channel choice is greatly affected by the fluctuation of gasoline price. The demand in retail channel fluctuates inversely to the gasoline price. Thus, when gasoline prices drops, the demand in retail channel increases and vice versa. According to Fig.7, the on-line demand and gasoline price move in the same direction. When the gasoline price decreases, the on-line demand decreases because some customerschoose the retail channel. However, when the gasoline price increases, the on-line demand also increases since some customers switch to buy the product from on-line channel to save their cost.

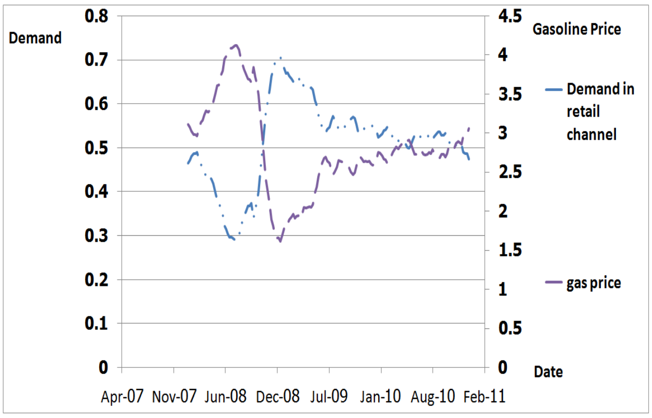

Fig. 6 The effect of gasoline price to retail demand in the market

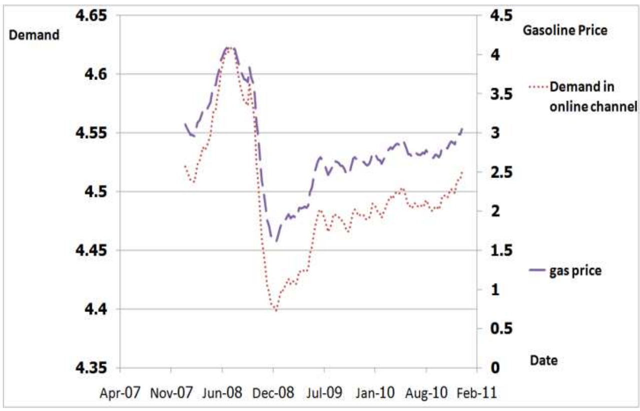

Fig. 7 The effect of gasoline price to online demand in the market

Fig. 8 shows the effect of gasoline price to the demand of supply chain. The gasoline price has a great impact to overall demand due to effect of gasoline price to retail channel. The gain of on-line demand is not enough to offset the loss of demand in retail channel.

From Fig.9, 10 and 11, the profit of both retail and online channel follows the same pattern as the demand. The on-line profit and total profit follow the gasoline price movement while the retail profit is opposite. As the total profit can increase when the gasoline price increases, the direct channel is very beneficial to the supply chain profit.

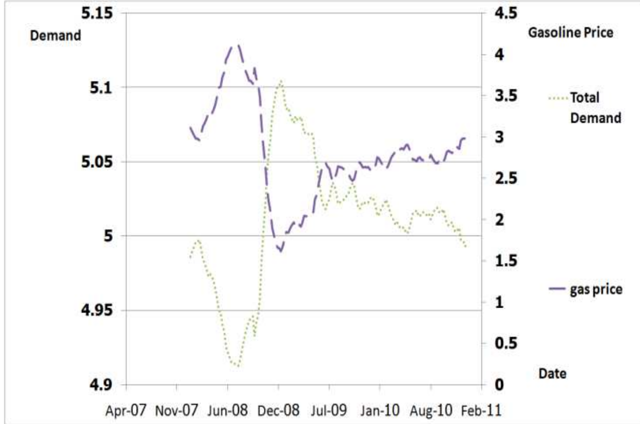

Fig. 8 The effect of gasoline price to total demand

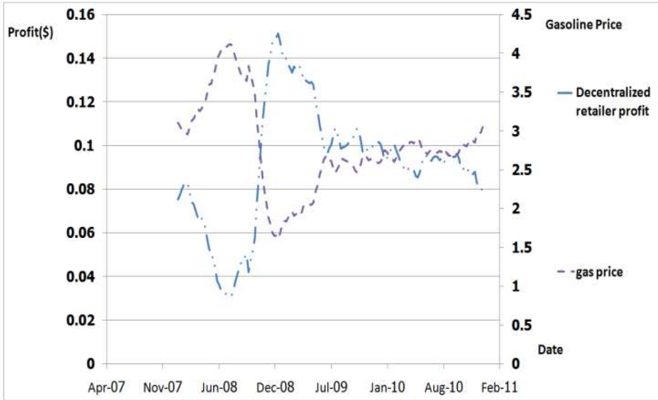

Fig. 9 The effect of gasoline price to decentralized retail profit

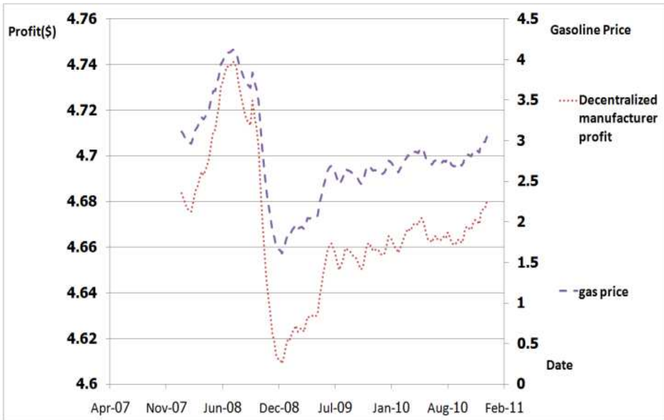

Fig. 10 The effect of gasoline price to decentralized online profit

V. CONCLUSION

In this report, we study the dual-channel supply chain under decentralization condition. We build a mathematical model to capture the major features of the channels. Our objective is to use the model to understand how pricing decisions on each channel should be made. We find the optimal pricing decisions on both retail and online channels. In this problem, a manufacturer who owns the online channel and the retailer channel sells the same product via a retail store.

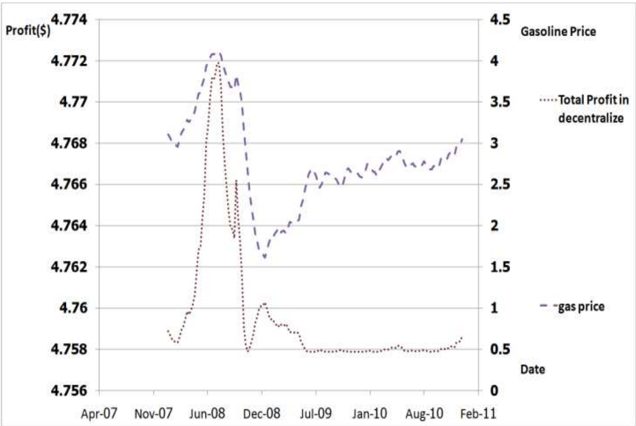

Fig. 11 The effect of gasoline price to total decentralized profit

A customer decides to buy the product from the channel giving them the highest utility gained from product and service. However, to buy the product from the retail store, the customer incurs a transportation cost affected by the fluctuating gasoline costs. We study the effect by developing a consumer's demand model. The analytical expressions for the optimal prices are proved analytically. Our numerical results lead to several insights, the effects of gasoline costs to the channel prices and profits. We found that the increase in gasoline cost will not greatly affect the online channel price while it has a great impact on the retail channel price. The total supply chain profit can increase even during the surge of gasoline price.We found that some of online demand will be lost and some of online demand will be transferred to the retail channel as the retail price decreases.

ACKNOWLEDGMENT

Author would like to thank another three research assistants, KanJantarach,SiraVapattanawong andWorawat Na Ayudhaya, for helping with the calculation and numerical results.

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