The Mode of Different Price in Dual-Channel Supply Chain

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Abstract

Manufacturers and retailers today are increasingly adopting a dual channel to sell their products, i.e., the traditional retail channel and an online direct channel. Empirical studies have shown that product price influencing consumer acceptance of the direct channel as one of the major factors. We respectively discuss the consistency pricing Stackelberg game mode under which retailers decide the channel prices and the inconsistence pricing Stackelberg game mode under which manufacturers and retailers decide their own channel prices. We try to find the relationship between the customer acceptance and the price in different mode. The numerical analysis compares the customer acceptance and the price under different modes and centralized decision model. We analytically show that the customer acceptance influences the pricing. Our numerical studies reveal that the difference between the demand transfer ratios with respect to manufacturers' and retailers' price, customer acceptance of the direct channel have great effects on the pricing decisions.

Keywords: Supply chain management, Dual channel, E-commerce, Stackelberg game

1. Introduction

With the rapid development of electronic commerce and logistics and transportation industry, great changes have taken place in the enterprise marketing mode. Product manufacturers can not only by retailers to sell products, but also through the establishment of direct marketing network marketing products. Compaq, HP, IBM, Samsung, Sony companies such as [1] have two channel and multiple sales channels. But the dual channel sales model in increasing product sales also led to conflict with downstream partners, causes the channel conflict. Choi [2] study shows that channel pricing of products is the key factor of channel conflict, therefore channel pricing model is an important problem in the study of dual channel supply chain.

The decision problem of dual channel supply chain now part of the theoretical and empirical study. Brynjolfsson [3] makes an empirical study of the book. CD products such as pricing, found that Internet sales price than the price of traditional retail low 9~16%, and network channels to frequent price changes. Webb [4] analysis of channel conflict management strategies from supplier's perspective, and puts forward some proposals for resolving conflicts. Tsay [5] were reviewed on the conflict and coordination. Chiang [6]
consumer utility theory based on the pricing problem of dual channel, this is the dual channel quantitative study of the earlier literature. Yao and Liu [7] to study the static and dynamic equilibrium pricing strategy price and service also influence the demand of. Yue and Liu [8] analyzed the direct channel effect on the performance of supply chain and the influence of information sharing on pricing and inventory decisions. Cohen [9] pointed out that sometimes firms use the direct channel for information and sales support and leave the actual sales to the retailer. Keenan [10] showed the steps that manufacturers can take in reducing channel conflict by explaining the direct channel as targeting a different market segment. Mukhopadhyay et al., [11] argued that retailers are able to differentiate their products from those sold through direct channels by adding value to on-the-shelf goods. Dumrongsiri [12] studies the pricing problem and retailers in dual channel supply chain ordering decision. Chiang and Monahan [13] presented a dual-channel inventory model with stochastic demands for two customer segments Hua et al., [14] examined a dual-channel supply chain and considered the factor of delivery lead time in the pricing decisions. Boyaci [15] found that simple contracts, such as wholesale price only, buyback, revenue-sharing, and Vendor Managed Inventory (VMI) contracts, cannot coordinate the dual-supply chain with inventory decisions. Cai et al., [16] showed that price discount contracts perform well in a dual-channel supply chain. Yao and Liu [17] discussed Bertrand and Stackelberg equilibrium pricing policies and compared the profit gains under these two types of competition in a dual channel. Cai [18] investigated the influence of channel structures and channel coordination on the supplier, the retailer, and the entire supply chain in a dual-channel supply chain.

Pricing decision in dual channel supply chain above literature price or service on demand is also researched, and most of them are inconsistent research dual channel pricing pattern. But the empirical research shows that about strategy of 2/3 has two channels of enterprises using uniform pricing [19, 20]. At the same time considering the real life, business advertising can attract more consumers, in this paper, on the basis of the existing research on market demand and price and advertising effect of double channel decision. At present the study on advertising decision mainly focused on single channel supply chain, Huang and Li [21] were studied using the cooperative advertising model for a single game theory to the supply chain composed of a manufacturer and a retailer. Yue noncooperation game and the cooperation game model of advertising and price of market demand by [22]. Karray and Zaccour [23] discuss products retailers and sales of private brand products and manufacturers, the conflict between the two cooperative advertising can be reduced. Xie optimal decision level two channel [24] analysis of market demand is influenced by advertising costs and prices of the case, and points out that cooperative game can improve the system benefits. Szmerekovsky and Zhang [25] on manufacturers and retailers are advertising case their decision problems. In the above study, the advertising decision-making and strategy of cooperative advertising into the research in dual channel supply chain less. But in reality, the retailer by sales area advertising can and manufacturers compete for market. Therefore, this paper is also under the assumption that the market demand price and advertising influence on the basis, respectively, to establish a direct sales channel and retail price and the price of non-consistent dual channel mode under the Stackelberg game model, the optimal pricing model under different channels and advertising, and to explore the influence of cooperative advertising on decision making in the price of non-consistent mode. Through the comparison of the decision of two pricing models and centralized decision-making model, on the supply chain optimal pricing model.
Table 1. Summary of Recent Research

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<tr>
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<th>Linear demand</th>
<th>Price competition</th>
<th>Channel coordination</th>
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<td>Boyaci[15]</td>
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<td>Cai[18]</td>
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<td>Cai et al.[16]</td>
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<td>Chiang and Monahan[13]</td>
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<td>Hua et al.[14]</td>
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<td>Yao and Liu[8]</td>
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2. The Basic Model

In the dual channel supply chain model, consumers can obtain products through traditional retail channels, can also buy products through the network of direct sales channels. Sources of demand is not only affected by the price and advertising investment, but also affected by other channel prices. Assume that the demand function respectively:

\[
Q_d = (\theta + \rho)a - p_d - b(p_d - p_r) - \sqrt{a}
\]  
\[
Q_r = (1 - \theta)a - p_r + b(p_d - p_r) + \sqrt{a}
\]

Where the subscripts \( d \) and \( r \) respectively represent two channels of direct sales channels and retail channel; \( Q_i (i = d, r) \), said \( i \) channel market demand; \( a \) is greater than zero and constant, said the size of the market in general only a single retail channels; constant \( \theta \) said the original market size distribution proportion in different channels.; constant \( \rho \) in order to increase the direct channel to attract potential demand ratio; \( b \) represents a substitution effect coefficient network channel and traditional retail channels, \( b \in (0, 1) \).

The decision variable \( p \), representing the product in different channel sales price; decision variable \( a \) said retailers advertising investment; decision variable \( w \) said manufacturers raised wholesale prices.

The demand function of advertisement investment impact on demand function of \( b\sqrt{a} \) is a function of \( a \), the function form and the documents in [24] form similar, also with Simon and Arndt (1980) obtained through the investigation of 100 cases of advertising effects on the demand function.

3. Game Dual Channel Stackelberg Prices Consistent Mode

When adding direct channel in the supply chain, the retailer will usually this behavior to the manufacturers take measures to fight against the manufacturers, such as Levis retailer opens online store activity [26]. To alleviate this contradiction, manufacturers have had to adopt some means of reducing conflict. Kevin (2002) [4] double channel that price is one of the methods to reduce channel conflict. This section discusses the dual channel price and the price is decided by the retailer decision making under. The game model is the Stackelberg game: manufacturers announced the wholesale price, the retailer determines the advertising expenses and retail price, manufacturers are pricing in accordance with the retail price.

Demand function two channels into:
\[ Q_r = (\theta + \rho)a - p_r - b\sqrt{a} \quad (3) \]
\[ Q_r = (1 - \theta)a - p_r + b\sqrt{a} \quad (4) \]

3.1. The Second Stage of the Decision Problem of Retailers

The decision problem for retailers:
\[
\max_{\pi_r, \sqrt{a}} \pi_r = (p_r - w)((1 - \theta)a - p_r + b\sqrt{a}) - a \\
\text{s.t. } Q_r (p_r, \sqrt{a}) = (\theta + \rho)a - p_r - b\sqrt{a} \geq 0 \\
a \geq 0
\]  
\[ (5) \]
Constraint conditions to ensure the direct channel sales and advertising costs are non-negative.

The problem is transformed into:
\[
\min_{p_r, a} f(p_r, a) = (p_r - w)[-(1 - \theta)a + p_r - b\sqrt{a}] + a \\
\text{s.t. } (\theta + \rho)a - p_r - b\sqrt{a} \geq 0 \\
a \geq 0
\]
\[ (6) \]

The Hessian matrix of the target is \( \frac{\partial^2}{\partial p_r \partial a} f(p_r, \sqrt{a}) = \begin{bmatrix} -b & 0 \\ 0 & 2 \end{bmatrix} \), obvious, \( f(p_r, \sqrt{a}) \) is a positive definite matrix, the existence of the optimal value of objective function.

Using the theory of constrained optimization of KKT conditions to solve and preserve meaningful solutions to the following proposition.

**Proposition 1**: The reaction function of the wholesale price of \( w \) second stage retailers respectively is:
\[
p_r (w) = \frac{2(1 - \theta)a + (2 - b^2)w}{4 - b^2} \quad (7)
\]
\[
\sqrt{a(w)} = \frac{b(1 - \theta)a - w}{4 - b^2} \quad (8)
\]

If and only if \( 1 - \theta \geq \theta + \rho \) and \( w = \frac{3(1 - \theta)a - (1 - \theta)a}{2} \) reaction function is

\[ p_r (w) = (\theta + \rho)a, a = 0 \]

Proof omitted.

For type (7), the \( \frac{\partial p_r (w)}{\partial w} > 0 \), retail price is an increasing function of the wholesale price, retail price increases with the wholesale price, which is consistent with previous. For type (8), \( \frac{\partial \sqrt{a(w)}}{\partial w} < 0 \) the retailer’s advertising input and decreases with the increase in wholesale prices.

3.2. The Decision Problem Faced by Manufacturer

Return on total income manufacturers from direct channel and traditional retail channel gains, the decision problem is
Fed the retailer's reaction function type (7) and (8) respectively into the decision problem of manufacturers, we can get the wholesale price for \( w^* \), and the solution of dual channel Stackelberg equilibrium under the price consistent mode.

\[
\begin{align*}
\max_w \quad & \pi_m = [p_r(w) - c][(\theta + \rho)\alpha - p_r(w) - b\sqrt{a(w)}] + (w - c)[(1 - \theta)\alpha - p_r(w) + b\sqrt{a(w)}] \\
\text{s.t.} \quad & Q(p_r, p_w, \sqrt{a}) \geq 0
\end{align*}
\]  

(9)

When \( 1 - \theta = \theta + \rho \), there is

\[
\begin{align*}
w^* & = \frac{(2 + b^4)(1 - \theta)\alpha + (2 - b^2)(4 - b^2)[2c + (\theta + \rho)\alpha]}{4(6 - 4b^2 + b^4)} \\
p_r & = \frac{2(1 - \theta)\alpha + (2 + b^4)(2 - b^2)(1 - \theta)\alpha + (2 - b^2)(4 - b^2)[2c + (\theta + \rho)\alpha]}{4(4 - b^2)(6 - 4b^2 + b^4)} \\
\sqrt{a} & = \frac{b(1 - \theta)\alpha + (2 + b^4)(1 - \theta)\alpha + (2 - b^2)(4 - b^2)[2c + (\theta + \rho)\alpha]}{4(4 - b^2)(6 - 4b^2 + b^4)}
\end{align*}
\]  

(10)

(11)

(12)

4. Double Channel Stackelberg Game under the Mode of non-consistent Price

When the manufacturer in the supply chain in a relatively strong position, the manufacturer will generally use a consistent strategy of non-price, make the price of direct sales channels. Suppose to compensate for the direct channel to transfer caused by the loss of demand for retailers, manufacturers use the cooperative advertising form, by the manufacturer for some retailers advertising. Advertising share ratio of \( t, t \in [0,1) \), supplier undertakes \( TA \) advertising costs.

The two decision sequence is as follows: in the first stage the manufacturer first announced the wholesale price of products \( w \) and \( t \) and direct marketing advertising share price \( p_r \); the second stage retailers determine the retail price \( p_r \) and advertising \( a \); from the overall decision, two belong to the Stackelberg game.

The manufacturer and the retailer's profit function respectively is:

\[
\begin{align*}
\pi_m & = (p_r - c)Q_d + (w - c)Q_r - ta \\
\pi_r & = (p_r - w)Q_r + (1 - t)a
\end{align*}
\]  

(13)

(14)

In order to solve the Stackelberg equilibrium solution, according to the backward induction, \( w, t \) and \( p_r \) are known, then solve the reaction function for second-stage retailers.

4.1. The Second Stage of the Decision Problem of Retailers

The decision problem for retailers is:
\[
\max_{\rho, \alpha, \theta} \quad \pi_\rho = (p_{\rho} - w)[(1 - \theta)\alpha - p_{\rho} + b(p_{\rho} - p_{\rho} + \sqrt{u})] - (1 - \theta)\alpha
\]
\[
\text{s.t.} \quad (\theta + \rho)\alpha - p_{\rho} - b(p_{\rho} - p_{\rho} + \sqrt{u}) \geq 0
\]
\[
a \geq 0
\]

(15)

Similar to proposition 1, retailers also use decision theory of constrained optimization of KKT conditions to solve, can get the following proposition.

**Proposition 2**: The second stage is the reaction function of retailers is:

\[
p_{\rho}(w, p_{\rho}, t) = \frac{2(1 - \theta)\alpha}{4 - b^2} + \frac{2(1 - t)(1 - \theta)\alpha + b p_{\rho} + [2 + (1 + b)(1 - t) - b^2]w}{4(1 + b)(1 - t) - b^2}
\]

(16)

\[
\sqrt{a(w, p_{\rho}, t)} = \frac{b[(1 - \theta)\alpha + b p_{\rho}] - b(1 + b)w}{4(1 + b)(1 - t) - b^2}
\]

(17)

if and only if when

\[
\frac{(1 - \theta)\alpha + b p_{\rho} + w}{2 + b} = \frac{-(\theta + \rho)\alpha + (1 + b)p_{\rho}}{b}
\]

there is

\[
p_{\rho}(w) = \frac{(1 - \theta)\alpha + b p_{\rho} + w}{2 + b}
\]

(18)

Proof omitted

For type (17), as the \[\frac{\partial}{\partial t} \sqrt{a(w, p_{\rho}, t)} = \frac{4(1 + b)(1 - \theta)\alpha + b p_{\rho} - (1 + b)w}{4(1 + b)(1 - t) - b^2} > 0\], the advertisement proportion \(\rho\) increases, the retailer’s advertising input will increase.

4.2. The Decision Problem Faced by Manufacturer

\[
\max_{\rho, \alpha, \theta} \quad \pi_\alpha = (\theta + \rho)\alpha - p_{\rho} - b[p_{\rho} - p_{\rho}(w, p_{\rho}, t) + \sqrt{a(w, p_{\rho}, t)}] + (w - c)\{(1 - \theta)\alpha - p_{\rho}(w, p_{\rho}, t) + b[p_{\rho} - p_{\rho}(w, p_{\rho}, t) + \sqrt{a(w, p_{\rho}, t)}] - \alpha\}
\]

(19)

Fed the retailer response function (16) and (17) into the manufacturer's decision problems to solve the constrained equilibrium.

Because the expression is complicated, we can’t get the analytic solution. To investigate the effects of solution properties and the calculation of the cooperative advertising to manufacturer and retailer gains by numerical only.

The type (18) into type (19), can be solved in \[a' = 0\].
\[
p_r^* = \frac{(1 + b)(\theta + \rho)\alpha + b(1 - \theta)\alpha + (1 + 2b)c}{2(1 + 2b)} \tag{20}
\]

\[
w = \frac{(-2 - 3b)[(1 + b)(\theta + \rho)\alpha + b(1 - \theta)\alpha + (1 + 2b)c]}{2(1 + b)(1 + 2b)} + (\theta + \rho)\alpha + \frac{3c + 4bc}{2(1 + b)} \tag{21}
\]

5. The Centralized Decision-making Model of Supply Chain

Spengler [27] points out the double marginalization problem, as long as the supply of both sides in the pursuit of maximizing their own interests as the goal in the chain, the total revenue of this system is always less than the centralized decision-making income. In the dual channel supply chain system, if the two cooperation, jointly make decisions on price and advertising, the system achieve the highest performance. The discussion in this section is mainly to compare performance with more than two kinds of different price modes.

Decision problem of dual channel is:

\[
\max_{\pi, \alpha, \beta} \pi^* = (p_r - c)[(\theta + \rho)\alpha - r_r - \beta(p_r - p_d - \sqrt{a})]
\]

\[
+ (p_r - c) [(1 - \theta)\alpha - p_r + b(\alpha\beta - p_r + \sqrt{a})]
\]

\[
-a
\]

s.t.

\[
a \geq 0
\]

\[Q_1(p_r, p_d, \sqrt{a}) \geq 0\]

\[Q_2(p_r, p_d, \sqrt{a}) \leq 0\]

When considering all constraints do not work, that all constraints are greater than zero, is used to solve this problem, a well-balanced solution is:

\[
p_r^* = \frac{\sqrt{a}}{2} + \frac{c}{2} + \frac{(2b - b^2)(1 + \rho)\alpha + 2(1 - \theta)\alpha}{2(2 + 4b - b^2)} \tag{22}
\]

\[
p_d^* = \frac{(1 + \rho)\alpha}{2} + c - p_r = \frac{(2 + 2b - b^2)(1 + \rho)\alpha - 2(1 - \theta)\alpha + (2 + 4b - b^2)c}{2(2 + 4b - b^2)} \tag{23}
\]

\[
\sqrt{a}^* = \frac{b(p_r^* - p_d^*)}{2} \tag{24}
\]

Constraint condition:

\[
\frac{(4 + 4b - b^2)(1 + \rho)}{4} \leq \frac{(2 + 4b - b^2)c}{2} \leq \theta \leq \frac{1 - \rho}{2}
\]

This constraint indicates when the traditional retail channel sales size larger than the size of the total direct sales channels, the optimal retail price than the direct channel price, namely \(p_r^* > p_d^*\).
When \( \theta \geq \frac{1-\rho}{2} \), requirements of \( a' = 0 \) the corresponding equilibrium solution meet

\[
\begin{align*}
p'_{\alpha} &= \frac{(1+b)(1+\rho)a + (1+2b)c - (\theta + \rho)a}{2 + 4b} \\
p'_{\beta} &= \frac{(1+b)(1+\rho)a + (1+2b)c - (1-\theta)a}{2 + 4b}
\end{align*}
\]  

(27)

(28)

As \( \theta + \rho \geq 1 - \theta \), compare with type (23) and (24), we know \( p_{\alpha} \leq p_{\alpha} \), i.e., when the direct channel sales scale of not less than the retail channel, direct channel price of not less than the retail price, which also helps us to understand network sale price is higher than that of the traditional retail price phenomenon exist in real life.

6. Numerical Studies

In this section we report the observations obtained from the numerical experiments carried out to examine the relationships between the customer acceptance and the price. All parameters were assumed in \( a = 100, \rho = 0.2, b = 0.4, c = 8 \), discuss the different proportion of demand assignment decision value, the results in tab...
Figure 2. The Relationship between the Customer Acceptance and the Retailers' Price, $\sqrt{a} = 3$

Figure 3. The Relationship between the Customer Acceptance and the Retailers' Price, $\sqrt{a} = 2$
In the four pictures we can see, in the traditional sales channels, regardless of manufacturer or retailer price decreased with the increase of customer acceptance. Due to direct customer acceptance increases, more inclined to buy products from the Internet, which the traditional mode of challenge, so businesses have to make countermeasures, to attract the attention of customers to price way.

Then we compare Figure 1 and Figure 3, Figure 2 and Figure 4. Obviously, advertising costs have an influence on the sales price. Due to the increase of the advertising expenses, whether the manufacturer or retailer, will be part of the cost through increased product prices means the transfer to the customer, this caused the rise in prices.

7. Conclusions

Price and customer acceptance are very important for manufacturers and retailers with a dual sale channel. In this paper, we examined the optimal decisions for the customer acceptance and prices in the different modes using the two-stage optimization technique and Stackelberg game. We provided a decision making aid for the manufacturer and the retailer and analyzed the impacts of the customer acceptance on the manufacturers’ and retailer’s pricing decisions and profits.

With the increase of customer acceptance, manufacturer or retailer price decrease in different modes. And as the increasing of the advertising expenses, manufacturer and retailer, will be part of the cost through increased product prices means the transfer to the customer.

There are several interesting topics for further research. In this paper, we assumed that supply chain is two-stage chain, How about three-stage chain. We also implicitly assumed that the manufacturer or its third-party logistics firm offers a standard delivery service in the direct channel. But in practice they may offer several delivery modes at different prices for customers to choose. So another potential topic for further research is to incorporate several delivery modes into the model, i.e., the direct channel’s service is measured by the delivery modes offered.
References


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