

Pricing/service strategies for a dual-channel supply chain with bi-direction free-riding and revenue-sharing contract

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Abstract: This paper considers a two-level and a dual-channel supply chain, where a manufacturer sells products through both her own online channel and a traditional retail channel. Both them provide customers with some pre-sales services by brick store and online consulting, which have positive impact on the market demand and lead to bi-direction free-riding. In order to improving supply chain performance, we investigate the coordination of the retailer channel and online channel by revenue-sharing contract. Our study presents the following findings. (i) Under the non-differential pricing scenario, retailer do not exist the optimal free-riding level, however the manufacturer have always the optimal free-riding level. The results are just reversed our intuition. (ii) Under each of the two pricing scenarios, the revenue-sharing contract can effectively stimulate the retailer to improve his service level while free riding occurred. (iii) Even if under the revenue-sharing contract, free riding has always a negative effect on the retailer's profit.

1. Introduction

Consider a supply chain where a manufacture uses both a traditional and own online channel in parallel to sell a single product. In practice, some manufacturers usually maintain the same sales price at the dual channels (Hann, 1999). For example, through the empirical research, Ernst (2001) showed that about 2/3 of enterprises having two channels use uniform pricing strategy. Researchers like Tsay and Agrawai (2004) etc. also discussed the uniform pricing strategy in their paper. Therefore, we study the corresponding pricing/service strategies under the non-differential pricing scenario in this section. Online stores can bring consumers more utilities in convenience, but have more uncertainties in product quality than brick stores, there is still free-riding between the online store and brick stores, even if the selling prices at two channels are the same. For example, for products like desktop computers, televisions, electric fans etc, consumers usually need visit retail stores to physically touch and inspect the quality of the products before purchasing (Lal and Sarvary, 1999). However, those products are not very easy for consumers to take home. If the retail stores have not delivery service, customers may enjoy the pre-sales service of those products in the retail stores but free ride to online stores to buy, although the price is the same at both online and retail stores. In the real life, however, it is also common that consumers often switch to retail store to buy somethings after searching information in online store or inquiring pre-sales services offered by online store.

2. Literature Review

Two streams of literature are related to our paper: service effort coordination between different partners and free-riding in dual channels. Heitz-Spahn (2013) further studied cross-channel free-riding from a consumer empowerment perspective. Huang et al. (2016) investigated the impact of the newly introduced mobile channel on the sales of the incumbent web channel and new consumption from the mobile channel. They found that the positive synergy effect of the new channel overrode the negative cannibalization effect. Zhang et al. (2010) investigate the effects of concession revenue sharing between an airport and its airlines. Hu et al. (2016) discuss the

three-echelon supply chain coordination with a loss-averse retailer and revenue-sharing contracts. Hou et al. (2017) analyze the revenue-sharing contract for the coordination of a three-echelon supply chain consisting of a manufacturer, a distributor, and a retailer. However those papers did not focus on pricing /services strategies under dual channel free-riding, and when bidirectional free-riding occurred how the manufacture set revenue-sharing to improve supply chain preferences.

3. Model framework

This paper consider dual channel free-riding. P Retail price, w Wholesale price of the product, d_i Demand of the channel i , a Market base or potential demand of channel, θ_i price sensitivity for the own channel, where $\theta_i \in (0,1)$ s_i The pre-sales service level of the channels, c_i The channel's service cost incurred by providing service level s_i , β_i The degree of free-riding, where $\beta_i \in [0,1]$, h The fraction of revenue-sharing paid by the manufacture, where $h \in [0,1]$. $c_1 = m_1 s_1^2 / 2$, $c_2 = m_2 s_2^2 / 2$; The traditional channel retailer's and the manufacturer's online channel demand function are follow : $d_1 = a_1 - \theta_1 p_1 + (1 - \beta_1)s_1 + \beta_2 s_2$; $d_2 = a_2 - \theta_2 p_1 + \beta_1 s_1 + (1 - \beta_2)s_2$; Their profits functions are follow:

$$\pi_r = (p_1 - w)(a_1 - \theta_1 p_1 + (1 - \beta_1)s_1 + \beta_2 s_2) - c_1; \pi_m = w(a_1 - \theta_1 p_1 + (1 - \beta_1)s_1 + \beta_2 s_2) + p_2(a_2 - \theta_2 p_1 + \beta_1 s_1 + (1 - \beta_2)s_2) - c_2$$

For the sake of simplicity, we assume that the unit production cost of the products is zero. Also, we assume $a_1 = a_2$ $p_1 = p_2$.

4. Without revenue-sharing

In this setting, the sequence of events is as follows. The manufacturer and retailer first decides the sets their service level. Observing the service level of the retailer, the manufacturer determines the wholesale price w . Finally, the retailer sets his traditional channel price p_1 to maximize his profit. The reasons that such sequence of events is used are two aspects. (i) Service level contract and retail pricing decision are separable in reality. (ii) Similar sequence of events was employed by many researchers, such as Sheu (2011), Xiao et al. (2014) and Zhou et al. (2016).

Proposition 1. For given w and (s_1, s_2) , the retailer optimal strategy is as follow:

$$p_1 = \frac{a + \beta_2 s_2 + \theta_1 w + s_1(1 - \beta_1)}{2\theta_1}; \quad d_1 = \frac{a + \beta_2 s_2 - \theta_1 w + s_1(1 - \beta_1)}{2}$$

Proposition 2. For given (s_1, s_2) , the manufacturer know the retailer's optimal pricing strategy, and determines his optimal w , d_2 is as follow:

$$w = \frac{\theta_1(2a + s_1 + s_2) - \theta_2(a + s_1 - \beta_1 s_1 + \beta_2 s_2)}{\theta_1(2\theta_1 + \theta_2)}; \quad d_2 = \frac{\theta_1(4a + 4\beta_1 s_1 + 4s_2 - 4\beta_2 s_2) - \theta_2(2a + 3s_1 - 4\beta_1 s_1 - s_2 + 4\beta_2 s_2)}{2(2\theta_1 + \theta_2)}$$

Proposition 3. The manufacturer and the retailer determine their optimal services level to pursue maximizing their profits are as follow:

When $\frac{(\theta_1 + 2\theta_2 - 2\beta_1\theta_1 - 2\beta_1\theta_2)^2}{2\theta_1(2\theta_1 + \theta_2)^2} < m_1$ and $4\beta_2^2(\theta_1 + \theta_2) + 2m_2\theta_1(2\theta_1 + \theta_2) > (1 + 4\beta_2)\theta_1$, we have

$$(s_1, s_2) = \frac{a(2\beta_2 + 2m_2\theta_2 - 1)(\theta_1 + 2\theta_2 - 2\beta_1\theta_1 - 2\beta_1\theta_2)}{\Delta_1} \quad s_2 = \frac{[-a(4\theta_1 + 4\theta_2)\beta_1^2 + a(4\theta_1 + 6\theta_2)\beta_1 - a\beta_2(4m_1\theta_2^2 + 8m_1\theta_1\theta_2)] - a(\theta_1 + 2\theta_2 - 8m_1\theta_1^2 - 4m_1\theta_1\theta_2)}{\Delta_1}$$

$$\Delta_1 = 4m_1(2\theta_1^2 + 3\theta_1\theta_2 + \theta_2^2)\beta_2^2 + (2 - 4m_2(\theta_1 + \theta_2))(\theta_1 + \theta_2)\beta_1^2 + (\beta_1(2\theta_1 + 2\theta_2) - 2\theta_2 - \theta_1 - 4m_1\theta_1(2\theta_1 + \theta_2))\beta_2 + \beta_1(4m_2\theta_1^2 + 12m_2\theta_1\theta_2 - 3\theta_1 + 8m_2\theta_2^2 - 4\theta_2) - m_2(\theta_1 + 2\theta_2)^2 + 8m_1m_2\theta_1^2(\theta_1 + \theta_2) - m_1\theta_1(2\theta_1 + \theta_2 - 2m_2\theta_2^2) + \theta_1 + 2\theta_2$$

Property 1. p_1, d_1 decrease with $\beta_1 \in [0,1]$ and increase with $\beta_2 \in [0,1]$; while w, d_2 increase with $\beta_1 \in [0,1]$ and decrease with $\beta_2 \in [0,1]$.

Property 1. indicates the retailer's pricing and demand decrease with the degree of own channel

free-riding, and increase with the degree of other channel free-riding; so do the manufacture's pricing and demand. It is show that when own channel free-riding increase, more customers can get much more utility to move other channel.so in order to obtain more market demand, they will have incentives to deduce their pricing to compensate the loss incurred by free-riding.

Property 2. $\partial''\pi_r / \partial\beta_1^2 > 0$ $\partial''\pi_m / \partial\beta_2^2 < 0$ $\partial''\pi_r / \partial\beta_2^2 > 0$ $\partial''\pi_m / \partial\beta_1^2 < 0$.

It is an interest conclusion the retailer does not exist the optimal free-riding level, but the manufacture exist. Form the leader manufacture perspective, he will select a optimal free-riding (β_1, β_2) level to obtain free-riding' profits. The follow retailer will get much more profits incurred by free-riding and will provide worse services to relieve profits loss. So as a leader manufacture, he is willing to expand their market share to obtain much more profits and will have the responsibility to protect and support his physical stores. We investigate the coordination of the retailer channel and online channel in follow sections

5. With revenue-sharing

In this section, we investigate retail and online channel optimal strategies under revenue sharing contract. In order to incentive to retailer provide fist-rate services, the manufacture shares his profits to retailer $h\pi_m$.The sequence of events is the same as the without revenue-sharing. Their profits functions are as follow:

$$\pi_r = (1+h)(p_1 - w)(a_1 - \theta_1 p_1 + (1-\beta_1)s_1 + \beta_2 s_2) - c_1 + h(p_2(a_2 - \theta_2 p_1 + \beta_1 s_1 + (1-\beta_2)s_2) - c_2)$$

$$\pi_m = (1-h)(w(a_1 - \theta_1 p_1 + (1-\beta_1)s_1 + \beta_2 s_2) + p_2(a_2 - \theta_2 p_1 + \beta_1 s_1 + (1-\beta_2)s_2) - c_2)$$

Proposition 4. For given w and (s_1, s_2) , under revenue sharing ,which the retailer optimal strategy is as follow:

$$p_1 = \frac{h(a + \beta_1 s_1 - s_2 \beta_2 + s_2) + (h+1)(a + \beta_2 s_2 + \theta_1 w - s_1 \beta_1 + s_1)}{2h\theta_2 + 2\theta_1(h+1)}; d_1 = a + \beta_2 s_2 - s_1 \beta_1 + s_1 - \frac{\theta_1 h(a + \beta_1 s_1 - s_2 \beta_2 + s_2) + \theta_1(h+1)(a + \beta_2 s_2 + \theta_1 w - s_1 \beta_1 + s_1)}{2h\theta_2 + 2\theta_1(h+1)}$$

Proposition 5. For given (s_1, s_2) , under revenue sharing ,which the manufacturer know the retailer's optimal pricing strategy, and determines his optimal w , d_2 are as follow:

$$w = \frac{(\theta_1^2(a + s_1 - \beta_1 s_1 + \beta_2 s_2) + 2\theta_2^2(a - \beta_1 s_1 + \beta_2 s_2) + \theta_1 \theta_2(a + 2s_1 - s_2 - 3\beta_1 s_1 + 3\beta_2 s_2))h^2 + (3a + 2s_1 + s_2 - \beta_1 s_1 + \beta_2 s_2)\theta_1^2 h + (a + s_1 - \beta_1 s_1 + \beta_2 s_2)(h-1)\theta_1 \theta_2 + (2a + s_1 + s_2)\theta_1^2}{\theta_1^2(h+1)(2\theta_1 + \theta_2 + 2h\theta_1 + 3h\theta_2)}$$

$$d_2 = \frac{(4(a + s_2 + \beta_1 s_1 - \beta_2 s_2)\theta_1^2 - 2(a + s_1 - \beta_1 s_1 + \beta_2 s_2)\theta_2^2 + (a - 3s_1 + 4s_2 + 7\beta_1 s_1 - 7\beta_2 s_2)\theta_1 \theta_2)h + 4(a + s_2 + \beta_1 s_1 - \beta_2 s_2)\theta_1^2 - (2a + 3s_1 - s_2 - 4\beta_1 s_1 + 4\beta_2 s_2)\theta_1 \theta_2}{2\theta_1(2\theta_1 + \theta_2 + 2h\theta_1 + 3h\theta_2)}$$

Proposition 6. Under revenue sharing the manufacturer and the retailer determine their optimal services level to pursue maximizing their profits are as follow: when

$$\Delta_2 = [\theta_1^3(h+1)^3 - \beta_1^2(\theta_1^3(7h^3 + 11h^2 - 4) + \theta_1^2\theta_2(31h^3 + 32h^2 - 8h - 8) + 4\theta_2^2\theta_1(11h^3 + 7h^2 - 2h - 1) + 4h^2\theta_2^3(5h+2))$$

$$- \beta_1(\theta_1^2\theta_2(-42h^3 - 46h^2 + 8h + 12) + \theta_2^2\theta_1(-68h^3 - 48h^2 + 16h + 8) - 8h^2\theta_2^3(5h+2) - 2\theta_1^3(5h-2)(h+1)^2)$$

$$+ \theta_2^2\theta_1(-24h^3 - 20h^2 + 8h + 4) - 4h^2\theta_2^3(5h+2) - 2m_1\theta_1^2(h+1)(2\theta_1 + \theta_2 + 2h\theta_1 + 3h\theta_2)^2 - \theta_1^2\theta_2(7h-4)(h+1)^2] < 0$$

$$\Delta_3 = [4(h-1)((h^2 + 2h + 1)\theta_1^3 + 2\theta_1^2\theta_2(3h^2 + 4h + 1))m_2 + (\theta_1^2(-h^2 + 4h + 4) - 4h^2\theta_2^2 + 4\theta_1\theta_2(-h^2 + h + 1))\beta_2^2 - \theta_1^2(4h^2 + 4h + 1) + (4h^2\theta_1\theta_2 - 2\theta_1^2(-2h^2 + h + 2))\beta_2] < 0$$

we have

$$\begin{aligned} s_1^* = & -\theta_2^2(h^3(4\beta_2 - 14) + h^4(8\beta_2 - 10) - 4h^2 + \theta_1(44m_2h^4 + 72m_2h^3 + 20m_2h^2 - 12m_2h - 4m_2)) - \theta_2^3(20m_2h^4 + 28m_2h^3 + 8m_2h^2) - \theta_1^3(7m_2h^4 + 18m_2h^3 + \\ & 11m_2h^2 - 4m_2h - 4m_2) - \theta_1^2((3\beta_2 - 6)h^4 + (2\beta_2 - 11)h^3 + (-3\beta_2 - 4)h^2 + (3 - 2\beta_2)h + 2) - \theta_2((24h^2m_2 - 16hm_2 - 8m_2 + 63h^3m_2 + 31h^4m_2) - \theta_1^2 + (h^4(10\beta_2 - 16) \\ & - h^2(4\beta_2 + 6) + h^3(6\beta_2 - 24) - h(2\beta_2 - 6) + 2)\theta_1) / a(\beta_1(3h^4 + 8h^3 + 7h^2 + 2h)\theta_1^3 + (11h^4 + 25h^3 + 14h^2 - 4h - 4)\theta_1^2\theta_2 + (24h^4 + 44h^3 + 12h^2 - 12h - 4)\theta_1\theta_2^2 \\ & + (20h^4 + 28h^3 + 8h^2)\theta_2^3) - \theta_2^2(20h^4 + 28h^3 + 8h^2) + \theta_1^2(7h^4 + 21h^3 + 21h^2 + 7h) + \theta_1^2\theta_2(7h^4 + 10h^3 + h^2 + 2) - \theta_1\theta_2^2(14h^4 + 30h^3 + 8h^2 - 12h - 4))m_2 \\ s_2^* = & -a(\theta_1^2(12h^4 + 42h^3 + 56h^2 + 34h + 8) - \beta_2((6h^4 + 16h^3 + 14h^2 + 4h)\theta_1^3 + (9h^4 + 26h^3 + 35h^2 + 26h + 8)\theta_1^2\theta_2 + (-8h^4 - 4h^3 + 20h^2 + 20h + 4)\theta_1\theta_2^2 \\ & - (12h^4 + 416h^3 + 4h^2)\theta_2^3) + \theta_1^2\theta_2(14h^4 + 43h^3 + 50h^2 + 25h + 4) - \theta_1\theta_2^2(6h^4 + 8h^3 + 2h^2))m_1 + \theta_2^2(10h^4 + 14h^3 + 4h^2) + \beta_1^2((12h^4 + 22h^3 + 8h^2 - 6h - \\ & 4)\theta_1^2 + (32h^4 + 48h^3 + 12h^2 - 12h - 4)\theta_1\theta_2 + (20h^4 + 28h^3 + 8h^2)\theta_2^3) - \beta_2(\theta_1^2(h^4 + 5h^3 + 7h^2 + 3h) - \beta_1((5h^4 + 12h^3 + 11h^2 + 4h)\theta_1^2 + (14h^4 + 18h^3 \\ & + 4h^2 - 2h)\theta_1\theta_2) / (\theta_1^2(h^4 + 4h^3 + 6h^2 + 4h + 1) - \theta_2^2(20h^4 + 28h^3 + 8h^2) + \beta_1((18h^2 - 2h + 26h^3 + 10h^4 - 4)\theta_1^3 + (38h^2 - 20h + 88h^3 + 42h^4 - 12)\theta_1^2\theta_2 \\ & + (32h^2 - 24h + 116h^3 + 68h^4 - 8)\theta_1\theta_2^2 + (16h^2 + 56h^3 + 40h^4)\theta_2^3) - \beta_1^2((11h^2 - 4h + 18h^3 + 7h^4 - 4)\theta_1^3 + (24h^2 - 16h + 63h^3 + 31h^4 - 8)\theta_1^2\theta_2 \\ & + (20h^2 - 12h + 72h^3 + 44h^4 - 4)\theta_1\theta_2^2 + (8h^2 + 28h^3 + 20h^4)\theta_2^3) - m_1((32h + 48h^2 + 32h^3 + 8h^4 + 8)\theta_1^4 \end{aligned}$$

we have the optimal services level (s_1^*, s_2^*) , and (s_1^*, s_2^*) are the function of revenue-sharing rate, price sensitivity, the degree of free-riding and so on.

Property 3. p_1, d_1 decrease with $\beta_1 \in [0,1]$ and increase with $\beta_2 \in [0,1]$; while w, d_2 increase with $\beta_1 \in [0,1]$ and decrease with $\beta_2 \in [0,1]$.

Property 4. $\partial^2 \pi_r / \partial \beta_1^2 > 0$ $\partial^2 \pi_m / \partial \beta_2^2 < 0$ $\partial^2 \pi_r / \partial \beta_2^2 > 0$ $\partial^2 \pi_m / \partial \beta_1^2 < 0$

The property 3,4 are the same as the property 1,2, and this is indifferent with our intuition.

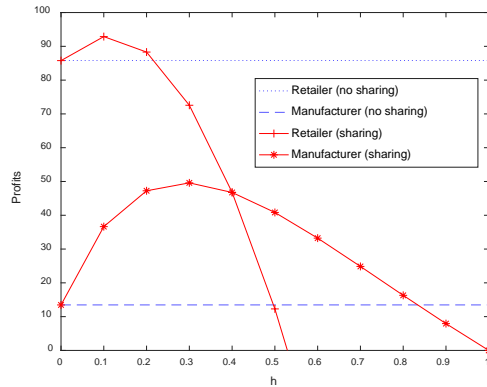


Fig. 1 varying revenue-sharing rate

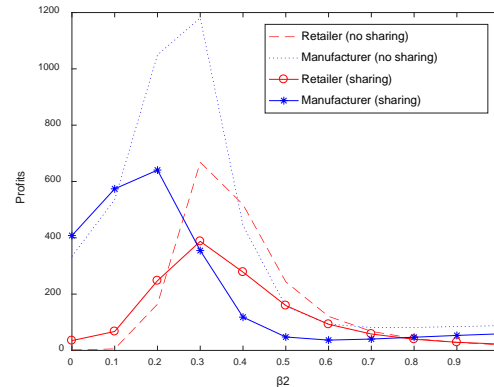


Fig. 2 varying free-riding level (manufacturer)

Based on Fig.1, both them negotiate the revenue-sharing rate for the channel coordination strategy. This means that, compared with the no revenue-sharing, the revenue-sharing contract can result in both partners obtaining more profits. Thus, we can obtain the feasible revenue-sharing rate for both them, which we denote as $[h_{\min}, h_{\max}]$. Both firms can negotiate the revenue-sharing rate during the feasible interval based on their bargaining power. Fig.2 indicate whichever scenario their profits first increase and then decrease with manufacturer's free-riding level, but is less related to retailer's free-riding level.

6. Conclusion

The main results in this paper are the following. (i) Under the non-differential pricing scenario, retailer do not exist the optimal free-riding level, but the manufacturer always have the optimal free-riding level. The results are just reversed our intuition. (ii) Under each of the two pricing scenarios, the revenue-sharing contract can effectively stimulate the retailer to improve his service level while free riding occurred. (iii) Even if under the revenue-sharing contract, free riding has always a negative effect on the retailer's profit. In reality, the manufacturer often does not know the information of the retailer's service effort cost. So considering the asymmetric service-cost information is also a good extension to our paper.

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