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Research on a preannounced pricing policy in a two-period dual-channel supply chain

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Abstract. The development of the e-commerce and the fast update of the product have an incentive to widespread attempts at multi-channel with multi-period sales. Prior studies have been mainly focused on revenue management issue in a multi-period traditional channel or a single-period multi-channel. This paper extends these studies by exploring the issue in a multi-period multi-channel context. We propose a two-period dual-channel supply channel model, where the manufacturer sells its product in each period through its direct channel and an independent retail channel. Both channels implement preannounced pricing. The results show that the selling prices of both channels in the first period is higher than those in the second period, and the price rate of change in the retail channel is higher than that in the direct channel. It implies that the manufacturer adopts a deeper discount in the direct channel than the retailer does in the retail channel. The numerical analysis reveals that the impact of channel substitutability on the price rate of change in the retail channel is more significant than the direct channel. In addition, the channel substitutability is harmful for the retailer and the manufacturer.

Keywords: Dual-channel supply chain, Preannounced pricing, Game theory.

1 Introduction

Due to the rapid development of economy and technology, products update speed gets faster and the product life cycle increasingly becomes shorter. More products are being sold in multi-period instead of single-period. Therefore, multi-period pricing has drawn attention to researchers and practitioners, among which preannounced pricing is one of the most popular pricing methods. Preannounced pricing represents that the firm announces the future market prices to consumers before the selling period [1]. In practice, preannounced pricing is common in industry applications, such as Costco, Sam's Club and Filene's Basement. The issue of preannounced pricing usually arises from literature on strategic consumer, where the pricing policy can mitigate strategic waiting behavior [2-4]. In contrast to prior studies, this paper considers the seller's perspective and aims to explore the impact of the preannounced pricing on the dual-channel supply chain.

The development of e-commerce increasingly encourages the manufacturer to introduce a direct online channel besides a traditional retail channel. A data shows that the number of online shopping users in China has reached 782 million by December 2020. Hence, adding an online channel helps the manufacturer to increase the consumer traffic. Meanwhile, such a strategy also adds the channel's flexibility. For instance, consumers can buy product online and pick up in store to examine the fit and quality [5], read the online reviews and purchase in physical store [6], or buy online and return in physical store or online [7]. Therefore, adopting dual-channel increases the consumer loyalty and satisfaction. Although a substantial body of literature discusses the dual-channel performance, they ignore a critical issue of a multi-period selling, which is filled the gap in this paper.

We develop a two-period dual-channel model, where the manufacturer sells its product via both manufacturer's direct channel and an independent retail channel to end market in two periods. The manufacturer adopts a static wholesale price and a preannounced pricing plans in two-period model. In the first period, both players announce the selling prices of both direct channel and retail channel to the market. We use a two-period Stackelberg game between the manufacturer and the retailer to derive a unique Stackelberg equilibrium, and find that the retail price and the direct channel price in the first period is higher than those in the second period. Meanwhile, the price rate of change in the retail channel is higher than that in the direct channel, implying that the manufacturer provides a deeper discount for consumers in the direct channel than the retailer does in the retail channel.

This paper is organized as follows. The related literature is reviewed in Section 2. Section 3 analyzes the model and a sensitivity analysis is presented in Section 4. Conclusion is presented in Section 5.

2 Literature review

The research on dual-channel has been a hot topic from different aspects. One of the most focused research is competition between direct channel and retailer channel, including price competition [8], inventory competition [9] and service competition [10], and others. However, this competition relationship between chains inevitably brings new challenge. The introduction of direct channel may harm the benefits of manufacturer or retailer, and thus the total supply chain [11]. As a result, some researchers embark study various coordination mechanism to mitigate the channel conflict, such as revenue-sharing contract [12], quantity discount contract [13] and buyback contract [14]. Based on prior studies that mostly focus on a dual-channel supply chain in a single period, this paper extends their investigation by considering a multiple- period selling.

The literature on pricing strategy in multi-period operations management is mainly based on preannounced pricing. Stokey [1] was the first to discuss the preannounced pricing in multiple periods when consumers are rational. Aviv and Pazgal [2] compare preannounced pricing with dynamic pricing, and find that the former outperforms the latter with revenue improvement up to 8.32% when consumers are strategic. Correa et al. [4] use a gradient-based method to solve a class of preannounced pricing policies

where the price path depends on the available inventory. Mersereau and Zhang [15] propose a robust pre-announced pricing policy, where the proportion of strategic consumers is uncertain. Different from these literatures that investigate the preannounced pricing in a single echelon or a traditional supply chain, this paper explores the impact of preannounced pricing on the multi-channel environment.

3 Model Analysis

We consider a two-period dual-channel supply chain, where the manufacturer sells its product through its own direct channel and an independent retail channel in each period. A two-period model could be applied by industry practices. For instance, Apple sells the two latest generations of products on official channels and the selling period of each generation iPhone is about two years. Let D_{jt} and p_{jt} denote demand and price of the j channel in period t , where $t = \{1, 2\}$ and $j = \{r, m\}$. Here r and m denote retail channel and direct channel, respectively. To characterize demand functions of the two channels in each period, we use a utility function of a representative consumer, which has been widely utilized in the field of marketing and operations management [16-18]. The utility function contains the classical economic characteristics of diminishing marginal substitution rate and diminishing marginal utility, and the representative consumer setup is better than the Hotelling model where the consumers have a preference heterogeneity. Based on these literatures, we present the representative consumer utility in the first period as

$$U_1 = D_{1r} - \frac{D_{1r}^2}{2} + D_{1m} - \frac{D_{1m}^2}{2} - \delta D_{1r} D_{1m} - (p_{1r} D_{1r} + p_{1m} D_{1m}), \quad (1)$$

where δ ($0 \leq \delta < 1$) denotes channel substitutability, namely, the competition between retail channel and direct channel. A larger δ indicates more intense competition between the two channels. Maximizing Eq. (1) with respect to D_{1r} and D_{1m} gets

$$\begin{aligned} D_{1m} &= \frac{1}{1+\delta} + \frac{\delta p_{1r}}{1-\delta^2} - \frac{p_{1m}}{1-\delta^2}, \\ D_{1r} &= \frac{1}{1+\delta} + \frac{\delta p_{1m}}{1-\delta^2} - \frac{p_{1r}}{1-\delta^2}. \end{aligned} \quad (2)$$

Since the realized demand of the two channels in the first period are D_{1m} and D_{1r} , the utility function for a representative consumer in the second period is given by

$$U_2 = (1 - D_{1r})D_{2r} - \frac{D_{2r}^2}{2} + (1 - D_{1m})D_{2m} - \frac{D_{2m}^2}{2} - \delta D_{2r} D_{2m} - (p_{2r} D_{2r} + p_{2m} D_{2m}) \quad (3)$$

Correspondingly, the demand function for each channel in the second period is

$$\begin{aligned} D_{2m} &= \frac{\delta}{(1+\delta)^2} + \frac{(1+\delta^2)}{(1-\delta^2)^2} p_{1m} - \frac{2\delta}{(1-\delta^2)^2} p_{1r} - \frac{1}{(1-\delta^2)^2} p_{2m} + \frac{\delta}{(1-\delta^2)^2} p_{2r}, \\ D_{2r} &= \frac{\delta}{(1+\delta)^2} + \frac{(1+\delta^2)}{(1-\delta^2)^2} p_{1r} - \frac{2\delta}{(1-\delta^2)^2} p_{1m} - \frac{1}{(1-\delta^2)^2} p_{2r} + \frac{\delta}{(1-\delta^2)^2} p_{2m}. \end{aligned} \quad (4)$$

In the two-period model, the manufacturer adopts the static wholesale price strategy, i.e., the wholesale prices in two periods are set the same. This is common in practice. For example, when there is no major technological innovation in smart phones, the

wholesale price will keep unchanged in whole selling period. Without loss of generality, product cost in this paper is normalized to zero. The assumption can be relaxed easily. However, such a relaxation cannot bring substantive result. Hence, the retailer's and manufacturer's profits are obtained by

$$\Pi_r = (p_{1r} - \omega)D_{1r} + (p_{2r} - \omega)D_{2r}, \quad (5)$$

$$\Pi_m = \omega D_{1r} + p_{1m} D_{1m} + \omega D_{2r} + p_{2m} D_{2m}. \quad (6)$$

To assure the concavity of profit functions, our analysis is carried out with a reasonable assumption of $\delta \leq 0.5$ to consider a weak the substitutability between the direct channel and the retail channel in reality. For instance, with in-store shopping restricted during the COVID-19 pandemic, most consumers can purchase online to reduce human-to-human contact. On the other hand, for some high-price products, such as cars and luxury goods, consumers tend to examine the product in person at physical stores and choose their favorite style.

The sequence of events under preannounced pricing is summarized as follows. The manufacturer announces firstly all its price decisions in the first period including wholesale prices (ω) and direct channel prices (p_{1m}, p_{2m}). Then the retailer reveals all its retail prices (p_{1r}, p_{2r}). Using a backward induction approach, we can obtain the following results.

Theorem 1. The optimal wholesale price, direct channel prices and retail prices in two periods are obtained as follows:

$$\begin{aligned} \omega = \frac{1}{2}, p_{1m} = \frac{6\delta^4 + 3\delta^3 - 22\delta^2 - \delta + 12}{2(6\delta^4 - 17\delta^2 + 9)}, p_{1r} = \frac{9\delta^4 - 2\delta^5 + 6\delta^3 - 26\delta^2 - 4\delta + 15}{2(6\delta^4 - 17\delta^2 + 9)}, \\ p_{2m} = \frac{6\delta^4 - 3\delta^3 - 12\delta^2 + \delta + 6}{2(6\delta^4 - 17\delta^2 + 9)}, p_{2r} = \frac{9\delta^4 - 2\delta^5 + 4\delta^3 - 23\delta^2 - 2\delta + 12}{2(6\delta^4 - 17\delta^2 + 9)}. \end{aligned} \quad (7)$$

Proof. The Hessian matrix of (5) is negative definite because $\frac{\partial^2}{\partial p_{1r}^2} \Pi_r = \frac{\partial^2}{\partial p_{2r}^2} \Pi_r = \frac{2}{\delta^2 - 1} < 0$ and $\Delta_2 = \frac{3\delta^4 - 10\delta^2 + 3}{(1-\delta)^4(1+\delta)^4} > 0$ (note $\delta \leq 0.5$). Therefore, the retailer's profit function is jointly concave in (p_{1r}, p_{2r}) . Solving the first order necessary conditions for optimality, that is $\frac{\partial \Pi_r}{\partial p_{1r}} = 0$ and $\frac{\partial \Pi_r}{\partial p_{2r}} = 0$, we get the reaction function as

$$\begin{aligned} p_{1r} = \frac{(2p_{1m} - p_{2m} - 1)\delta^5 + 3\omega\delta^4 + 6(1 - p_{1m})\delta^3 - (6 + 4\omega)\delta^2 + (p_{2m} - 1)\delta + 2 + \omega}{3\delta^4 - 10\delta^2 + 3}, \\ p_{2r} = \frac{(2p_{2m} - p_{1m} - 1)\delta^5 + 3\delta^4 + 4(p_{1m} - p_{2m})\delta^3 - (4 + 6\omega)\delta^2 + (-3p_{1m} + 2p_{2m} + 1)\delta + 1 + 2\omega}{3\delta^4 - 10\delta^2 + 3}. \end{aligned} \quad (8)$$

Substituting (8) into (6), we still find that the profit function of the manufacturer is joint concave in (ω, p_{1m}, p_{2m}) . Hence, there is a unique optimal solution for the wholesale price and direct channel prices, which is given by Theorem 1.

Correspondingly, substituting (7) into (5) and (6), the manufacturer's and the retailer's profits are given by

$$\Pi_m = \frac{4\delta^4 + 12\delta^3 - 29\delta^2 - 8\delta + 18}{4(6\delta^4 - 17\delta^2 + 9)}, \Pi_r = \frac{(1 - \delta^2)(3\delta^4 - 7\delta^2 + 3)(3 - 2\delta)^2}{4(6\delta^4 - 17\delta^2 + 9)^2}. \quad (9)$$

Based on Theorem 1, we discuss the comparison of the first-period equilibria and the second-period equilibria as follows, where the price rate of change (ROC) in two channels are defined as $\frac{p_{2r} - p_{1r}}{p_{1r}}$ in the retail channel and as $\frac{p_{2m} - p_{1m}}{p_{1m}}$ in the direct channel.

Corollary 1. (1) the retail price and the direct channel price decrease over time; (2) ROC in the retail channel is higher than that in the direct channel.

Proof. Since $\delta \leq 0.5$, $p_{1r} - p_{2r} = \frac{(1-\delta^2)(3-2\delta)}{2(6\delta^4-17\delta^2+9)} \geq 0$, $p_{1m} - p_{2m} = \frac{(\delta-1)(3\delta^2-2\delta-3)}{6\delta^4-17\delta^2+9} \geq 0$;

$$\frac{p_{2r}-p_{1r}}{p_{1r}} - \frac{p_{2m}-p_{1m}}{p_{1m}} = \frac{(\delta-1)(12\delta^7-50\delta^6-12\delta^5+169\delta^4-33\delta^3-171\delta^2+27\delta+54)}{(6\delta^4+3\delta^3-22\delta^2-\delta+12)(2\delta^5-9\delta^4-6\delta^3+26\delta^2+4\delta-15)} \geq 0.$$

Corollary 1 indicates that the retailer and the manufacturer set higher retail price and direct channel price in the first period than they do in the second period, which means that the ROC in both channels are negative. Moreover, the ROC in the retail channel is higher than that in the direct channel, which suggests that the direct channel provides a deeper discount than the retail channel.

4 Sensitivity Analysis

We investigate the impact of channel substitutability (i.e., δ) on: (1) retail prices and direct channel prices in two periods; (2) the price rate of change in two channels; (3) the profits of the retailer and the manufacturer.

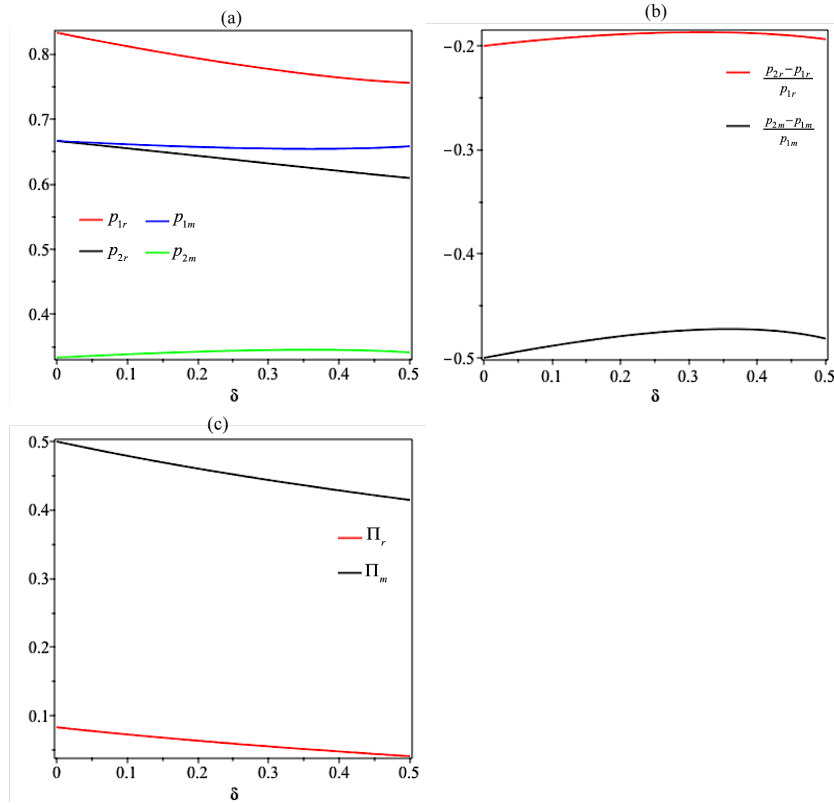


Fig. 1(a)-(c). Impact of channel substitutability.

Fig. 1(a) shows that when the channel substitutability increases, the retail prices in two

periods decrease, while the first-period (second-period) direct channel price first decreases (increases) and then increases (decreases). The selling prices of both channels in the first period are higher than those in the second period, which is consistent with Corollary 1(1). The result leads to the ROCs of both channels are negative as shown in **Fig. 1(b)**, which means that the discount in the direct channel is deeper than that in the retail channel. The impact of the channel substitutability on the ROCs in both channels is not monotonic. The ROCs first increase and then decrease as the competition between retail channel and direct channel becomes more intense. In other words, the retailer and the manufacturer adopt the same pace of discount policies to make profits. The channel substitutability has more significant effect on the retail channel than the direct channel because the impact degree of the channel substitutability on the retail channel is higher than that on the direct channel. Finally, the fierce competition is harmful for the players' profits as shown in **Fig. 1(c)**. Correspondingly, we can get that the competition between the two channels has a negative impact on the total profit of dual-channel.

5 Conclusion

This paper investigates a two-period dual-channel supply chain where the manufacturer's products are sold via a dual-channel in each period. We develop a two-period model, and analyze a leader-follower game framework for each period, where the manufacturer determines his wholesale price and direct channel price and the retailer then decides on her retail price. The results derive a unique Stackelberg equilibrium for each period. The finding reveals that the retail price and the direct channel price decrease over time and that the ROC in the retail channel is higher than that in the direct channel. The impact of channel substitutability on the retail channel is higher than that on the direct channel.

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