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Pricing strategy for B&M store in a dual-channel supply chain based on hotelling model

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ABSTRACT

We use hotelling model to analyse store brands as a strategy for B&M (brick-and-mortar) retailers to combat showrooming. We investigate how national-brand product mismatch and store-brand awareness affect supply chain's performance. We reach four major conclusions. First, store-brand strategy may be an effective means for B&M stores to mitigate showrooming. However, it's better to introduce premium store brands. Second, the B&M store's profit grows – and the online store's profit declines – as national-brand product mismatch increases in breadth. When many consumers feel the national-brand product does not match their needs, a product positioning strategy for the store brand can help B&M retailers improve profit margins. Third, as national-brand product mismatch increases in depth, the B&M store's profit rises and online store's profit falls. If national-brand products lack many features that consumers need, a product differentiation strategy can be implemented to use store brands to fill in the gaps left by national brands. Finally, the growth of store-brand awareness will not necessarily benefit the B&M store. The impact of store-brand awareness on the B&M store's profit depends on the hassle cost factor *t*, and a brand promotion strategy will reduce the loss of B&M retailer's profit.

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Showrooming; store-brand strategy; hotelling model; pricing theory; retail supply chain

1. Introduction

With the rise of smartphones and digital information, more and more consumers are searching for products online. Showrooming is a form of free-riding by consumers. They visit a B&M store to examine the products, but then they complete their purchases through an online store in order to benefit from a lower retail price, time-saving logistics, convenient return services, and so on (Bell, Gallino, and Moreno 2015; Li, Zhang, and Dan 2019). According to the China Consumer Market Analysis Report (2017), the annual growth rate of online retail sales in 2015 was 53%, and 47% of this growth came from the conversion of offline channel sales.[1] A survey from Accenture shows that nearly two-thirds (63%) of Canadian consumers engage in 'showrooming'.[2] Thus, whether in China or elsewhere in the world, consumers may visit a B&M store with no intention of making a purchase.

When showrooming occurs, the switch from the offline to the online purchase channel causes physical stores to lose potential customers. Hubert Joly, Executive Chairman and former CEO of Best Buy (one of the largest chains of B&M stores in North America), said that many consumers expected Best Buy to shut down due to the growth of showrooming. It is a huge challenge for B&M stores to combat the ongoing negative impact of showrooming.

Previous studies (e.g. Bell, Gallino, and Moreno 2015; Zhou, Guo, and Zhou 2018; Chen and Chen 2019) have examined some effective strategies, such as price-matching and omnichannel marketing, to help physical stores recapture market share. However, we find that store-brand strategy may be another powerful weapon in the hands of B&M retailers resisting the adverse impact of e-commerce, especially in the field of food product. Store brand (SB) product, usually contrasted with national brand (NB) product, is defined as a good or service sold by a B&M retailer with a private label.

For example, Hema, a well-known fresh food store owned by Alibaba, recently developed a SB product called 'Hema Fresh Rice', which is made from excellent rice variety and adopts cold storage technology to ensure the freshness. In spite of a high up-front cost, its sales in the three-month period have increased by more than 57%.

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For another example, Uchida Shinji, the chairman of China's 7-Eleven convenience store, said: 7-Eleven is not worried about the shock of e-commerce, because 50% of its sales come from its store brand. And food product accounts for most of the store-brand sales. It is said that it takes about 4–6 months for 7-Eleven to turn an idea to a PB product on shelves. Although it costs much upfront time and effort, store brand brings huge profits for 7-Eleven and becomes one of its most important competitiveness. Showrooming is made possible by the homogeneity of products sold both online and offline. It is not possible if the product that interests the consumer is sold only at physical stores. Hence, a major research issue in this paper is whether the negative effects of showrooming can be mitigated by the implementation of a store-brand strategy.

In addition, several factors may have decisive influences on the successful introduction of store brands. For example, understanding the product mismatch of existing national brands is of great help when implementing store-brand strategy. Product mismatch, the failure of brand to deliver a product that matches consumer expectations, can be relatively easily observed as B&M stores usually have first-hand information of consumer's preferences. Brand awareness, the familiar and willing to buy the product, is another factor that has strong positive association with the purchase decision and corporate profits. In 2005, Procter & Gamble was willing to acquire Gillette for $ 57 billion because of Gillette's high brand awareness among consumers, although Gillette had an accounting book value of only $ 2 billion in earnings and $ 11 billion in revenue at that time. Brand awareness is a crucial consideration for a newly introduced store brand, especially when the presence of competing national brand is taken into account. Hence, we pose the following research questions:

(1) Can the implementation of a store-brand strategy enable B&M stores to increase profit, mitigating the effect of showrooming?
(2) What pricing strategy should B&M stores adopt when introducing store brands as a means to combat showrooming?
(3) How do national-brand product mismatch and store-brand awareness affect the B&M and online stores' pricing, profit and demand?

Our study contributes to existing literature on store brands and showrooming. It presents a systematic examination of how a store-brand strategy can effectively combat showrooming. We propose a premium store-brand strategy for B&M stores to mitigate the adverse effects of showrooming. Then we develop pricing strategies that online and offline stores can use when introducing store brands. Against this background, we define two discrete dimensions of product mismatch – breadth and depth – and investigate their effects on the performance of the supply chain. Then we broaden the model to include store-brand awareness, and we analyse its effect on store-brand strategy. Finally, to assist B&M retailers in effectively implementing a store-brand strategy, we propose specific measures regarding product positioning, product differentiation and brand promotion.

The remainder of the paper is structured as follows. Section 2 reviews relevant antecedent work. In Sections 3 and 4, we develop the model framework and study the null case in which showrooming is practiced but the B&M retailer does not introduce a store brand. Section 5 examines the effectiveness of the store-brand strategy and develops pricing strategies for the two members of the supply chain. In this section, we also investigate the effect of national-brand product mismatch. In Section 6, we extend the model to include store-brand awareness and analyse how this affects the performance of the supply chain. Section 7 concludes the paper and suggests avenues for future research. All proofs are provided in the Appendix.

2. Literature review

Our work draws on three related research streams, namely (1) store brand, (2) brand awareness, and (3) showrooming in a dual-channel supply chain.

2.1. Store brand

The literature on store brands related to our study includes research on the introduction of store brands and of premium store brands. Verhoef, Nijssen, and Sloot (2002) conduct a questionnaire survey to investigate the strategies used by NB manufacturers facing competition from store brands in the Netherlands. Their results suggest that NB manufacturers should improve their advertising and product innovation in order to resist the store-brand strategies of B&M retailers. Kurata, Yao, and Liu (2007) study pricing strategies in dual distribution channels where national brands and store brands compete. They also examine the effects of key marketing activities on the equilibrium price. Groznik and Heese (2010) find that the introduction of a store brand increases the retailer's bargaining power, leading the NB manufacturer to offer a discount on the wholesale price. Premium store brands, which are usually similar to or even higher in quality than the national brands, have proliferated in recent years. Some of them are more in line with consumer demand, thus enabling B&M retailers

to compete directly with the national brand (Geyskens, Gielens, and Gijsbrechts 2010; Hara and Matsubayashi 2017). Ter Braak, Geyskens, and Dekimpe (2014) find that retailers are more likely to introduce premium store brands in categories with more frequent promotions, a longer interpurchase time, a higher need for variety, and higher functional, but lower social, risk. Schnittka (2015) finds that premium store brands are more beneficial for high-priced grocery stores than for low-priced ones, and more promising in product categories of high brand relevance. Hara and Matsubayashi (2017) study the introduction of a premium store brand through collaboration between a retailer and a NB manufacturer. The results indicate that both partners benefit from developing a premium store brand when store brands have relatively high value.

2.2. Brand awareness

Brand awareness is the probability that, consumers are familiar about the availability and accessibility of a company's product and service. When selecting a product or service, brand awareness plays a decisive role in a series of brands that consumers are interested in (Barreda et al. 2015). Naik, Prasad, and Sethi (2008) investigate how to build brand awareness in a dynamic oligopoly model, they develop an estimation approach and offer managers a systematic way to assess advertising effectiveness and predict awareness levels for their own brands as well as the competitors' brands. Malik et al. (2013) conduct an empirical analysis to identify the effect of brand awareness on purchase intention. They find that brand awareness has a strong positive association with purchase intention. Barreda et al. (2015) use SEM to examine the differential effects of OSN (Online Social Networks) elements (system quality, virtual interactivity, information quality, and rewards for activities) on brand awareness, which, in turn, influence WOM (Word of Mouth Marketing). The results show that building brand awareness in OSNs promotes WOM traffic. Langaro, Rita, and de Fátima Salgueiro (2018) demonstrate the positive and significant effect of users' participation on brand awareness. They also find that users' participation has a positive effect on brand attitude, but this relationship is mediated by brand awareness. Some scholars also pay attention to the store-brand awareness. Vahie and Paswan (2006) find that the B&M store quality, B&M store convenience, B&M store price/value, and the congruence between national brand and store brand have a positive effect on the affective dimension of store-brand awareness. Hsu and Hsu (2015) examine whether brand awareness and experiential perceived quality generate consumers' different brand attitudes. They find that national brands clearly possess better brand awareness than store brands do. Store brands need to overcome their disadvantages by improving product quality.

2.3. Showrooming in a dual-channel supply chain

Literature on showrooming relevant to our study includes research on the impact of showrooming and on strategies to combat it.

Many studies analyse the effects of showrooming. Balakrishnan, Sundaresan, and Zhang (2014) examine the ways in which showrooming influences competitive behaviour between online and offline stores. Their results demonstrate that with the intensification of competition, showrooming can lead to declining profits not only for B&M retailers but also for e-retailers. He, Xiong, and Lin (2016) evaluate the impact of showrooming on carbon emissions in a closed-loop dual-channel supply chain. They find that although manufacturers' online store may benefit from showrooming, total carbon emissions in the supply chain as a whole increase. Pu, Gong, and Han (2017) study showrooming in a supply chain consisting of a manufacturer's online direct channel and a traditional offline channel. Their results indicate that as the showrooming phenomenon grows, both the sales effort level of the B&M retailer and the total profit in the supply chain decrease. Setak, Kafshian Ahar, and Alaei (2017) examine how showrooming affects supply chain coordination and information-sharing between the manufacturer and the traditional retailer. Zhou, Guo, and Zhou (2018) investigate the different effects of consumers' free-riding behaviour on the pricing/service strategies and profits of supply chain members when the manufacturer's online channel and the traditional channel adopt differential or non-differential pricing scenarios.

Reflecting the generally negative attitude in both academic and management circles towards the showrooming phenomenon, an increasing body of research considers ways to reduce or eliminate its adverse impact. Basak et al. (2017) explore the viability of a B&M retailer's opening its own online channel to stem its losses. Gu and Tayi (2017) study the optimal product placement strategy allowing an online-to-offline (O2O) retailer to coordinate the two channels so as to mitigate consumer showrooming. Mehra, Kumar, and Raju (2018) propose price-matching as a short-term strategy and product exclusivity as a long-term strategy for B&M retailers to counter showrooming. They suggest that it is better to implement exclusivity through a store brand rather than a national brand when the product category has few digital attributes. Chen and Chen (2019) study the circumstances under which a B&M retailer should implement

price-matching to combat showrooming. They find that it is better for such a retailer not to adopt a price-matching strategy when the cost of online shopping is either low or high. However, when the cost is moderate, the physical store should try to match the online price. Liu, Lu, and Qi (2019) suggest that a multichannel retailer running both online and offline channels can intentionally establish a channel price gap to facilitate the switch from the offline to the online channel, thus realising significant cost savings.

To the best of our knowledge, studies that consider the use of store brands as a strategy to combat consumer showrooming are scarce. Mehra, Kumar, and Raju (2018) consider three competitive anti-showrooming strategies for B&M retailers: price- matching, product exclusivity through known brands, and product exclusivity through store brands. Our paper differs from this study in that we focus on exploring the effects of national-brand product mismatch and of store-brand awareness on the performance of the supply chain. On this basis, we design a series of specific management measures to help B&M stores mitigate the negative impact of showrooming. Thus, our study addresses a limitation in current literature and presents a systematic examination of how a store-brand strategy can effectively combat showrooming.

3. Model framework

We model a dual-channel supply chain consisting of a B&M store and an online store, in which both retailers purchase a national-brand product from the manufacturer and sell it through their own channels. Each consumer intends to purchase at most one item. We assume that the managers of the two retail outlets are both rational pursuers of profit maximisation. The retail price of the NB product in the offline channel is p_r and its price in the online channel is p_o. In addition, the B&M retailer has introduced a store-brand strategy and also sells SB products at the retail price p_a in the offline channel, as shown in Figure 1. We assume that the SB product differs horizontally from the NB product, so they have the same function value, denoted by $v(> 0)$.

As consumers have an increasing focus on store brand programmes, store brands are changing consumers' shopping behaviour these years (Ter Braak, Geyskens, and Dekimpe 2014; Hara and Matsubayashi 2017). According to data provided by Acosta (a U.S. sales and marketing company), 53% of shoppers use store brands to determine where they shop in 2017, versus 34% in 2011.[3] And this proportion is increasing year by year. When a store brand is launched at the physical store, which may be more in line with consumer expectations, consumers more tend to go to the B&M store to experience both products and make the final rational consumption. Moreover, in the traditional business setting, consumers may evaluate the quality of products by looking, touching, and feeling the products. However, for experience goods, whose quality can only be ascertained after purchase (e.g. perfume, clothing and glass), these traditional ways of searching for more information are not available online, which exposes consumers to a significant high risk. Therefore, there is a high probability that consumers choose to try out the experience products offline first to avoid the risk of direct online shopping (Luo, Ba, and Zhang 2012). Additionally, in some retail industries, such as electrical appliances and luxury goods retailings, the absence of in-person guidance and lack of 'touch & feel' in online shopping cause a very low proportion of pure online purchase (Passariello, Kapner, and Mesco 2014; Burns et al. 2018). According to the China Luxury Report 2019, 90% of survey respondents claim that in-person experiences at brand stores is the most impactful sources of information that influence purchase.[4] The pure online purchase of Luxury is still at its infancy. Therefore, we assume that consumers will go to the B&M store to experience both SB and NB products, and then decide which brand to purchase, and in which channel, so as to maximise their expected surplus.

In keeping with previous research (e.g. Tao, Gou, and Zhang 2020; Chen and Chen 2019), we use the Hotelling model to describe the competitive relationship between the online and offline channels. We consider the B&M store and online shop lie on a Hotelling line by index 0 and 1, respectively. Consumers have corresponding hassle costs when shopping in B&M store or online shop

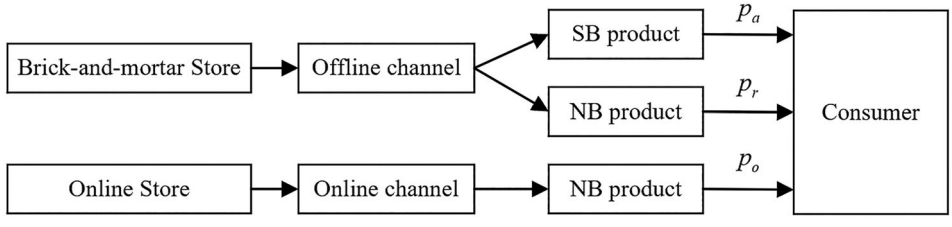

Figure 1. The model.

Table 1. Notations used in the paper.

Notations	The meanings
p_r	Price of the NB product at the B&M store
p_o	Price of the NB product at the online store
p_a	Price of the SB product at the B&M store
v	Customer perceived value of the product
t	Hassle cost factor
x	Customer's location, distance from the B&M store
α	The proportion of consumers whose best-matched product is the SB product
β	Awareness of store brand
Δ	Mismatch factor of a non-best-matching product
d_i	Demand for NB or SB product at a B&M or online store
U_i	Customer's utility
π_i	Profit of the B&M or online store

(Gao and Su 2017; Li and Wang 2019). We assume that index x shows the proportion of hassle cost of visiting B&M store and that a customer whose position is x will pay an offline hassle cost tx (e.g. travelling to the B&M store or searching for the product on shop shelves). On the other hand, if a consumer purchases online, he or she will pay an online hassle cost $t(1-x)$ (e.g. paying delivery charge or waiting for the package to arrive). We use the hassle cost factor t as the proportionality constant to scale costs. In a sense, the two kinds of hassle costs in hoteling model show consumers' different preferences for online and offline channels. As the development cost of the store brand is a sunk cost, we assume that any additional production costs with regard to SB products are normalised to zero for simplicity, as is done in many related studies (e.g. Sayman, Hoch, and Raju 2002; Mehra, Kumar, and Raju 2018). Table 1 summarises key notations in the paper.

4. Showrooming when the B&M retailer implements no strategy

For comparison, we first analyse the optimal pricing strategies when B&M retailers do not take any measures to deal with showrooming. In keeping with previous studies (e.g. Lee and Staelin 1997; Wang et al. 2019), because the B&M store and the online store are independent of each other, we apply the Nash game model. This means that the B&M retailer and the online store retailer make simultaneous decisions on retail prices to maximise their respective profits.

In the first case, the B&M retailer does not implement strategies to combat consumer showrooming. Therefore, both the B&M store and the online store sell only NB products. The utility derived by a customer who purchases at a B&M store is $U_r = v - tx - p_r$ while for a customer who practices showrooming it is $U_o = v - tx - t(1-x) - p_o$. Setting $v - tx - p_r = v - tx - t(1-x) - p_o$ and solving for x, we determine the indifference location as $x = 1 - (p_r - p_o)/t$. A customer located at $[0, x)$ will purchase the product at the B&M store; a customer located at $[x, 1]$ will purchase it at the online store.

Table 2. The equilibrium solutions of the three models.

	No strategy	Store-brand strategy	Considering store-brand awareness
p_r	$\frac{2t}{3}$	$\frac{4t-\alpha\Delta}{6}$	$\frac{4t-\alpha\beta\Delta}{6}$
p_o	$\frac{t}{3}$	$\frac{t-\alpha\Delta}{3}$	$\frac{t-\alpha\beta\Delta}{3}$
p_a	—	$\frac{4t+3\Delta-\alpha\Delta}{6}$	$\frac{4t+3\Delta-\alpha\beta\Delta}{6}$
d_o	$\frac{1}{3}$	$\frac{t-\alpha\Delta}{3t}$	$\frac{t-\alpha\beta\Delta}{3t}$
d_r	$\frac{2}{3}$	$\frac{(1-\alpha)(4t-\alpha\Delta)}{6t}$	$\frac{(1-\alpha\beta)(4t-\alpha\beta\Delta)}{6t}$
d_a	—	$\frac{(4t+3\Delta-\alpha\Delta)\alpha}{6t}$	$\frac{(4t+3\Delta-\alpha\beta\Delta)\alpha\beta}{6t}$
d_{r+a}	—	$\frac{2}{3}+\frac{\alpha\Delta}{3t}$	$\frac{2}{3}+\frac{\alpha\beta\Delta}{3t}$
π_r	$\frac{4t}{9}$	$\frac{16t^2+16t\alpha\Delta+\alpha\Delta^2(9-5\alpha)}{36t}$	$\frac{16t^2+16t\alpha\beta\Delta+\alpha\beta\Delta^2(9-5\alpha\beta)}{36t}$
π_o	$\frac{t}{9}$	$\frac{(t-\alpha\Delta)^2}{9t}$	$\frac{(t-\alpha\beta\Delta)^2}{9t}$

Therefore, the demand for the NB product at the two stores is as follows:

$$\text{B\&M store: } d_r = x = 1 - (p_r - p_o)/t \quad (1)$$

$$\text{Online store: } d_o = 1 - x = (p_r - p_o)/t \quad (2)$$

The profit of the two stores can be expressed as follows:

$$\text{B\&M store: } \pi_r = p_r d_r = p_r(1 - (p_r - p_o)/t) \quad (3)$$

$$\text{Online store: } \pi_o = p_o d_o = p_o(p_r - p_o)/t \quad (4)$$

Taking the first-order derivative of π_r with respect to p_r and the first-order derivative of π_o with respect to p_o, respectively, we obtain the optimal retail prices $p_r^N = 2t/3$ and $p_o^N = t/3$ by letting the derivatives be equal to zero.

Substituting $p_r^N = 2t/3$ and $p_o^N = t/3$ into equations (1) to (4), we determine the two stores' respective demands and profits, as shown in Table 2.

5. Showrooming when the B&M retailer implements a store-brand strategy

In the second case, the B&M retailer introduces a store brand and offers a SB product which is so similar to the NB product that the two can be substituted for each other. While the B&M store now sells both products, the online store still sells only the NB product. Consumers choose only one product, either the national brand or the store brand. Let us assume that

(1) for a proportion $\alpha(0 < \alpha < 1)$ of customers, the best-matching product is the store brand offering.

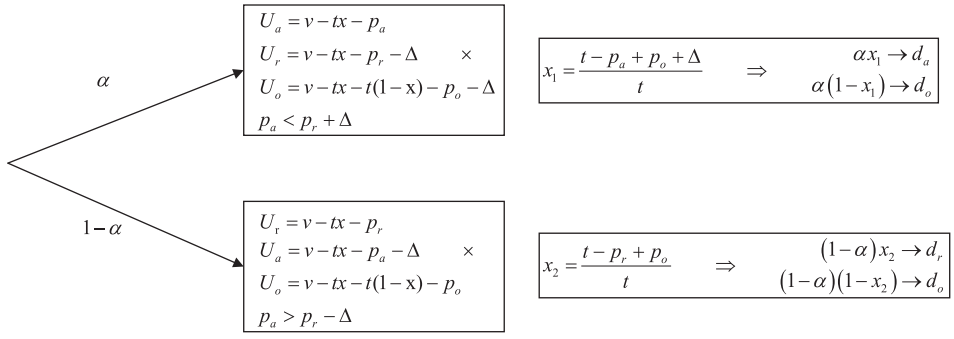

Figure 2. Customer's decision-making process under a store-brand strategy.

Hence, for a proportion $1-\alpha$ of customers, the best-matching product is the one from the national brand.

(2) the utility of any product that is not the best match is $v - \Delta$, where $0 < \Delta < v$.

A customer whose best-matching product is the store brand and who buys the SB product at the B&M store derives the utility $U_a = v - tx - p_a$. A customer with the same store-brand preference who buys the NB product at the same store derives the utility $U_r = v - tx - p_r - \Delta$. Assuming that $p_a < p_r + \Delta$, the proportion α of customers for whom the SB product is the best match will always, if they buy at the B&M store, choose to purchase the store brand, since $U_a > U_r$ always holds. On the other hand, a customer who switches to the online channel to purchase the NB product will incur two hassle costs and derive the utility $U_o = v - tx - t(1-x) - p_o - \Delta$. Setting $v - tx - p_a = v - tx - t(1-x) - p_o - \Delta$ and solving for x, we determine the indifference point $x_1 = (t - p_a + p_o + \Delta)/t$. From this discussion, we may conclude that αx_1 customers will prefer to purchase the SB product at the B&M store, while $\alpha(1-x_1)$ customers will prefer to switch channels and purchase the NB product at the online store.

A customer whose best-matching product is the national brand and who purchases it at the B&M store derives the utility $U_r = v - tx - p_r$. A customer with the same NB preference who buys the store-brand product at the same store derives the utility $U_a = v - tx - p_a - \Delta$. Assuming that $p_a > p_r - \Delta$, the proportion $1-\alpha$ of customers for whom the NB product is the best match will always, if they buy at the B&M store, choose to purchase the national brand, since $U_r > U_a$ always holds. However, a customer who purchases the NB product online derives the utility $U_o = v - tx - t(1-x) - p_o$. Setting $v - tx - p_r = v - tx - t(1-x) - p_o$ and solving for x, we determine the indifference point $x_2 = (t - p_r + p_o)/t$. From this analysis, we conclude that $(1-\alpha)x_2$ customers will buy the NB product at the B&M store, while $(1-\alpha)(1-x_2)$ customers will switch channels and purchase it at the online store. Figure 2 illustrates the customer's decision-making process in this case.

5.1. Pricing strategies when a store-brand strategy is used to combat showrooming

As the above figure shows, the demand for the SB and NB products at B&M and online stores is as follows:

$$\text{SB product demand at B\&M store: } d_a = \alpha x_1 = \alpha(t - p_a + p_o + \Delta)/t \tag{5}$$

$$\text{NB product demand at B\&M store: } d_r = (1-\alpha)x_2 = (1-\alpha)(t - p_r + p_o)/t \tag{6}$$

$$\text{NB product demand at online store: } d_o = \alpha(1-x_1) + (1-\alpha)(1-x_2) = (\alpha p_a - \alpha\Delta + p_r - \alpha p_r - p_o)/t \tag{7}$$

Accordingly, the profits of the B&M and online retailers can be expressed as follows:

$$\text{B\&M retailer's profit: } \pi_r = p_a d_a + p_r d_r = p_a \alpha(t - p_a + p_o + \Delta)/t + p_r(1-\alpha)(t - p_r + p_o)/t \tag{8}$$

$$\text{Online retailer's profit: } \pi_o = p_o d_o = p_o(\alpha p_a - \alpha\Delta + p_r - \alpha p_r - p_o)/t \tag{9}$$

To find the equilibrium solution maximising π_r and π_o, we take the first-order derivative of π_r with respect to p_r, p_a and the first-order derivative of π_o with respect to p_o, respectively. Letting the derivatives be equal to zero, we obtain:

$$\begin{cases} \partial\pi_r/\partial p_r = 0 \\ \partial\pi_r/\partial p_\alpha = 0 \\ \partial\pi_o/\partial p_o = 0 \end{cases} \tag{10}$$

From the above equations, we determine the optimal retail prices p_r^S, p_a^S and p_o^S. In addition, we verify that the optimal prices satisfy the constraint $p_r - \Delta < p_a < p_r + \Delta$. By substituting p_r^S, p_a^S and p_o^S into equations (5) to (9), we derive the B&M and online retailers' demand and profit for this case, as shown in Table 2. After obtaining the optimal prices, we discuss the rationality of the assumption on prices in the Appendix.

Proposition 5.1: *Implementing a store-brand strategy increases profit margins and demand for B&M retailers. The store-brand strategy may be an effective tool for such retailers to combat showrooming.* ■

See Appendix for the proof.

In Proposition 5.1, we know that as the B&M retailer adopts a store-brand strategy, demand for the NB product decreases in both online and offline stores, reducing the profit of the online retailer. However, for the B&M retailer, the increased demand for SB product offsets the decreased demand for the NB product, leading to growth in the retailer's overall profit. An immediate implication of this proposition is that the B&M retailer has an incentive to adopt a store-brand strategy so as to mitigate the negative effect of consumer showrooming.

Proposition 5.2: *When B&M retailers consider implementing a store-brand strategy to mitigate showrooming, it may be better for them to introduce premium (as opposed to economy or mid-range) store brands.* ■

See Appendix for the proof.

From Proposition 5.2, we know that in the B&M store, the price of the SB product is higher than that of the NB product, and that the NB product in the online store has the lowest price of the three. The reason may be that, on the one hand, overall demand is always higher for a B&M retailer than for an online retailer (see Table 2), so the online retailer tends to set a lower price for the NB product in order to attract consumers. On the other hand, when α is at a moderate or high level – meaning that the SB products are more in line with consumer expectations – demand for the SB product at the B&M store is greater than demand for the NB product. Thus, the B&M retailer may maximise profit by setting a higher price for the SB product than for the NB one. When α is at a low level, meaning that NB products are more popular than SB products, the B&M store relies mainly on the sale of NB products to make a profit. In this case, the retailer may set a higher price for the SB product to avoid price competition between its two products.

The management insight we obtain from Proposition 5.2 is that, instead of introducing a mid- to low-end store brand, the B&M retailer should consider introducing a premium store brand that better meets consumer expectations. This conclusion is consistent with some real-world observations. For example, Hema Fresh recently launched a popular store-brand product called 'Daily Fresh Milk' at a price of 19.9 yuan per carton. Contrary to the 'low price and low quality' image of store brands in the traditional retail era, this price is higher than that of most milk on the market. However, Hema promises not to sell overnight milk, guaranteeing that Daily Fresh Milk is fresher than most milk. Because 'fresher' matches consumer expectations of milk, Daily Fresh Milk has become a new benchmark for dairy products. In fact, it is common that many of Hema's SB products are more expensive than NB products. In short, a premium store-brand strategy can entice some consumers to buy store-brand products, ending their free-riding behaviour. In this way, the adverse impact of consumer showrooming on the profit of the B&M retailer is mitigated.

5.2. Effects of national-brand product mismatch

With global technology integration, product homogeneity is becoming an increasingly serious issue for marketers. It is especially important for enterprises to discover, perhaps even to guide, the new needs of consumers in today's fiercely competitive markets. When a B&M retailer considers introducing a store brand, discovering the shortcomings of existing products is a top priority. To provide analytical insight, we investigate how national-brand product mismatch (that is, failure to match consumer expectations and needs) affects pricing strategies, demand and profits in the supply chain. Like previous research (Su 2009), our study considers two discrete dimensions: the breadth of the national-brand product mismatch (i.e. α, the proportion of consumers whose mismatching product is the national brand) and the depth, or degree, of the mismatch (i.e. Δ).

Proposition 5.3: *Table 2 indicates the effect of* α *on* p, d, π.

(i) $\partial p_a^S/\partial\alpha < 0$; $\partial p_r^S/\partial\alpha < 0$; $\partial p_o^S/\partial\alpha < 0$;
(ii) $\partial d_a^S/\partial\alpha > 0$; $\partial d_r^S/\partial\alpha < 0$; $\partial d_{r+a}^S/\partial\alpha > 0$; $\partial d_o^S/\partial\alpha < 0$;
(iii) $\partial\pi_r^S/\partial\alpha > 0$; $\partial\pi_o^S/\partial\alpha < 0$. ■

See Appendix for the proof.

Proposition 5.3(i) shows that the prices of the SB and NB products at the B&M store and the price of the NB product at the online store are all negatively associated with the breadth of the national-brand product mismatch

α. This is plausible because the greater the number of consumers for whom the national-brand product fails to meet expectations, the more likely it is that the online retailer will set a lower price for the NB product in order to retain customers. The B&M store may also reduce its price for the NB product so as to match the online price. Because of price competition between the national brand and the store brand, the B&M store may also lower the price of the SB product.

Proposition 5.3(ii) shows that demand for the SB product increases with α, while demand for the NB product at both B&M and online stores decreases when α becomes greater. As the breadth of national-brand product mismatch increases, more customers switch to SB products at the B&M store, leading to increased demand for the SB product and reduced demand for the NB offering at the online store. This trend also hurts the demand for the NB product at the B&M store. However, Proposition 5.3(ii) also shows that the total demand for SB and NB products at the B&M store increases with α. This result implies that although demand for the NB product at the B&M store falls, growing demand for the SB product offsets the loss and may even result in a higher total demand.

Proposition 5.3(iii) indicates that the profit of the B&M store increases in a linear fashion with α, while the profit of the online store always declines with the growth of α. Clearly, although demand for the NB product and the prices of both SB and NB products at the B&M store all decrease as α becomes greater, the rising price of the SB product may result in increased total profit for the B&M retailer.

These observations highlight the fact that the breadth of the national-brand product mismatch α is a strategic factor affecting the performance of the supply chain. If more and more customers prefer SB products to NB products, the result is not good for the online store that sells only NB products. However, from the perspective of the B&M retailer, this is an opportunity to enhance its profits and combat consumer showrooming. Hence, the management insight for B&M retailers is to implement a product positioning strategy. These retailers have a richer set of consumer data and insights into customer preferences than do the manufacturers of NB products. Before introducing a store brand, they can scrutinise consumer market surveys, determine the degree of consumer satisfaction with NB products, and explore the market potential. Such analysis will allow the B&M retailer to identify product categories in which customer satisfaction is low, with a view to introducing SB products in these categories. In this way, the retailer can formulate a product positioning strategy that uses store brands to increase customer satisfaction and improve competitiveness.

Proposition 5.4: *Table 2 illustrates the impact of* Δ *on* p, d, π.

(i) $\partial p_a^S/\partial\Delta > 0$; $\partial p_r^S/\partial\Delta < 0$; $\partial p_o^S/\partial\Delta < 0$;
(ii) $\partial d_a^S/\partial\Delta > 0$; $\partial d_{r+a}^S/\partial\Delta > 0$; $\partial d_o^S/\partial\Delta < 0$; $\partial d_r^S/\partial\Delta < 0$, *if* $\Delta \in (0, 1/2)$, *otherwise*, $\partial d_r^S/\partial\Delta > 0$;
(iii) $\partial\pi_r^S/\partial\Delta > 0$; $\partial\pi_o^S/\partial\Delta < 0$. ■

See Appendix for the proof.

Proposition 5.4(i) indicates that the price of the SB product at the B&M store increases with Δ, while the prices of the NB product at both the B&M and online stores respond negatively to rising Δ. As the depth of national-brand product mismatch becomes greater, consumers are more motivated to buy the SB product, leading to an increase in its retail price. Thus, both the B&M and online stores must reduce the NB product price in order to attract consumers.

Proposition 5.4(ii) indicates that demand for the SB product and total demand at the B&M store increase with Δ, while demand for the NB product at the online store is negatively associated with Δ. However, the relationship between demand for NB product at B&M stores and the depth of the national-brand product mismatch varies at different intervals of Δ. If consumer dissatisfaction with NB product is relatively small ($0 < \Delta < 1/2$), demand for NB product at the B&M store shows a negative association with Δ. However, if consumer dissatisfaction with the NB product is relatively large ($\Delta \geq 1/2$), demand for the product at the B&M store increases with Δ. This finding is counterintuitive. The explanation may be that as the depth of the national-brand product mismatch becomes greater, the price of the store brand continuously rises. Thus, the NB product gains a price advantage that may stimulate an increase in demand.

Proposition 5.4(iii) states that a greater depth of national-brand product mismatch results in higher revenue for the B&M store and declining profit for the online store. The direct implication for management is that a B&M retailer can implement a product differentiation strategy, identifying desired features that are missing from NB products so as to improve the SB product. In other words, such retailers can move into the market gap resulting from the depth of the national-brand product mismatch by increasing the difference between SB and NB products. Their efforts in this direction will bring greater profits.

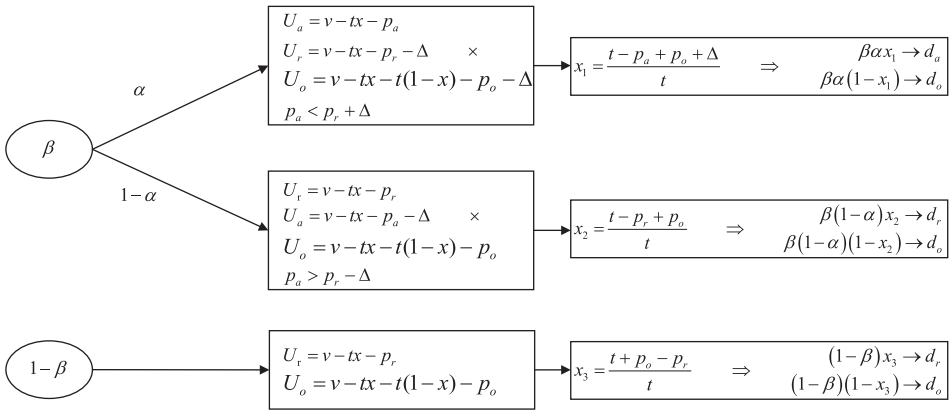

Figure 3. Consumers' decision-making process considering store-brand awareness.

6. Considering store-brand awareness

Store brands are generally not as famous as national ones. Many consumers do not understand their benefits, and some do not even know of their existence. Therefore, we introduce $\beta(0 < \beta < 1)$ to describe the proportion of store customers who are familiar with the store brand. As in the second case, these customers may choose to purchase either the SB or the NB product. However, a proportion $1 - \beta$ of customers will not take the store-brand products into consideration. Therefore, there are only two choices for these customers. If they purchase the NB product directly at the B&M store (without showrooming), their utility is $U_r = v - tx - p_r$. If they switch channels to purchase the NB product at an online store, their utility is $U_o = v - tx - t(1 - x) - p_o$. Setting $v - tx - p_r = v - tx - t(1 - x) - p_o$, we determine the indifference point $x_3 = (t + p_o - p_r)/t$. A fraction β of customers behave the same way as in the second case. As for the rest of the consumers (the $1 - \beta$ fraction), we conclude that $(1 - \beta)x_3$ consumers will buy the NB product directly from the B&M store, while $(1 - \beta)(1 - x_3)$ consumers will switch channels to purchase the NB product at an online store. Figure 3 depicts consumers' decision-making process in this case.

6.1. Pricing strategies when considering store-brand awareness

In this case, demand for the SB product and for the NB product marketed in dual channels is as follows:

$$\begin{aligned}&\text{SB product demand at B\&M store: } d_a\\ &= \beta\alpha x_1 = \beta\alpha(t - p_a + p_o + \Delta)/t \qquad (11)\\ &\text{NB product demand at B\&M store : } d_r\\ &= \beta(1-\alpha)x_2 + (1-\beta)x_3\\ &= (1 - \alpha\beta)(t - p_r + p_o)/t \qquad (12)\end{aligned}$$

$$\begin{aligned}&\text{NB product demand at online store: } d_o\\ &= \beta\alpha(1 - x_1) + \beta(1-\alpha)(1 - x_2)\\ &\quad + (1-\beta)(1 - x_3)\\ &= (\alpha\beta p_a - \alpha\beta p_r - \alpha\beta\Delta - p_o + p_r)/t \qquad (13)\end{aligned}$$

The respective profits of the two retailers can be expressed as follows:

$$\begin{aligned}&\text{B\&M store's profit: } \pi_r\\ &= p_a d_a + p_r d_r = p_a\beta\alpha(t - p_a + p_o + \Delta)/t\\ &\quad + p_r(1 - \alpha\beta)(t - p_r + p_o)/t \qquad (14)\end{aligned}$$

$$\begin{aligned}&\text{Online store's profit : } \pi_o\\ &= p_o d_o = p_o(\alpha\beta p_a - \alpha\beta p_r - \alpha\beta\Delta - p_o + p_r)/t \qquad (15)\end{aligned}$$

By taking the first-order derivatives of π_r with respect to p_r, p_a and the first-order derivative of π_o with respect to p_o, respectively, we set the derivatives at zero and solve the equations to obtain the optimal retail prices p_r^A, p_a^A and p_o^A, as in the previous case. The optimal retail prices again satisfy the constraint. Substituting p_r^A, p_a^A and p_o^A into equations (11) to (15), we derive the B&M and online stores' demand and profit, as shown in Table 2.

Proposition 6.1: *The premium store-brand strategy may also be an effective means for B&M stores to combat showrooming when store-brand awareness is considered.* ■

See Appendix for the proof.

From the proof, we can see that the demand for NB products at the online store decreases due to the influence of the store-brand strategy. Although the demand for the B&M store's NB products also declines, the overall demand for SB and NB products at the B&M store

increases. Moreover, the SB product commands the highest optimal price, followed by the NB product at the B&M store and the NB product at the online store, a finding that replicates case 2. The management implication is that when store-brand awareness is taken into account, a premium store-brand strategy is still an effective means to combat consumer showrooming. Even if the level of store-brand awareness is not high, some previously free-riding consumers will choose SB products, increasing the profit of the B&M store.

6.2. Effects of store-brand awareness

Store-brand awareness has been the focus of much research. To develop insight regarding the store-brand strategy, we pose the following research question: How does store-brand awareness affect the B&M store's and the online store's pricing decisions, profit and demand?

Proposition 6.2: *Table 2 illustrates the impact of* β *on* p, d, π.

(i) $\partial p_a^A/\partial\beta < 0$; $\partial p_r^A/\partial\beta < 0$; $\partial p_o^A/\partial\beta < 0$;
(ii) $\partial d_a^A/\partial\beta > 0$; $\partial d_r^A/\partial\beta < 0$; $\partial d_{r+a}^A/\partial\beta > 0$; $\partial d_o^A/\partial\beta < 0$;
(iii) $\partial\pi_o^A/\partial\beta < 0$;
If $0 < t < \Delta(10\alpha - 9)/16$, $\partial\pi_r^A/\partial\beta > 0$ *when* $\beta \in (0, \beta^*)$, $\partial\pi_r^A/\partial\beta \leq 0$ *when* $\beta \in [\beta^*, 1)$, $\beta^* = (16t + 9\Delta)/10\alpha\Delta$.
If $t \geq \Delta(10\alpha - 9)/16$, $\partial\pi_r^A/\partial\beta > 0$. ■

See Appendix for the proof.

Proposition 6.2(i) indicates that as the store brand becomes better known, the prices for the NB products at both B&M and online stores decrease, and so does the price of the SB product. Proposition 6.2(ii) shows that demand for NB product at both the B&M and online stores decreases when store-brand awareness grows. Nonetheless, total demand for SB and NB product at the B&M store still increases, due to growing demand for the store brand.

Proposition 6.2(iii) shows that the online store's profit decreases with β. This is intuitive. Proposition 6.2(iii) also indicates that the impact of store-brand awareness on the B&M store's profit depends on the hassle cost factor t. If the hassle cost factor is relatively small, the B&M store's profit first increases with β, and then decreases. If the hassle cost factor is relatively large, the B&M store's profit always increases with store-brand awareness. This means that the growth of store-brand awareness will not necessarily benefit the B&M store. The explanation may be that when the hassle cost factor is relatively small, the difference between utility values purchasing online and offline is getting smaller, which means the competition between B&M store and online store may be fierce. The B&M store's profit increases with consumer store-brand awareness at the beginning due to the growing demand for SB product. However, when the store-brand awareness reaches a high level, online store continues to lower the price of NB product to retain consumers. In order to gain competitive advantage, the B&M store will also lower the both prices of NB product and SB product. In this case, although the demand for SB product has increased, the reduced prices of both SB and NB products may lead to a decline in the B&M store's total profit. We can also see some real-world observations. For example, most popular supermarket (e.g. Walmart, Tesco) usually choose to retain the best-selling NB products while introducing their SB products. They will not use the home-court advantage to excessively expand store-brand awareness.

In sum, a brand promotion strategy can be implemented for B&M stores. When the hassle cost factor is relatively high, raising the visibility of the store brand will increase B&M store's profit. Regular marketing campaigns, including advertising, promotions and membership activities, can be used to increase store-brand awareness. However, when the hassle cost factor is relatively low, it's better for B&M stores not to promote store brands overly. That may lead to excessive competition, causing damage to the total profit of the B&M store.

7. Conclusion

The phenomenon of showrooming by consumers has posed a great challenge to B&M retailers. In this context, we consider the introduction of store brands as a strategy to help physical stores combat showrooming. For this purpose, we model a dual-channel supply chain consisting of a physical store and an online store and analyse the equilibrium pricing strategies for the two retailers. We first examine the effectiveness of the store-brand strategy. Then we investigate the ways in which national-brand product mismatch, both in breadth and depth, affects the B&M retailer's and the online retailer's pricing decisions, profit and demand. To develop insight into the store-brand strategy, we extend the model by taking store-brand awareness into consideration. Finally, we propose a series of measures that B&M retailers may take to ensure that the strategy is implemented effectively so as to mitigate showrooming.

Our main results are as follows. First, the store-brand strategy may be an effective means for B&M retailers to combat consumer showrooming. However, it may be better for them to introduce premium store brands to reduce the adverse impact of showrooming.

Second, the B&M store's profit increases with the breadth of national-brand product mismatch, while the online store's profit decreases. Thus, if the national brand is a mismatch for many consumers, a product positioning strategy for the store brand can increase the profits of B&M stores. Third, as national-brand product mismatch increases in depth, the B&M retailer's profit again increases, whereas the online store's profit declines. If the mismatch is very deep – that is, if the national brand fails to meet many consumer expectations – a B&M retailer can implement a product differentiation strategy to promote product improvement and innovation, filling the gaps created by the depth of the national-brand product mismatch. Finally, the impact of store-brand awareness on the profit of a B&M store depends on the hassle cost factor. If the hassle cost factor is relatively small, the B&M store's profit first increases, but then decreases, as store-brand awareness grows. If the hassle cost factor is relatively large, the B&M retailer's profit always increases with store-brand awareness. This means that the expansion of store-brand awareness will not necessarily benefit the B&M store.

Our study has several limitations. We assume that the B&M store and the online store make their pricing decisions simultaneously, which implies that the two retailers have the same pricing power. However, it is quite possible that the physical store has more pricing power. In this setting, the B&M retailer decides the prices of the store-brand and national-brand products first as a Stackelberg leader, and then the online store sets its price for the national-brand product. An interesting direction for further research would be to study how different power structures affect the equilibrium results. Another limitation is that we consider a relatively simple supply channel that consists of a B&M store and an online store. It would be interesting to analyse the case in which the B&M retailer also operates an online channel to compete directly with the online store. In such an extension, the consumer's showrooming and the B&M retailer's store-brand strategy would be more complex.

Notes

1. See the China Consumer Market Analysis Report (2017).
2. See Accenture holiday shopping survey reveals Canadians are 'webrooming' and 'showrooming' to save money available at https://newsroom.accenture.com/industries/retail/accenture-holiday-shopping-survey-reveals-canadians-are-webrooming-and-showrooming-to-save-money.htm.
3. See the Acosta data available at https://www.grocerydive.com/news/grocery–report-majority-of-consumers-visit-multiple-stores-for-their-groceries/534424/.
4. See the China Luxury Report 2019 available at https://www.mckinsey.com.cn.

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Appendix

Discussion of the assumption on prices

We address the equilibrium solutions under the assumption $p_r - \Delta < p_a < p_r + \Delta$. Now, let us consider the possibility of other optimal solutions, that is, the price order is inconsistent with the assumption. Therefore, we make the following assumptions in the opposite direction.

(i) if $p_a < p_r - \Delta$

By assuming this, we can obtain that each consumer will either purchase SB product at the B&M store or buy NB product at the online store. No customers will go to the B&M store to buy NB products even if one consumer's best-matching product is a NB product, which definitely causes the B&M retailers no longer have the incentive to sell NB products. Consequently, the showrooming phenomenon will cease to exist. Furthermore, the situation that B&M stores only sell SB products is an extreme case, which is out of line with reality.

(ii) if $p_a > p_r + \Delta$

In this case, no customers will purchase SB products from the B&M store even if one customer's best-matching product is a SB product. It implies that SB products are completely ruled out and the B&M store would not introduce store brand at all. The situation that only considering the showrooming between NB products has been discussed in many previous papers, which is inconsistent with the focus of this paper that research on implementing store-brand strategy to combat showrooming.

In conclusion, these two assumptions that may exist other equilibrium solutions are unsuitable for the research background of this paper. Hence, the rationality of the assumption on prices is proven.

Proof of Proposition 5.1

Due to $\pi_r^S - \pi_r^N = \alpha\Delta(16t + \Delta(9 - 5\alpha))/36t > 0$, $d_r^S - d_r^N = -\alpha(4t + (1 - \alpha)\Delta)/6t < 0$ and $d_{r+\alpha}^S - d_r^N = \alpha\Delta/3t > 0$, *Proposition 5.1* is proven.

Proof of Proposition 5.2

Due to $p_a^S > p_r^S > p_o^S$, *Proposition 5.2* is proven.

Proof of Proposition 5.3

Proof of Proposition 5.3(i)

Taking the first derivative of retail prices, we can get $\partial p_a^S/\partial\alpha = -\Delta/6 < 0$, $\partial p_r^S/\partial\alpha = -\Delta/6 < 0$ and $\partial p_o^S/\partial\alpha = -\Delta/3 < 0$. *Proposition 5.3(i)* is proven.

Proof of Proposition 5.3(ii)

Taking the first derivative of demands, we can obtain $\partial d_a^S/\partial\alpha = (4t + \Delta(3 - 2\alpha))/6t > 0$, $\partial d_{r+a}^S/\partial\alpha = \Delta/3t > 0$, $\partial d_o^S/\partial\alpha = -\Delta/3t < 0$.

As $p_o^S = (t - \alpha\Delta)/3$, we know $t - \alpha\Delta > 0$. Therefore, $\partial d_r^S/\partial\alpha = (-2(t - \alpha\Delta) - 2t - \Delta)/6t < 0$. *Proposition 5.3(ii)* is proven.

Proof of Proposition 5.3(iii)

Taking the first derivative of the physical and online stores' profits, we get $\partial\pi_r^S/\partial\alpha = \Delta(16t + 9\Delta - 10\alpha\Delta)/36t = (10\Delta(t - \alpha\Delta) + 6t\Delta + 9\Delta^2)/36t > 0$ and $\partial\pi_o^S/\partial\alpha = -2\Delta(t - \alpha\Delta)/9t < 0$. *Proposition 5.3(iii)* is proven.

Proof of Proposition 5.4

Proof of Proposition 5.4(i)

Taking the first derivative of retail prices with respect to Δ, we can get $\partial p_a^S/\partial\Delta = 3 - \alpha/6 > 0$, $\partial p_r^S/\partial\Delta = -\alpha/6 < 0$ and $\partial p_o^S/\partial\Delta = -\alpha/3 < 0$. *Proposition 5.4(i)* is proven.

Proof of Proposition 5.4(ii)

Taking the first derivative of the demands with respect to Δ, we can obtain $\partial d_a^S/\partial\Delta = \alpha(3 - \alpha)/6t > 0$, $\partial d_{r+a}^S/\partial\Delta = \alpha/3t > 0$ and $\partial d_o^S/\partial\Delta = -\alpha/3t < 0$.

As $\partial d_r^S/\partial\Delta = \alpha(2\Delta - 1)/6t$, the value of the derivative depends on Δ. When $0 < \Delta < 1/2$,$\partial d_r^S/\partial\Delta < 0$; when $\Delta > 1/2$, $\partial d_r^S/\partial\Delta \geq 0$. *Proposition 5.4(ii)* is proven.

Proof of Proposition 5.4(iii)

Similarly, taking the first derivative of both stores' profits with respect to Δ, we get $\partial\pi_r^S/\partial\Delta = (16t\alpha + 2\alpha\Delta(9 - 5\alpha))/36t > 0$ and $\partial\pi_o^S/\partial\Delta = -2\alpha(t - \alpha\Delta)/9t < 0$. *Proposition 5.4(iii)* is proven.

Proof of Proposition 6.1

Due to $\pi_r^A - \pi_r^N = \alpha\beta\Delta(16t + \Delta(9 - 5\alpha\beta))/36t > 0$, $d_r^A - d_r^N = -\alpha\beta(4t + (1 - \alpha\beta)\Delta)/6t < 0$ $d_{r+\alpha}^A - d_r^N = \alpha\beta\Delta/3t > 0$ and $p_a^A > p_r^A > p_o^A$, *Proposition 6.1* is proven.

Proof of Proposition 6.2

Proof of Proposition 6.2(i)

Taking the first derivative of retail prices with respect to β, we can get $\partial p_a^A/\partial\beta = -\alpha\Delta/6 < 0$, $\partial p_r^A/\partial\beta = -\alpha\Delta/6 < 0$ and $\partial p_o^A/\partial\beta = -\alpha\Delta/3 < 0$. *Proposition 6.2(i)* is proven.

Proof of Proposition 6.2(ii)

Taking the first derivative of the demands with respect to β, we can obtain $\partial d_{r+a}^A/\partial\beta = \alpha\Delta/3t > 0$, $\partial d_o^A/\partial\beta = -\alpha\Delta/3t < 0$, $\partial d_a^A/\partial\beta = \alpha(4t + \Delta + 2\Delta(1 - \alpha\beta))/6t > 0$.

As $p_o^A = (t - \alpha\beta\Delta)/3 > 0$, we know $t - \alpha\beta\Delta > 0$. Therefore, $\partial d_r^A/\partial\beta = -(2t + 2(t - \alpha\beta\Delta) + \Delta)/6t < 0$. *Proposition 6.2(ii)* is proven.

Proof of Proposition 6.2(iii)

Taking the first derivative of online store's profit with respect to β, we get $\partial\pi_o^A/\partial\beta = -2\alpha\Delta(t - \alpha\beta\Delta)/9t < 0$.

Taking the first and second derivative of physical store's profit with respect to β, ($\partial\pi_r^A/\partial\beta = 16t\alpha\Delta + \alpha\Delta^2(9 - 10\alpha\beta)/36t$, $\partial^2\pi_r^A/\partial\beta^2 = -5\Delta^2\alpha^2/18t < 0$), it shows that the first derivative decreases monotonically.

Moreover, we can easily see that $\partial\pi_r^A/\partial\beta_{(\beta=0)} = 16t\alpha\Delta + 9\alpha\Delta^2/36t > 0$.

Further, let $\partial\pi_r^A/\partial\beta = 16t\alpha\Delta + \alpha\Delta^2(9 - 10\alpha\beta)/36t = 0$, we have the only extreme point $\beta^* = (16t + 9\Delta)/10\alpha\Delta$.

We can easily prove that:

If $t \geq \Delta(10\alpha - 9)/16$, $\beta^* \geq 1$ always holds, π_r^A increases with β over $(0, 1)$;

If $0 < t < \Delta(10\alpha - 9)/16$, $0 < \beta^* < 1$ always holds, π_r^A increases with β over $(0, \beta^*)$and then decreases with β over $[\beta^*, 1)$.

Proposition 6.2(iii) is proven.