Competition in dual-channel supply chains: The manufacturers' channel selection

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Abstract: Innovative selling channels have brought about opportunities as well as challenges for upstream manufacturers. The past few years have witnessed both the success and failure of manufacturers with different channel strategies. To explore the rationale of different channel strategies in various contexts, we develop a model to analyze a manufacturer's channel selection decision among three channel strategies, i.e., a direct-channel strategy, a retail-channel strategy, and a dual-channel strategy consisting of both direct and retail channels. The model rests on the channel differentiation in terms of consumers' channel preferences and operating costs of retail and direct channels. Specifically, we incorporate the action of a competitor and track down its influence on the focal manufacturer's channel preference. Our research clarifies the role of competition in the market and offers insights into the competitive nature of business in real life. Results show that the manufacturer's channel preference depends not only on the channels' operating costs and consumers' channel preferences but also on the competitor's channel strategy. We find that symmetric manufacturers can adopt asymmetric strategies as Nash equilibria and also that there are situations where no Nash equilibrium exists. We characterize the Nash equilibria in the channel selection game based on the exogenous parameters of the model.

Keywords: Supply chain management; channel selection; game theory; competition; multi-channel supply chain

1. Introduction

Manufacturers use a variety of channel strategies to satisfy changing consumer requirements and differentiate themselves from competitors. A traditional channel structure allows the manufacturers to collaborate with retailers or distributors who intermediate between upstream manufacturers and end-of-use consumers. Recently, two channel strategies are widely discussed as alternatives to this traditional retail marketing due to the development of the internet and delivery innovation (Sorescu, Frambach, Singh, Rangaswamy, & Bridges, 2011). First, pure direct selling can be an appropriate strategy for manufacturers to replace traditional retailing with the purpose of eliminating intermediaries. For example, manufacturers like Everlane, Dollar Shave Club, and Glossier sell their products directly to consumers via an online platform. Second, introducing an additional direct channel has become an optional channel strategy for top manufacturers who are collaborating with incumbent retailers, e.g., Hewlett Packard, Procter & Gamble, and Estee Lauder.

However, each channel strategy has its own drawbacks. In traditional retail channels, the intermediaries, such as retailers and distributors, can deprive manufacturers of profits and potential consumers. Manufacturers and retailers in the retail channels are thus vertical competitors, i.e., the competition happens among channel members along a channel or a value chain (Ertek & Griffin, 2002; Zhou, Zhao, & Wang, 2019). Direct channels may lose the benefits of intermediaries' functions such as market coverage and information collection (Tsay & Agrawal, 2004), thus manufacturers and retailers become horizontal competitors, i.e., competitors who are offering substitute products or services at the same level in the supply chain (Choi, 1991). A dual-channel strategy combining retail channels with direct selling also has its downside; it forces manufacturers to become both vertical and horizontal competitors to their retailers, which, in turn, cannibalizes their sales due to the horizontal substitutability (Hezarkhani, Slikker, & Van Woensel, 2018; Matsui, 2020; Shipley, Egan, & Edgett, 1991). Additionally, Choi (2003) finds that a direct channel can raise the entry barrier for latecomers, which is another factor that cuts off the extension of dual-channel manufacturers. Consequently, manufacturers face a dilemma to choose among different channel strategies and acquire comparative advantages.

Prior research has extensively compared and discussed a variety of channel strategies in terms of different characteristics, from sales effort, service offerings, and pricing, to sales cost (Cattani, Gilland, Heese, & Swaminathan, 2006; Li, Li, & Sun, 2019; Tsay & Agrawal, 2004). Researchers have outlined the benefits, as well as the threats, when a manufacturer or a retailer is involved in different channel strategies, especially in the context of a simplified supply chain with one manufacturer and one retailer. Our research suggests, however, the process of understanding a successful channel strategy is more complex; in particular, manufacturers must respond to vertical partners and horizontal competitors simultaneously. Competition has been seen as an important factor that influences the distribution or outsourcing strategies of manufacturers and retailers in different industries (Chen, Fang, & Wen, 2013; Pun & Ghamat, 2016; Wei, Lu, & Zhao, 2020; Xu, Gurnani, & Desiraju, 2010). For example, a firm is more likely to introduce an additional online channel if the consumers purchase from competitors' online channels (Li, Konuş, Langerak, & Weggeman, 2017). Although manufacturers' channel selections have been investigated by many researchers, less is known about how manufacturers would interplay with each other in terms of channel strategies within a competitive environment. Considering this gap in the extant research, i.e., the unclear role of competition in channel selection, this research aims to answer two questions: (1) *What is the best channel strategy for manufacturers?* and (2) *How can horizontal competition influence a manufacturer's channel selection*?

We develop a mathematical model to answer these questions. First, we examine the benchmark model with only one manufacturer and one retailer. Using the concept of a subgame perfect Nash equilibrium, we explore the game in which three channel strategies for the manufacturer, i.e., the direct channel only, the retail channel only, and a mixed channel consisting of both a direct channel and a retail channel, are considered and compared. Prior literature has primarily focused on this interaction between one manufacturer and one retailer, whereas little is known about how the competition between multiple manufacturers can influence their channel strategies. We then further extend the model to a more comprehensive one that adds an additional manufacturer. Each manufacturer makes their channel selection, and thus, the Nash equilibria of the corresponding non-cooperative game between the two manufacturers are explored. Finally, we compare the manufacturer's channel selection in these two settings and formulate our findings.

This research makes several contributions. First, our findings show that there is not a single consistently optimal strategy for the manufacturer. The channel selection is thereby a dynamic choice that depends on the channels' different cost structures and consumers' channel preferences. For example, the dual-channel strategy will lose its advantage when more consumers would like to accept their less preferred channels. Second, the results show that consumers' channel preferences and cost structures play different roles when the manufacturer is facing a competitor with distinct strategies, while it is difficult to capture these roles thoroughly if only considering a single manufacturer's channel strategy. Finally, competing manufacturers can reach different Nash equilibria under a variety of exogenous parameters, and also there are situations where no Nash equilibrium exists. Two competing manufacturers can engage in different channel strategies at equilibrium even when they have symmetric cost structure and market size. We provide the conditions for optimality of different strategies.

The remainder of the paper is organized as follows. Section 2 discusses the literature on channel competition and presents the distinctive features of our model. Section 3 introduces the model structure, justifies our assumptions, and analyses the channel strategy of a single manufacturer. Section 4 focuses on the channel selection under competition and explores the Nash equilibria of the game between two manufacturers. A summary of results and managerial implications are provided in Section 5. Proofs and notations are presented in the Appendix.

2. Literature review

This paper focuses on upstream supply chain members' competition and their channel selection problems. As discussed in the literature, competition has mainly been caused by competing channel members or multiple channel formats. One stream of literature has considered the competition among multiple manufacturers in a supply chain, in which the substitutability of products from distinct manufacturers is the main reason that causes competition, as well as conflict. Choi (1991) and Trivedi (1998) first differentiate the products sold by manufacturers and explore the impacts of different power structures on channel members' performance. Many studies have built upon Choi (1991) and Trivedi (1998) initial work by considering coordination schemes (Sinha & Sarmah, 2010) and manufacturers' pricing strategies (Wei & Zhao, 2016; Xia, 2011; Zhao, Wei, & Li, 2014). Thus, the flexible pricing strategies or coordinating agreements with downward retailers allow the manufacturers to compete with rivals. We thus extend the story by examining how this competition can influence the manufacturers' pricing strategies and in turn changes their channel strategies.

In another stream without horizontal competitors, competition can also arise due to the conflict between traditional channels and new channel formats based on innovative selling platforms such as e-business. Vertical competition can extend to both vertical and horizontal conflicts in this case, in which both double marginalization and channel substitutability play important roles (Hezarkhani et al., 2018). Some studies have considered a multi-channel manufacturer that sells to consumers through both intermediaries and direct stores and discussed whether adding a new channel can benefit the channel members (Cai, 2010; Chen, Liang, Yao, & Sun, 2017; Dumrongsiri, Fan, Jain, & Moinzadeh, 2008; Huang & Swaminathan, 2009; Lu & Liu, 2015; Tsay & Agrawal, 2004; Yan, Zhao, & Liu, 2018). In two seminal papers, Chiang, Chhajed, and Hess (2003) and Tsay and Agrawal (2004) initially introduce the manufacturer's additional direct selling strategy. They demonstrate that a Pareto zone exists that benefits both the manufacturer and the retailer under a manufacturer's dual-channel strategy. In this case, the channels members (e.g., manufacturers and retailers) are thus under pressure to constantly update and improve their strategies, such as inventory strategies (Boyaci, 2005; Chiang & Monahan, 2005; Yao, Yue, Mukhopadhyay, & Wang, 2009), product quality (Chen et al., 2017), value-adding services in the retail channel (Chen, Kaya, & Özer, 2008; Dan, Xu, & Liu, 2012; Yan & Pei, 2009), and the delivery lead time in the web-based direct channel (Chen et al., 2008; Hua, Wang, & Cheng, 2010; Modak & Kelle, 2019). While it is insightful to examine a manufacturer's channel selection, the single-manufacturer perspective presupposes that a manufacturer is independent and neglects the influence of other competitors in the market.

Prior literature has examined either the competition among channel members or the competition among their channel strategies and provided insightful discussion in each case. However, less is known about the co-existence of these two types of competition, i.e., how the manufacturers can design their channel structures in the context of competing manufacturers. As an exception, a game between two manufacturers and their exclusive retailers has been introduced by Matsui (2016) to examine and compare six channel strategies. The equilibria reveal that a symmetric distribution policy is not optimal under price competition. Matsui's work, however, assumes the symmetric cost structure in channels, i.e., identical marginal cost in the retail and direct channels, and zero double marginalization of retailers, i.e., the selling price equals the wholesale price, and thus, retailers have no decision-making role and profit margin. In this paper, we focus on a duopoly of manufacturers and their channel strategy problem with a common retailer who sets the market price if involved. One distinction of our model is that the manufacturer is deciding on channel selection under competition with another manufacturer. Comparing this new scenario with the single manufacturer's channel selection in previous literature clarifies the effects of competition in the same market segment and offers insights into the current intertwined business relationships in practice. Another distinction is our consideration of channel differentiation in two levels, i.e., we consider the general case in practice that operating costs in direct and retail channels are not necessarily identical. We also introduce the consumer's channel preference between retail and direct channels. This assumption positions the conflict in the nature of channel differentiation on both the cost and market characteristics.

Consumers are divided into different segments when comparing channel structures in some literature. Kumar and Ruan (2006) and Cai, Zhang, and Zhang (2009) propose a model with two segments of consumers: store loyal and brand loyal. The store loyal consumers purchase products only from the retailer, whereas the brand loyal consumers purchase their preferred brand from both the retail channel and direct channel. In this model, a portion of the brand loyal consumers prefers the direct channel and others prefer the retail channel, and they may switch their channel preference with the change of prices in different channels. Therefore, the demand for the direct channel includes only a portion of the brand loyal consumers, while the store loyal consumers and another portion of the brand loyal consumers choose to buy from the retail channel. Under this assumption, the total demand remains the same before or after the supplier enters the direct channel and all the brand loyal consumers will buy from the offline stores when there is no direct channel. Similarly, Wang, Li, and Cheng (2016) develop a linear demand model based on Cai et al. (2009) and discuss the channel selection of a dominant multi-channel retailer. The consumers are divided into two types: store preferred consumers and web preferred consumers. Contrary to the previous hypothesis that all the store loyal consumers will switch to the online channel when lacking store channels, Wang et al. (2016) assume that some store loyal consumers will buy nothing in this case. Thus, they introduce a new parameter to indicate the discount coefficient of demand due to consumers' channel mismatch, e.g., some store preferred consumers will give up buying when only the online channel exists. The total demand may change under different channel structures. As discussed above, the demand function of consumer segmentation captures consumers' attitudes towards different segments and helps depict the distinction between direct and retail channels; thus, we develop this function explicitly in our mathematical model.

3. Single manufacturer's channel selection

3.1. Model

We start with a model with one manufacturer and one retailer. This research investigates three channel strategies (see Figure 1): (1) the direct channel only (strategy D), (2) the retail channel only (strategy R), and (3) a channel mix consisting of both direct and retail channels (strategy RD). We denote the choice of strategy with $S\epsilon\{D, R, RD\}$. In strategy R, a manufacturer focuses on the production process and sells its products through an independent retailer that decides the retail price. In strategy D, the manufacturer integrates the production with selling activities and thus decides the selling price without depending on a third-party retailer. In addition, combining the above two strategies is also an option for manufacturers in strategy RD.

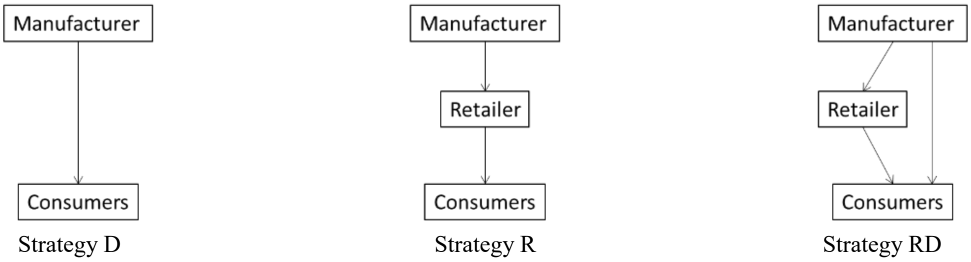


Figure 1 Single manufacturer's channel strategies

One common pricing strategy for these dual-channel manufacturers is to sell the product in the direct channel at full-retail price. Although setting separated prices may benefit the manufacturers, three explanations contribute to the understanding of this equal pricing strategy. The first is brand image concerns (DellaVigna & Gentzkow, 2019). Given the well-developed and interconnected digital selling platforms, firms offer multiple channels and deliver a seamless and consistent shopping experience across channels (MacCarthy, Zhang, & Muyldermans, 2019; Verhoef, Kannan, & Inman, 2015). Thus, the differential prices across channels can result in the consumers' perceived unfairness and lead to the negative demand volatility, especially when the value-adding is not distinguishable across channels (Choi & Mattila, 2009). The second is the potential channel conflict as the equal pricing strategy helps to prevent customer irritation across channels (Cattani et al., 2006; Tsay & Agrawal, 2004). Research has shown that the equal pricing strategy can be motivated by intense competition and a large number of existing channels (Wolk & Ebling, 2010). The third explanation is the managerial inertia, such that the pricing teams can have limited sophistication and organizational barriers to set flexible price (DellaVigna & Gentzkow, 2019). Empirical results corroborate these explanations by showing that price levels remain identical for the multi-channel selling in the same regions (Cavallo, 2017). The identical prices across channels are also commonly observed in the market. For example, consumers can purchase an iPhone 11, in early 2020, with the same price (i.e., £729) either from Apple's website or from retailers such as Amazon and Currys. Compared with electronics, the prices of cosmetics are more likely to be observed as identical due to the undistinguishable augmented products offered by different channels (Wolk & Ebling, 2010). Therefore, seminal papers, e.g., Cattani et al. (2006) and Huang and Swaminathan (2009) have considered the equal pricing strategy in the multi-channel analysis. We thus assume that in the case when direct and indirect channels co-exist, manufacturers sell the product in the direct channel at full-retail price.

3.1.1. Demand transfer process

We develop linear demand functions in which the consumer's choice is decided by the channel preference and the product's selling price. In line with Cai et al. (2009) and Wang et al. (2016), the consumers can be divided into two types in terms of their channel preference, i.e., direct channel consumers and retail channel consumers. The numbers of consumers who prefer the direct channel versus the retail channel are α^D and α^R ($\alpha^D, \alpha^R > 0$), respectively. We introduce parameter α to indicate the ratio of these two numbers, i.e., $\alpha = \alpha^D/\alpha^R$, reflecting the ratio of direct to retail customers. α is affected by factors such as the geographic information of physical stores and the selection of online selling platforms. α^D and α^R can be interpreted as consumers' initial channel preference, and parameter $\eta \in [0,1]$ is also introduced as the discount coefficient of demand due to consumers' channel mismatch. There are two extreme cases: $\eta = 0$ indicates that none of the consumers would change to retail (direct) channels when their preferred direct (retail) channels are absent in the market, whereas $\eta = 1$ indicates that all consumers would change their preferences and can thus easily accept their less preferred channels. Therefore, parameter η also denotes the degree of consumers' acceptance of their less preferred channels.

We denote p as the selling price in the market. In strategy R, the retailer decides p as the retail price, and the manufacturer follows this retail price as the direct price in strategy RD. The manufacturer decides p as the direct price in strategy D. We normalize the maximum possible price to 1; thus, nonnegative demands exist only when $p \in [0,1]$. Accordingly, Table 1 summarizes the demand functions in one manufacturer's different channel strategies.

Table 1 Demand functions in the supply chain with one manufacturer

	Channel strategy (S)		
Demand	Direct channel (D)	Retail channel (R)	Dual channel (RD)
$d^D(S)$	$(\alpha^D + \eta\alpha^R)(1-p)$	0	$\alpha^D(1-p)$
$d^R(S)$	0	$(\alpha^R + \eta\alpha^D)(1-p)$	$\alpha^R(1-p)$

3.1.2. Cost structure

Let c^R denote the operating cost in the retail channel and c^D denote the operating cost in the direct channel. Operating costs are less than the selling price for profitability. Thus, the unit operating costs of the channels are normalized between 0 and 1; i.e., $c^R \in (0,1)$ and $c^D \in (0,1)$ distinguish the costs of selling activities between two channels, such as marketing, pre-purchasing and after service, delivering, warehousing, and other processes (Wang et al., 2016). For example, the direct channel may achieve lower warehousing and inventory costs in industries like PCs and furniture in which manufacturers can adopt an "assemble-to-order" strategy that requires a lower inventory level than the "make-to-order" strategy in physical stores; thus, $c^R > c^D$ (Tsay & Agrawal, 2004). If $c^R < c^D$, the delivery and customization costs in the direct channel may be considerable, especially for products with low margins and low volumes. In the case with a simple manufacturer, the cost structure can be simplified as:

$$\delta^{\circ} = \frac{1-c^D}{1-c^R}.$$

as the relative cost structure in direct and indirect channels. $\delta^{\circ} > 1$ indicates that the retail channel has a higher operating cost than the direct channel; $0 < \delta^{\circ} < 1$ indicates that the direct channel has a higher operating cost than the retail channel; and $\delta^{\circ} = 1$ indicates that operating costs in two channels are identical. α and η represent consumers' preferences for the direct and retail channels, i.e., the difference between two channels at the market level, while δ° represents the cost structure that shows the difference between direct and retail channels at the operational level. This allows us to explore the manufacturers' channel selection in terms of both the market side and the operational side simultaneously. Notations are summarized in Table Appx 1.

3.1.3. Sequence of events

Using the concept of a subgame perfect Nash equilibrium, we explore a sequential game where the retailer is the Stackelberg leader and the manufacturer is the price follower and find the subgame-perfect equilibrium under the manufacturer's each channel strategy. Under strategy R and RD, the retailer thus decides the retail price, and the manufacturer decides the wholesale price. This sequence allows us to explore the case where the manufacturer understands what the market will bear (as the retail price determined by the powerful retailer) first and then work backwards to calculate the wholesale price. We consider the case where the manufacturer follows the retailer's retail price as the selling price in the direct channel in strategy RD, following Cattani et al. (2006) and Ding, Dong, and Pan (2016). The manufacturer thus maximizes its profit through setting the wholesale price. The manufacturer can only decide the selling price when a retail channel is absent in the market, i.e., strategy D. Let w denote the wholesale price, π_M denote the profit of the manufacturer, and π_R denote the profit of the retailer. The profit functions of the manufacturer and the retailer under different channel strategies ($S \epsilon \{D, R, RD\}$) are determined, respectively, with:

$$\pi_M(S) = (p - c^D)d^D(S) + wd^R(S),$$

$$\pi_R(S) = (p - w - c^R)d^R(S).$$

3.2. Analysis

Table 2 Equilibria in strategies D, R and RD

	Strategy D	Strategy R	Strategy RD
$w(S)$	-	$\frac{1-c^R}{2}$	$\frac{(1-c^R)(1+2\alpha-3\alpha\delta^{\circ}-2\alpha^2\delta^{\circ})}{4(1+\alpha)}$
$p(S)$	$\frac{1+c^D}{2}$	$\frac{3+c^R}{4}$	$\frac{3+c^R+4\alpha-\alpha\delta^{\circ}+\alpha\delta^{\circ}c^R}{4(1+\alpha)}$
$\pi_M(S)$	$\frac{(1-c^R)^2\delta^{\circ 2}(\alpha+\eta)\alpha^R}{4}$	$\frac{(1-c^R)^2(1+\alpha\eta)\alpha^R}{16}$	$\frac{(1+\alpha\delta^{\circ})^2(1-c^R)^2\alpha^R}{16(\alpha+1)}$

Table 2 lists the manufacturer's payoffs in three channel strategies. Although operating costs from both direct and retail channels as well as consumers' channel preferences to these two channels come into play, common factors such as $(1 - c^R)^2$ and α^R exist in all the three equilibria profit functions.

In other words, the manufacturer's channel selection only depends on factors that reflect the difference between the direct and retail channels, i.e., cost structure (δ°), channel market size ratio (α), and the discount coefficient of demand due to consumers' channel mismatch (η). Let $p(S)$ denote the optimal selling price in strategy S ($S\epsilon\{D,R,RD\}$) and $w(S)$ denote the optimal wholesale price in strategy S ($S\epsilon\{R,RD\}$).

Lemma 1. *The selling prices and wholesale prices in different channel strategies satisfy:*
(1) $w(RD)\geq w(R)$ *when* $\delta^{\circ}\epsilon\left(0,\frac{1}{2\alpha+3}\right]$*;* $w(R)>w(RD)$ *when* $\delta^{\circ}\epsilon\left(\frac{1}{2\alpha+3},+\infty\right)$*;*
(2) $p(D)\geq p(RD)>p(R)$ *when* $\delta^{\circ}\epsilon\left(0,\frac{1}{\alpha+2}\right]$ *;* $p(RD)>p(D)\geq p(R)$ *when* $\delta^{\circ}\epsilon\left(\frac{1}{\alpha+2},\frac{1}{2}\right]$*;* $p(RD)\geq p(R)>p(D)$ *when* $\delta^{\circ}\epsilon\left(\frac{1}{2},1\right]$*;* $p(R)>p(RD)>p(D)$ *when* $\delta^{\circ}\epsilon(1,+\infty)$.

Lemma 1 shows that the cost structure influences the relative prices in three channel strategies. The wholesale price in strategy RD is lower (higher) than that in strategy R, if the operating cost in the direct channel is decreasing (increasing). Similarly, when the operating cost in the direct (retail) channel is much higher, strategy D (R) has the highest selling price; otherwise, the selling price in strategy RD is the highest.

Prior literature has found that the additional direct channel allows the manufacturer to lower the wholesale price and the selling price in the retail channel, i.e., the wholesale price and selling price under strategy RD are lower than that under strategy R (Chiang et al., 2003). Therefore, although the manufacturer cannot decide the direct price in this case, adding a direct channel to the initial retail channel allows the manufacturer to indirectly control the selling price in the market. Our results in Lemma 1 extend this argument by adding the conditions that the prices can be lower in strategy RD only when the operating cost in the direct channel is relatively controllable. Otherwise, an additional direct channel with a relatively higher operating cost can raise the overall cost to operate within the supply chain and thus increase the wholesale price and the selling price. As such, the operating costs in the direct and retail channels can influence the interaction between the manufacturer and the retailer and thus the manufacturer may select different channel strategies under different cost structures.

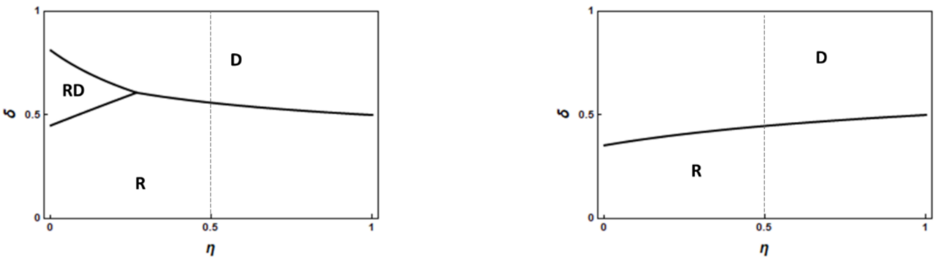
When comparing the two channel strategies (e.g., strategy S_a and strategy S_b), we introduce δ_{S_a,S_b} to represent the threshold of the cost structure where strategy S_a and strategy S_b have the same performance ($S_a,S_b\epsilon\{D,R,RD\}$); thus, $\delta^{\circ}>\delta_{S_a,S_b}$ indicates that strategy S_a outperforms strategy S_b, whereas $\delta^{\circ}<\delta_{S_a,S_b}$ indicates that strategy S_b outperforms strategy S_a.

Proposition 1. *The manufacturer's best strategy is: strategy R when* $\delta^{\circ}\epsilon\left(0,min\left(\delta_{RD,R},\delta_{D,R}\right)\right)$*; strategy D when* $\delta^{\circ}\epsilon\left(max\left(\delta_{D,RD},\delta_{D,R}\right),+\infty\right)$ *; strategy RD when* $\delta^{\circ}\epsilon\left(min\left(\delta_{RD,R},\delta_{D,R}\right),max\left(\delta_{D,RD},\delta_{D,R}\right)\right)$*, where* $\delta_{D,RD}=\frac{\alpha+2\sqrt{(\alpha+\eta)(\alpha+1)}}{3\alpha^2+4\alpha+4\eta+4\alpha\eta}$*,* $\delta_{RD,R}=\frac{\sqrt{(\alpha\eta+1)(\alpha+1)}-1}{\alpha}$*, and* $\delta_{D,R}=\frac{\sqrt{\alpha\eta+1}}{2\sqrt{\alpha+\eta}}$.

Proposition 1 clarifies the importance of the operating costs in different channels when the manufacturer swings among channel strategies. The results are intuitive, as the manufacturer's channel choice seems to be cost-driven. When the operating cost in the direct channel is relatively higher, strategy R outperforms strategy D and strategy RD, and strategy RD outperforms strategy D. When the operating cost in the retail channel is relatively higher, strategy D outperforms strategy R and strategy RD, and strategy RD outperforms strategy R. Overall, the manufacturer will choose strategy R (D) when the operating cost in the direct channel is relatively higher (lower); otherwise, strategy RD is the best choice. Proposition 1 also goes beyond the intuitive results by indicating the boundary cost structures (i.e., $\delta_{D,RD}$, $\delta_{D,R}$, and $\delta_{RD,R}$) that explicate when one channel strategy would outperform another one.

Corollary 1. *If* $\eta = 1$, *then* $\delta_{RD,R} = 1$, *thus strategy RD always outperforms strategy R when* $c^R > c^D$*; if* $0 \leq \eta < 1$, *then* $\delta_{RD,R} < 1$, *thus strategy RD always outperforms strategy R when* $c^R \geq c^D$.

Corollary 1 further specifies the range of the boundary cost structure (i.e., $\delta_{RD,R}$). $\delta_{RD,R} \leq 1$ in Corollary 1 shows that the manufacturer would always choose a direct channel when the operating cost in the retail channel is higher than that in the direct channel. If $\eta \neq 1$, strategy RD outperforms strategy R when operating in the retail channel requires the same costs as operating in the direct channel. This reveals that the cost advantage of the direct channel can bring sufficient benefits to the manufacturer and become a dominant factor that decides the manufacturer's channel selection.



(a) $\alpha = 0.5$ (b) $\alpha = 2$

Figure 2 The segments of one manufacturer's best strategies

Other factors, such as channel market size ratio (α) and the discount coefficient of demand caused by consumers' channel mismatch (η), also come into play and influence the thresholds of evaluating cost structures $\delta_{D,RD}$, $\delta_{RD,R}$ and $\delta_{D,R}$. Figure 2 offers numerical examples and shows the segments of the manufacturer's channel selection in terms of various factors, i.e., strategy S ($S \epsilon \{D, R, RD\}$) indicates the best channel strategy in a segment. Comparing Figure 2(b) with Figure 2(a) reveals that relatively greater market size of the direct channel (i.e., a higher α) extends the segment of strategy D, especially when η is low. Thus, strategy D becomes more effective in Figure 2(b) and outperforms strategy R even though the retail channel has a cost advantage over the direct channel (e.g., $\delta \approx 0.5$).

In addition, strategy RD is more effective at increasing the manufacturer's performance when both of α and η become sufficiently small. When the consumers can easily switch across the direct and retail channels, i.e., η is close to 1, running both channels would not be an optimal selection by the manufacturer because the manufacturer would benefit from the ease of operating one channel without the expense of losing consumers.

There is not a single best strategy for the manufacturer that maintains the channel's priority under various cost structures. This finding is consistent with business practice in the real world. For instance, Dell started to develop its selling activities through multiple resellers in addition to its continuous pure direct business model in 2006 when the development of high technology products boosted demand and raised the requirements for marketing and service. This change requires high operating costs in Dell's direct channel and thus influences the cost structure between direct and retail channels, which is one of the reasons that Dell modified its channel strategy. On the flip side, our results are inconsistent with Cai (2010), who finds the dual-channel strategy outperforms the single-channel strategy in this scenario. Although they use Dell to support their finding that Dell changed to the dual-channel strategy, the fact that Dell obtained rapid expansion based on its direct-channel strategy before 2005 is an example that corroborates the findings of this paper.

4. Two manufacturers' channel selection

4.1. Model

Next, we consider a supply chain with two manufacturers and one retailer in which products from two manufacturers are similar. Figure 3 shows six examples of strategy profiles. Each strategy profile (S_1, S_2) indicates that two manufacturers are using strategies S_1 and S_2, respectively, where $S_1, S_2 \epsilon \{D, R, RD\}$. The manufacturers thus compete with flexible channel structures. Given the assumption of the manufacturers' equal pricing strategy across alternative channels, the price of the product from manufacturer i (i.e., p_i, $i\epsilon\{1,2\}$) is set to be identical in the direct and retail channels under strategy RD. In addition, we assume the wholesale price between the manufacturers and the retailer is w_i, $i\epsilon\{1,2\}$. Notations are summarized in Table Appx 1.

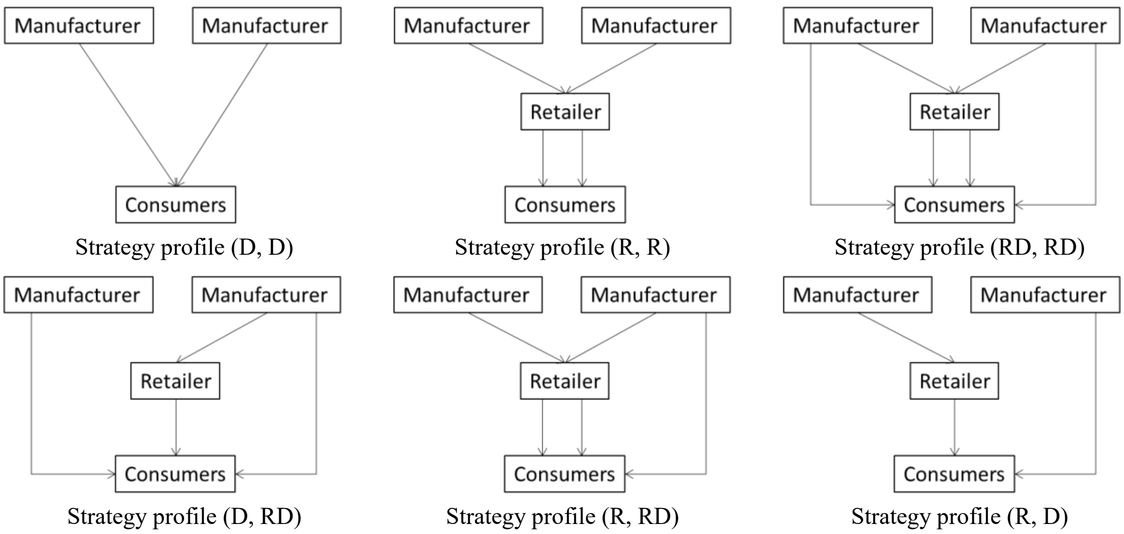


Figure 3 Examples of two manufacturers' strategy profiles

4.1.1. Demand transfer process

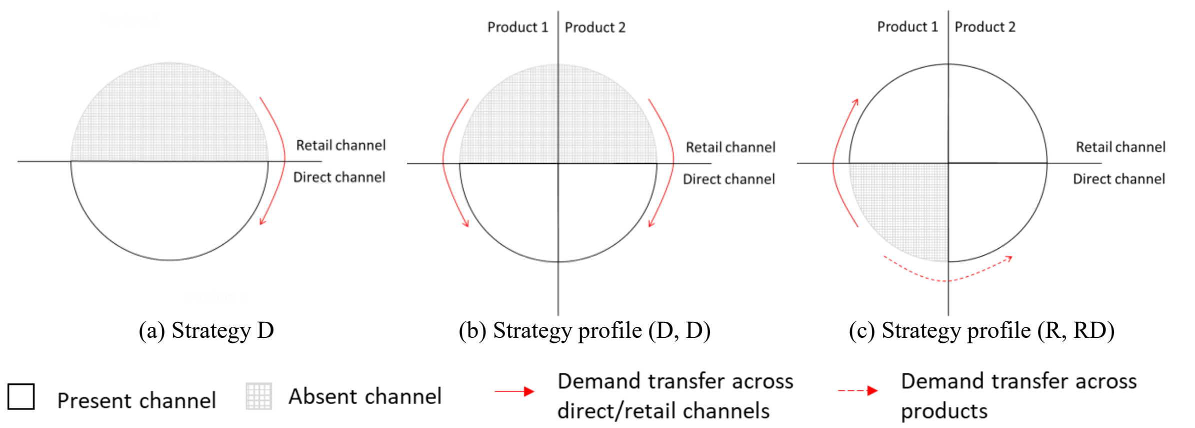


Figure 4 Demand transfer process

Figure 4 delineates how consumers immigrate across different channels. Figure 4(a) shows the demand transfer within the single-manufacturer case, whereas Figure 4(b, c) illustrates the demand transfer process within the two-manufacturer case. When two manufacturers are competing in the market, consumers also select between their products. Parameter $\theta_i \in [0,1], i \in \{1,2\}$ describes the fraction of the brand-driven component of total demand that is captured by manufacturer i, where $\theta_1 + \theta_2 = 1$. Therefore, θ_1 of the consumers will prefer the product from one manufacturer and θ_2 of the consumers will prefer that product from another manufacturer. Similarly, parameter $\lambda \in [0,1]$ denotes consumers' acceptance of their less preferred products due to the lack of another product. In two extreme cases, $\lambda = 0$ indicates that none of the consumers would change to another product when their preferred product is absent in their preferred channel, whereas $\lambda = 1$ indicates that all consumers would change their product preference; thus, they can easily accept their less preferred product in their preferred channel. Therefore, a low parameter λ denotes a high level of consumer loyalty towards the preferred brand.

As such, demands for different channels are dynamic in terms of manufacturers' various channel strategies because consumers immigrate across different channels (see examples of demand transfer in Figure 4). When the consumers switch from the absent channel to adjacent channels, λ of them switch to another product in the same channel, whereas η of them switch to a different type of channel to buy the same product. For example, in Figure 4(c), the consumers initially from the absent channel can select either the same product in the retail channel or the different product in the direct channel. If λ of them switch to the different product in the direct channel, then $(1-\lambda)\eta$ of the consumers will select the same product in the retail channel; if η of them switch to the same product in the retail channel, then $(1-\eta)\lambda$ of the consumers will select the different product in the direct channel. We thus assume that both transfer directions can have a 50% probability of happening if the two adjacent channels co-exist. As an example, in Figure 4(c), there is a 50/50 chance that the absent channel can increase the demand $d_1^R(R,RD)$ either by $\eta\theta_1\alpha^D$ or $(1-\lambda)\eta\theta_1\alpha^D$, thus the expected demand $d_1^R(R,RD)$ increases by $(1-\lambda/2)\eta\theta_1\alpha^D$. One benefit of making this assumption is to ensure that the sum of increased demand in adjacent channels is less than the initial demand in the absent channel.

β represents the degree to which the two manufacturers' products are substitutable, and $\beta \in (0,1)$. We assume that the two products are equally substitutable, i.e., there is a unified parameter β in each product's demand function; the market is symmetric in terms of the products' substitutability. Thus, the price of one product has a larger influence on another product if the products have a higher degree of substitutability (i.e., β is close to 1), whereas this influence becomes slighter if the degree of substitutability is lower (i.e., β is close to 0). Table 3 summarizes the demand functions in different strategy profiles. The demands are thus functions of the demand transfer, the substitutability of two products, and the selling prices.

Table 3 Demand functions in the supply chain with two manufacturers

	Strategy profile (S_i, S_j) $(i, j \epsilon \{1,2\}$ and $i \neq j)$	
Demand	Strategy profile (D, D)	Strategy profile (D, RD)
$d_i^D(S_i, S_j)$	$(\alpha^D + \eta\alpha^R)\theta_i(1 - p_i + \beta p_j)$	$\left[\alpha^D + \left(1 - \frac{\lambda}{2}\right)\eta\alpha^R\right]\theta_i(1 - p_i + \beta p_j)$
$d_j^D(S_i, S_j)$	$(\alpha^D + \eta\alpha^R)\theta_j(1 - p_j + \beta p_i)$	$\alpha^D\theta_j(1 - p_j + \beta p_i)$
$d_i^R(S_i, S_j)$	0	0
$d_j^R(S_i, S_j)$	0	$\alpha^R\left[\theta_j + \left(1 - \frac{\eta}{2}\right)\lambda\theta_i\right](1 - p_j + \beta p_i)$
	Strategy profile (R, R)	Strategy profile (R, RD)
$d_i^D(S_i, S_j)$	0	0
$d_j^D(S_i, S_j)$	0	$\alpha^D\left[\theta_j + \left(1 - \frac{\eta}{2}\right)\lambda\theta_i\right](1 - p_j + \beta p_i)$
$d_i^R(S_i, S_j)$	$(\alpha^R + \eta\alpha^D)\theta_i(1 - p_i + \beta p_j)$	$\left[\alpha^R + \left(1 - \frac{\lambda}{2}\right)\eta\alpha^D\right]\theta_i(1 - p_i + \beta p_j)$
$d_j^R(S_i, S_j)$	$(\alpha^R + \eta\alpha^D)\theta_j(1 - p_j + \beta p_i)$	$\alpha^R\theta_j(1 - p_j + \beta p_i)$
	Strategy profile (RD, RD)	Strategy profile (D, R)
$d_i^D(S_i, S_j)$	$\alpha^D\theta_i(1 - p_i + \beta p_j)$	$\left[\alpha^D\theta_i + \left(1 - \frac{\lambda}{2}\right)\eta\alpha^R\theta_i + \left(1 - \frac{\eta}{2}\right)\lambda\alpha^D\theta_j\right](1 - p_i + \beta p_j)$
$d_j^D(S_i, S_j)$	$\alpha^D\theta_j(1 - p_j + \beta p_i)$	0
$d_i^R(S_i, S_j)$	$\alpha^R\theta_i(1 - p_i + \beta p_j)$	0
$d_j^R(S_i, S_j)$	$\alpha^R\theta_j(1 - p_j + \beta p_i)$	$\left[\alpha^R\theta_i + \left(1 - \frac{\lambda}{2}\right)\eta\alpha^D\theta_j + \left(1 - \frac{\eta}{2}\right)\lambda\alpha^R\theta_i\right](1 - p_j + \beta p_i)$

4.1.2. Sequence of events

We follow the assumptions in the case of a single manufacturer, in which the retailer is the Stackelberg leader and the manufacturers are the followers. This power balance scenario is described as Retailer-Stackelberg in Choi (1991). Figure 5 illustrates the sequence of the game. If a manufacturer uses strategy RD, this manufacturer follows the retail price as the direct price; if a manufacturer uses strategy D, this manufacturer decides its direct price. As such, if both manufacturers select the same channel strategy, they set the wholesale prices (in strategy R or RD) or direct prices (in strategy D) simultaneously. Otherwise, if the manufacturers select different strategies, they set the wholesale price(s) and the direct price simultaneously after the retailer sets the retail price(s). Let $\pi_M(S_1, S_2)$ denote the profit of the focal manufacturer with strategy S_1 and facing a competitor with strategy S_2, and $\pi_R(S_1, S_2)$ denote the profit of the retailer when the two manufacturers' strategy profiles are (S_1, S_2). The profit functions of the focal manufacturer and the retailer are:

$\pi_M(S_1, S_2) = (p_1 - c^D)d_1^D(S_1, S_2) + w_1 d_1^R(S_1, S_2)$,

$$\pi_R(S_1, S_2) = (p_1 - w_1 - c^R)d_1^R(S_1, S_2) + (p_2 - w_2 - c^R)d_2^R(S_1, S_2).$$

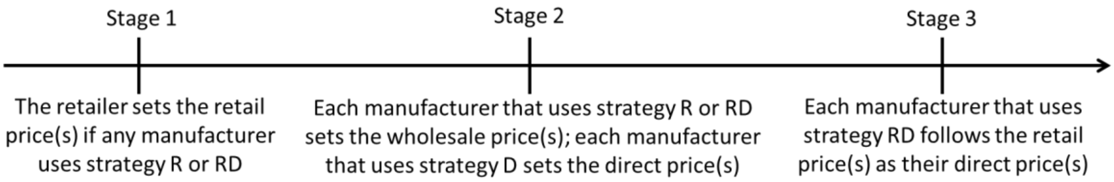


Figure 5 Sequence of events

4.2. Analysis

4.2.1. Best response channel strategies

This subsection compares a manufacturer's response channel strategies in terms of the competitor's choice, followed by figures illustrating numerical examples. The results have been discussed respectively according to the competitor's different channel strategies. The assumptions that $\theta_i \in [0,1], i \in \{1,2\}$, and $\lambda \in [0,1]$ allow for flexibility, such that two manufacturers' products can be asymmetric in terms of consumers' preference. In the case with two competing manufacturers, we thus define the cost structure as:

$$\delta = \frac{1-(1-\beta)c^D}{1-(1-\beta)c^R}.$$

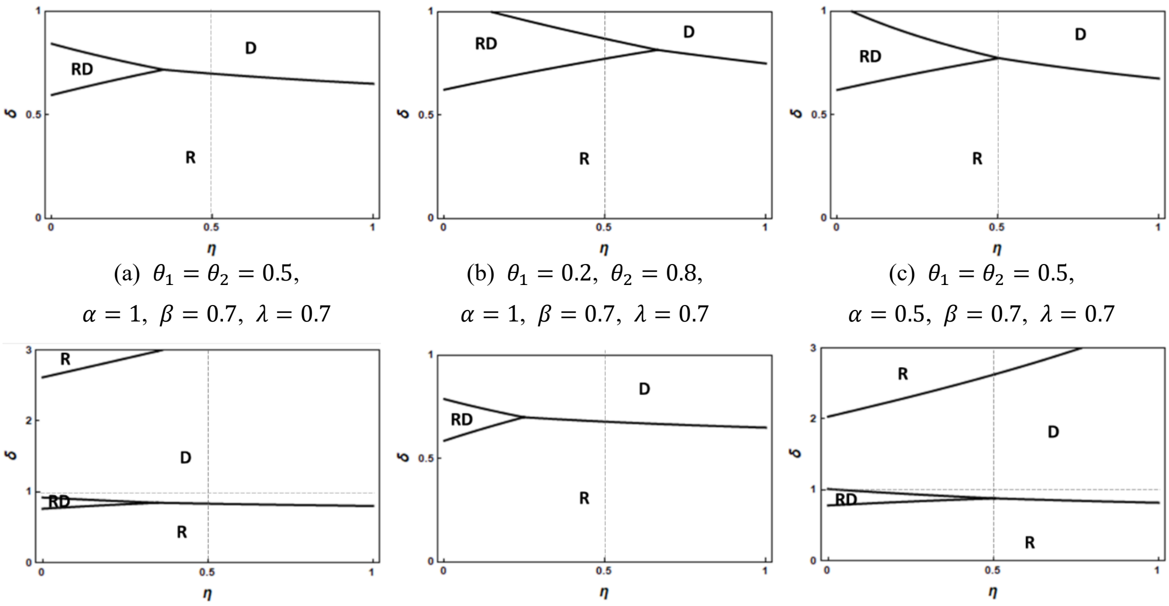
Apart from the factors that reflect the difference between the direct and retail channels, i.e., cost structure (δ), channel market size ratio (α), and the discount coefficient of demand due to consumers' channel mismatch (η), the manufacturer (S_1)'s channel selection and selling price also relates to consumers' product preferences (i.e., θ_1, θ_2, β, and λ). θ_1 of the total consumers choose the product from the focal manufacturer (S_1) and θ_2 of the total consumers choose the product from the competitor (S_2).

When comparing the manufacturer's two-channel strategies (e.g., strategy S_a and strategy S_b) under the competitor's channel strategy S_c, we introduce $\delta_{S_a, S_b}^{S_c}$ to represent the threshold of cost structure that strategy S_a and strategy S_b have the same performance ($S_a, S_b, S_c \epsilon \{D, R, RD\}$). Thus, when facing a competitor with strategy S_c, $\delta > \delta_{S_a, S_b}^{S_c}$ indicates that strategy S_a outperforms strategy S_b for the manufacturer whereas $\delta < \delta_{S_a, S_b}^{S_c}$ indicates that strategy S_b outperforms strategy S_a for the manufacturer.

Let $Z_{S_a > S_b}^{S_c}$ denote the set of δ in which strategy S_a outperforms strategy S_b when the competitor adopts strategy S_c, $S_a, S_b, S_c \epsilon \{D, R, RD\}$, thus $Z_{S_a > S_b}^{S_c} = \{\delta | \pi_M(S_a, S_c) > \pi_M(S_b, S_c)\} = \left\{\delta \middle| \delta \epsilon \left(\delta_{S_a, S_b}^{S_c}, \delta_{S_b, S_a}^{S_c}\right), \delta_{S_a, S_b}^{S_c} < \delta_{S_b, S_a}^{S_c} \right\} \cup \left\{\delta \middle| \delta \epsilon \left(0, \delta_{S_b, S_a}^{S_c}\right) \cup \left(\delta_{S_a, S_b}^{S_c}, +\infty\right), \delta_{S_a, S_b}^{S_c} > \delta_{S_b, S_a}^{S_c} \right\}$.

Proposition 2. *When the competitor adopts strategy S_c, the manufacturer's best response is: strategy R when $\delta \in Z_{R>D}^{S_c} \cap Z_{R>RD}^{S_c}$; strategy D when $\delta \in Z_{D>R}^{S_c} \cap Z_{D>RD}^{S_c}$; strategy RD when $\delta \in Z_{RD>D}^{S_c} \cap Z_{RD>R}^{S_c}$.*

The following figures exhibit the numerical examples of Proposition 2. Figure 6, Figure 7, and Figure 8 offer numerical examples and shows the segments of the manufacturer's channel selection in terms of various factors, i.e., strategy S ($S\epsilon\{D, R, RD\}$) indicates the best channel strategy in a segment. Figure 6 shows the manufacturer's best response strategies to the competitor's strategy D. Figure 6(a) can be seen as a basic example, while Figure 6(b, c, d, e) illustrates the numerical examples in which only the value of one parameter varies in each example compared with Figure 6(a). For example, Figure 6(a, c) shows the numerical cases when α is different and others remain the same. In a similar vein, Figure 7 and Figure 8 show the manufacturer's best response strategies to the competitor's strategy R and RD, respectively; they can be read in the same way as Figure 6.



(a) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1$, $\beta = 0.7$, $\lambda = 0.7$

(b) $\theta_1 = 0.2$, $\theta_2 = 0.8$, $\alpha = 1$, $\beta = 0.7$, $\lambda = 0.7$

(c) $\theta_1 = \theta_2 = 0.5$, $\alpha = 0.5$, $\beta = 0.7$, $\lambda = 0.7$

(d) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1$, $\beta = 0.9$, $\lambda = 0.7$

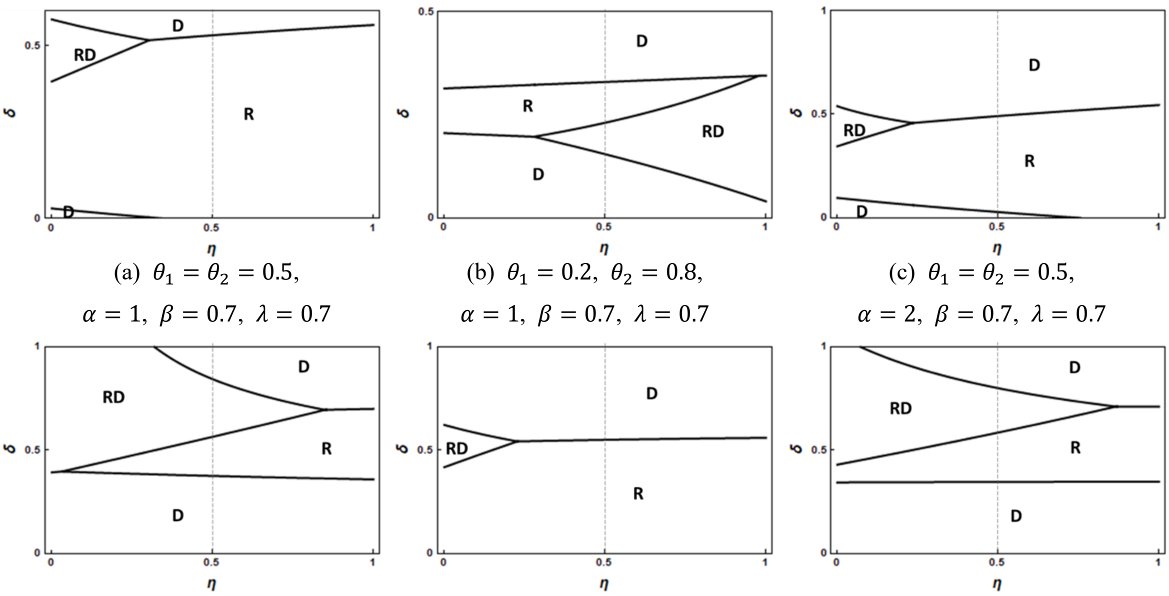
(e) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1$, $\beta = 0.7$, $\lambda = 0.4$

(f) $\theta_1 = \theta_2 = 0.5$, $\alpha = 0.5$, $\beta = 0.9$, $\lambda = 0.7$

Figure 6 The segments of best response strategies to strategy D

The results from one manufacturer's channel selection suggest that strategy RD will no longer be considered when α is high. When competition exists, however, Figure 6 shows that strategy RD is still optional when α is high and η is small. This implies that when consumers can easily switch to their less preferred channels (high η), strategy RD loses its advantage of market coverage, while the high market size of the direct channels, i.e., a higher α in Figure 6(a) than that in Figure 6(c), weakens this loss and thus strategy RD are more likely to be selected. In addition, consumers' product preferences are also involved in the manufacturer's channel selection. For example, given $\eta = 0$ and $\delta = 1$, the manufacturer's channel strategy changes from strategy D in Figure 6(a) to strategy RD in Figure 6(b) due to the decreasing market share of the manufacturer. Similarly, from Figure 6(e) to Figure 6(a), the increasing λ strengthens the benefits of strategy RD. As such, facing a single direct-channel competitor, strategy RD may in turn outperform strategy D when the manufacturer has disadvantaged consumer preference and loyalty.

Figure 6(a, b, c, e) shows that the manufacturer will choose strategy R (D) when the operating cost in the direct channel is relatively higher (lower); otherwise, strategy RD is preferred. However, Figure 6(d, f) illustrates that when the two products are highly substitutable (i.e., $\beta = 0.9$), the manufacturer can choose strategy R to respond even though the operating cost in the retail channel is high. The high substitutability between the two products can thus weaken the dominant influence of cost structure on the manufacturer's channel preference.



(a) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1$, $\beta = 0.7$, $\lambda = 0.7$

(b) $\theta_1 = 0.2$, $\theta_2 = 0.8$, $\alpha = 1$, $\beta = 0.7$, $\lambda = 0.7$

(c) $\theta_1 = \theta_2 = 0.5$, $\alpha = 2$, $\beta = 0.7$, $\lambda = 0.7$

(d) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1$, $\beta = 0.9$, $\lambda = 0.7$

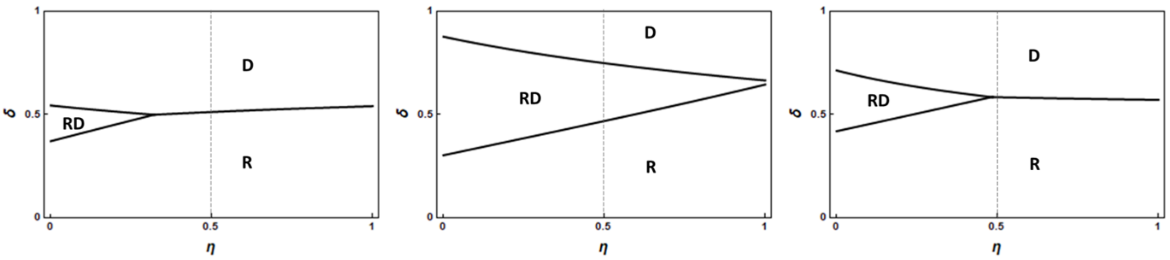
(e) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1$, $\beta = 0.7$, $\lambda = 0.2$

(f) $\theta_1 = \theta_2 = 0.5$, $\alpha = 0.5$, $\beta = 0.9$, $\lambda = 0.7$

Figure 7 The segments of best response strategies to strategy R

In both the case with the single manufacturer and the case when the competitor adopts strategy D, the manufacturer will select strategy R when δ is low, i.e., when the operating cost in the retail channel is relatively lower than that in the direct channel. As shown in Figure 7, however, when the competitor adopts strategy R and the operating cost in the direct channel is high, strategy R is not always the best selection and strategy D can even be selected as the best response. Thus, the cost factors are not always the key determinants in manufacturers' channel selection. One possible reason relates to the pricing issue that the direct channels follow the pricing strategy in the retail channels. When both the manufacturer and the competitor invest in the retail channels, their competition can benefit the leading retailer and thus squeeze both manufacturers' profit in the market. Therefore, when the competitor is adopting strategy R, neither strategy R not strategy RD can avoid this intense competition within the retail channels, thus strategy D could be seen as a better alternative strategy even though the operating cost in the direct channel becomes high. As shown in Figure 7(a, b), strategy D is particularly considered by the manufacturer when its product's market size is lower than the competitor.

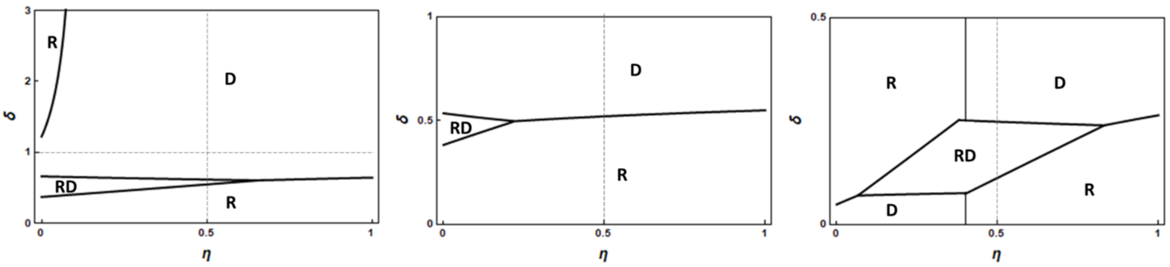
Figure 6 and Figure 7 reveal that the manufacturer follows multiple rules when the competitor selects any single-channel strategies, i.e., strategy D or strategy R. A basic rule, which also applies to the one-manufacturer's case, shows that the manufacturer considers the relative operating costs in different channels and thus tends to select the channel with a cost advantage. Therefore, the manufacturer will choose strategy R (D) when the operating cost in the direct channel is relatively higher (lower); otherwise, strategy RD is preferred. The manufacturer also considers another rule when the competitor adopts strategy D or strategy R, i.e., selecting a distinct channel can avoid the intense competition and benefit the manufacturer. This particularly applies when the operating cost in the competitor's channel is relatively lower. The low operating cost in such a channel seems feasible but can actually trap the manufacturer into the fierce competition. Therefore, the manufacturer can jump out of the trap and respond to the competitor's strategy R (D) with strategy D (R) when the operating cost in the retail (direct) channel is much lower.



(a) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$

(b) $\theta_1 = 0.8,\ \theta_2 = 0.2$, $\alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$

(c) $\theta_1 = \theta_2 = 0.5$, $\alpha = 0.5,\ \beta = 0.7,\ \lambda = 0.7$



(d) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1,\ \beta = 0.9,\ \lambda = 0.7$

(e) $\theta_1 = \theta_2 = 0.5$, $\alpha = 1,\ \beta = 0.7,\ \lambda = 0.4$

(f) $\theta_1 = 0.2,\ \theta_2 = 0.8$, $\alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$

Figure 8 The segments of best response strategies to strategy RD

Figure 8 shows that when the competitor adopts strategy RD, the manufacturer will choose strategy R (D) when the operating cost in the direct channel is relatively higher (lower); otherwise, strategy RD is preferred. Exceptions can happen when the product's market size of the manufacturer is much lower than that of the competitor, as shown in Figure 8(f). The manufacturer may have different selections under different values of η when others remain the same.

Numerical examples from Figure 6 to Figure 8 show that given the same consumers' preference and cost structure, the manufacturer makes different decisions in terms of the competitor's channel strategies. The manufacturer's selection is thus a function of competition, cost structure, and consumers' preferences. For example, the manufacturer may choose to compete in the same channel, i.e., by selecting the same channel strategy as the competitor, even when η equals 0 such that the direct channel and the retail channel are absolutely separated.

In addition, when operating in two channels requires similar expenses or efforts (i.e., $\delta \approx 1$), investing in the direct channel is expected to have better returns to the manufacturer due to the elimination of intermediaries. Thus, strategy D and strategy RD are more likely to outperform strategy R. As shown from Figure 2 to Figure 8, when $\delta \approx 1$, the manufacturer is more likely to prefer strategy D when the consumers can easily transfer their preference across channels (high η); otherwise, strategy RD is more likely to be selected.

4.2.2. Nash equilibria in channel selection

We have discussed that a manufacturer can have different responses to a competitor's different channel strategies. The manufacturers' channel selections, however, are dynamic processes, as the competitor can adjust its selection in turn after observing the manufacturer's channel selection. A Nash equilibrium thus may exist in their channel competition. In this section, we follow the rationale that a manufacturer's channel selection is a non-cooperative game, such that the channel competition game with the competitor can drive the manufacturers to different equilibria. A symmetric Nash equilibrium exists when both manufacturers adopt the same channel strategy, e.g., strategy profile (D,D), (R,R), or (RD,RD), whereas an asymmetric Nash equilibrium exists when manufacturers adopt different channel strategies, e.g., strategy profile (D,RD), (R,RD), or (RD,D).

Let $Z_{S_a>S_b}^{(S_c,\theta_i)}(i=1,2;\theta_1+\theta_2=1)$ denote that the set of δ in which strategy S_a outperforms strategy S_b when the competing manufacturer adopts strategy S_c and the fractions of the brand-driven component of total demand that is captured by the competing manufacturers are θ_1 and θ_2, respectively.

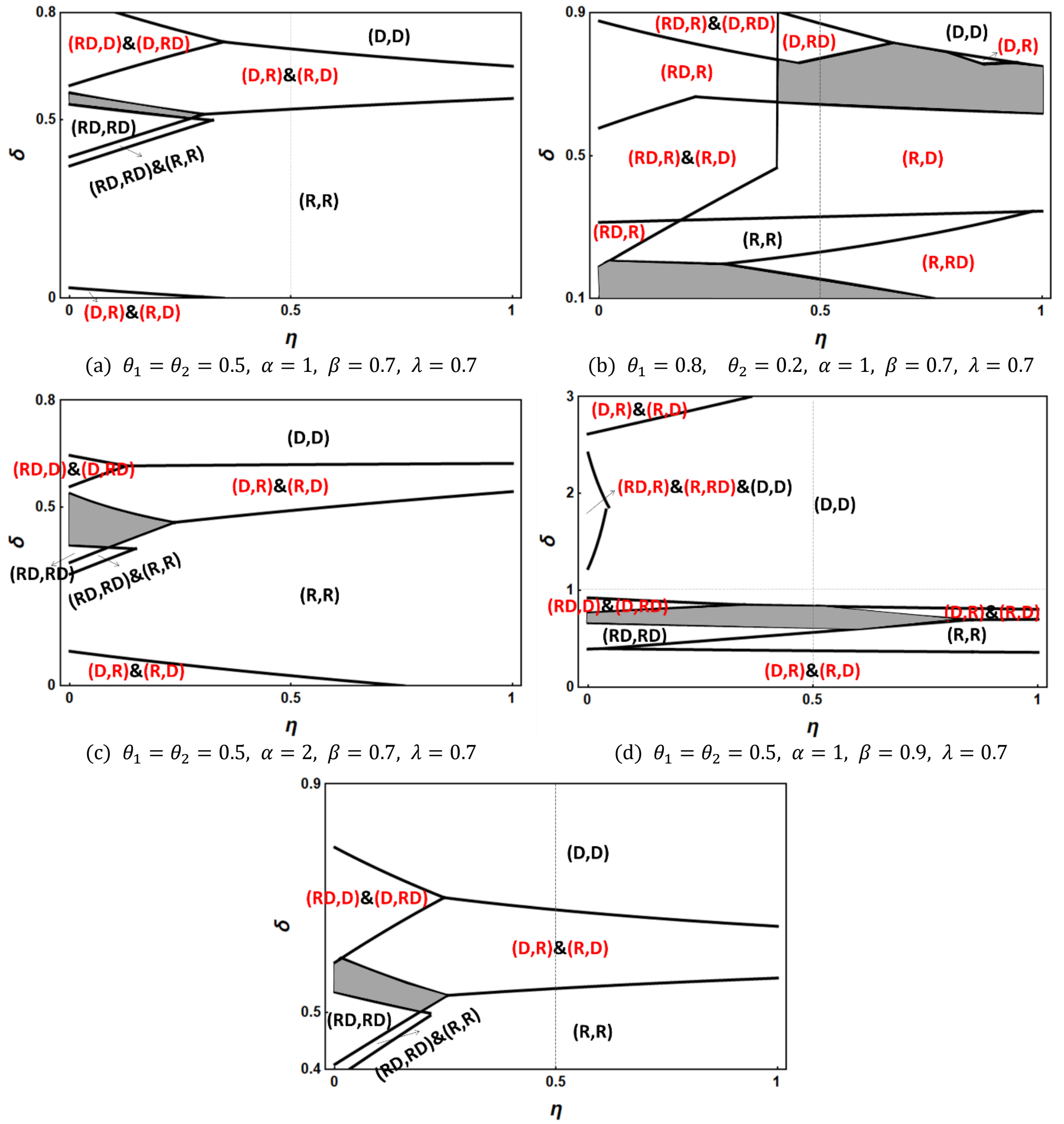
Proposition 3. *Nash equilibria between the manufacturers (with θ_1 and θ_2 of the demand) are:*
(1) when $\delta\epsilon\ Z_{D>R}^{(D,\theta_1)}\cap Z_{D>RD}^{(D,\theta_1)}\cap Z_{D>R}^{(D,\theta_2)}\cap Z_{D>RD}^{(D,\theta_2)}$, strategy profile (D,D) is a Nash equilibrium;
(2) when $\delta\epsilon Z_{R>D}^{(R,\theta_1)}\cap Z_{R>RD}^{(R,\theta_1)}\cap Z_{R>D}^{(R,\theta_2)}\cap Z_{R>RD}^{(R,\theta_2)}$, strategy profile (R,R) is a Nash equilibrium;
(3) when $\delta\epsilon Z_{RD>D}^{(RD,\theta_1)}\cap Z_{RD>R}^{(RD,\theta_1)}\cap Z_{RD>D}^{(RD,\theta_2)}\cap Z_{RD>R}^{(RD,\theta_2)}$, strategy profile (RD,RD) is a Nash equilibrium;
(4) when $\delta\epsilon Z_{R>D}^{(D,\theta_1)}\cap Z_{R>RD}^{(D,\theta_1)}\cap Z_{D>R}^{(R,\theta_2)}\cap Z_{D>RD}^{(R,\theta_2)}$, strategy profile (R,D) is a Nash equilibrium;
(5) when $\delta\epsilon Z_{R>D}^{(D,\theta_2)}\cap Z_{R>RD}^{(D,\theta_2)}\cap Z_{D>R}^{(R,\theta_1)}\cap Z_{D>RD}^{(R,\theta_1)}$, strategy profile (D,R) is a Nash equilibrium;
(6) when $\delta\epsilon Z_{D>R}^{(RD,\theta_1)}\cap Z_{D>RD}^{(RD,\theta_1)}\cap Z_{RD>D}^{(D,\theta_2)}\cap Z_{RD>R}^{(D,\theta_2)}$, strategy profile (D,RD) is a Nash equilibrium;
(7) when $\delta\epsilon Z_{D>R}^{(D,\theta_1)}\cap Z_{D>RD}^{(D,\theta_1)}\cap Z_{RD>D}^{(RD,\theta_2)}\cap Z_{RD>R}^{(RD,\theta_2)}$, strategy profile (RD,D) is a Nash equilibrium;
(8) when $\delta\epsilon Z_{R>D}^{(RD,\theta_1)}\cap Z_{R>RD}^{(RD,\theta_1)}\cap Z_{RD>D}^{(R,\theta_2)}\cap Z_{RD>R}^{(R,\theta_2)}$, strategy profile (R,RD) is a Nash equilibrium;
(9) when $\delta\epsilon Z_{R>D}^{(RD,\theta_2)}\cap Z_{R>RD}^{(RD,\theta_2)}\cap Z_{RD>D}^{(R,\theta_1)}\cap Z_{RD>R}^{(R,\theta_1)}$, strategy profile (RD,R) is a Nash equilibrium;
(10) otherwise, there is no Nash equilibrium.

Proposition 3 shows the conditions of the different Nash equilibria. These conditions are affected by the relative fractions of the brand-driven component of total demand that is captured by the competing manufacturers and the best response strategies to different channel strategies.

Corollary 2. *In the symmetric market where $\theta_1=\theta_2=0.5$:*
(1) when $\delta\epsilon\ Z_{D>R}^{D}\cap Z_{D>RD}^{D}$, strategy profile (D,D) is a Nash equilibrium;
(2) when $\delta\epsilon Z_{R>D}^{R}\cap Z_{R>RD}^{R}$, strategy profile (R,R) is a Nash equilibrium;
(3) when $\delta\epsilon Z_{RD>D}^{RD}\cap Z_{RD>R}^{RD}$, strategy profile (RD,RD) is a Nash equilibrium;

(4) when $\delta \epsilon Z^{D}_{R>D} \cap Z^{D}_{R>RD} \cap Z^{R}_{D>R} \cap Z^{R}_{D>RD}$, *strategy profile (D,R) or (R,D) is a Nash equilibrium;*
(5) when $\delta \epsilon Z^{RD}_{D>R} \cap Z^{RD}_{D>RD} \cap Z^{D}_{RD>D} \cap Z^{D}_{RD>R}$, *strategy profile (D,RD) or (RD,D) is a Nash equilibrium;*
(6) when $\delta \epsilon Z^{RD}_{R>D} \cap Z^{RD}_{R>RD} \cap Z^{R}_{RD>D} \cap Z^{R}_{RD>R}$, *strategy profile (RD,R) or (R,RD) is a Nash equilibrium;*
(7) otherwise, there is no Nash equilibrium.

Proposition 3 outlines the conditions of different Nash equilibria, whereas Corollary 2 specifically investigates the symmetric market where $\theta_1 = \theta_2 = 0.5$. Numerical examples, as shown in Figure 9 further delineate the segmentation of Nash equilibria in Proposition 3 and Corollary 2. In the symmetric market, there is not a unique Nash equilibrium in the channel competition game. From an intuitive view, symmetric manufacturers with similar cost structures and market coverages should benefit most from similar channel strategies. Corollary 2, however, implies that this is not always the case.



(a) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$

(b) $\theta_1 = 0.8,\ \ \theta_2 = 0.2,\ \alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$

(c) $\theta_1 = \theta_2 = 0.5,\ \alpha = 2,\ \beta = 0.7,\ \lambda = 0.7$

(d) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.9,\ \lambda = 0.7$

(e) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.7,\ \lambda = 0.4$

Note. Strategy portfolio (S_1, S_2) $(S_1, S_2 \epsilon \{D, R, RD\})$ *indicates the Nash equilibrium in a segment. The black font indicates that* *two manufacturers select the same channel strategy in the equilibrium, whereas the red font indicates that two manufacturers select different channel strategies in the equilibrium. Grey segments indicate that there is no Nash equilibrium in these segments.*

Figure 9 The segments of Nash equilibria

Figure 9 illustrates the Nash equilibria for both the symmetric market and the asymmetric market. Manufacturers may not always reach a Nash equilibrium in either the symmetric or the asymmetric market under some conditions. Numerical examples in Figure 9 also show that manufacturers can reach multiple equilibria in other conditions. This implies that the optimal channel strategies as Nash equilibria between competing manufacturers are context-specific and vary according to the exogenous factors of consumer preference and cost structure.

Symmetric equilibria, i.e., strategy profile (D,D), (R,R), and (RD,RD), can exist, no matter whether the competing manufacturers have the same market size or not (as shown in Figure 9). These symmetric equilibria seem to corroborate the competition between Coca-Cola and Pepsi as an example. The low marginal cost of soft drinks increases the operating cost of running a separate direct channel (low δ), and the direct or retail channel can be alternative to each other because of consumers' familiarity with soft drinks (high η). As such, Coca-Cola and Pepsi have competed in retail stores. The competition can reach the equilibrium (RD,RD) when the consumers' willingness to accept their less preferred channels is low (low η) and c^R is relatively lower than c^D (low δ).

In addition, the existence of asymmetric equilibria confirms the significant importance of competition that has been neglected by previous literature. Matsui (2016) has proposed an analogous argument that strategy profile (D,RD) or (RD,D) always arises in the equilibrium of two symmetric manufacturers, in terms of the same marginal cost in both direct and retail channels. We generalise the assumption with a channel-specific cost structure that is not stable due to the technology or industry development. Our results thus extend the argument by proposing that for symmetric manufacturers, other asymmetric strategy profiles such as (R,RD) or (R,D) also arise when the cost structure and consumers' purchasing preferences vary. Figure 9 shows intuitively that symmetric equilibria are more likely to exist when the competing manufacturers have the same market size (i.e., $\theta_1 = \theta_2 = 0.5$), whereas asymmetric equilibria are more likely to exist when the competing manufacturers have differential market sizes (e.g., $\theta_1 = 0.8$, $\theta_2 = 0.2$). It is also worthy to note that asymmetric strategies arise even under a symmetric environment as shown in Figure 9 (a, c, d, e). We thus illustrate when and how asymmetric strategies arise under a symmetric environment (i.e., $\theta_1 = \theta_2 = 0.5$).

Operating in distinct channels with little overlap can be one approach for manufacturers to mitigate the intense competition. Figure 9 develops the understanding of this approach by positioning the strategy profile (D,R) or (R,D) at equilibrium in terms of different parameter values. Operating in separate channels can be an effective approach when c^R is relatively lower than c^D. Although the retail channel can create more profits with a relatively lower c^R, in this case, operating in the retail channel provides manufacturers with similar returns as operating in the direct channel because of the compensation to intermediaries. Therefore, strategy profile (D,R) or (R,D) is more likely to be preferred when manufacturers can receive similar net profits from the two channels. In another case when c^R is relatively higher than c^D, Figure 9(d) shows that the competition can reach equilibrium (D,R) or (R,D) when two products are highly substitutable (high β) and the consumers' willingness to accept their less preferred channels is low (low η). The direct channel and retail channel are thus relatively isolated with each other in this case as customers are more likely to remain within the same channel and purchase another product as an alternative. As such, choosing separate channels can mitigate channel conflict and benefit both manufacturers.

Manufacturers can reach the asymmetric equilibrium (D,RD) or (RD,D) when c^R is relatively lower than c^D and the consumers' willingness to accept their less preferred channels is low, as shown in Figure 9 (a, c, d, e), whereas the asymmetric equilibrium (R,RD) or (RD,R) can occur when c^R is relatively higher than c^D, the consumers' willingness to accept their less preferred channels is low, and two products are highly substitutable, as shown in Figure 9 (d). A common condition is that the consumers' willingness to accept their less preferred channels is low, i.e., η is low. Thus, strategy RD can avoid the manufacturer's potential loss because of the low η. An interesting phenomenon is that with the low η, manufacturers may reach equilibrium (D,RD) or (RD,D) when c^D is relatively higher and reach equilibrium (R,RD) or (RD,R) when c^D is relatively higher. This corroborates our previous argument that the cost structure is not the only factor that influences the manufacturers' channel selection.

Therefore, symmetric or asymmetric strategies are not an exclusive result from the symmetric or asymmetric environment. That is, symmetric strategies can arise under an asymmetric environment and asymmetric strategies can arise even under a symmetric environment. Selecting symmetric strategies under an asymmetric environment can be primarily driven by the cost structure, in which manufacturers tend to lower their operating cost. While selecting asymmetric strategies under a symmetric environment can be triggered by other non-cost factors such as the channel conflict and consumers' low channel loyalty.

Finally, Figure 9 exhibits that manufacturers may not always reach a Nash equilibrium in this channel competition game. The environment is dynamic, and the cost structure and customer preference are not always constant. Once the environmental factors have changed, each manufacturer's channel selection and reaction may vary accordingly. Therefore, manufacturers must continuously adjust their distribution channels in order to satisfy the industrial environmental changes.

4.2.3. Pareto optimality

Next, we check whether the derived Nash equilibria are optimal for both manufacturers. Following Chiang et al. (2003) and Matsui (2016), the Nash equilibrium strategy profile (S_1, S_2) that makes both manufacturers better off than those in the strategy profile (R,R) is defined as Pareto optimal. Proposition 4 provides conditions a Nash equilibrium must meet if it is Pareto optimal, i.e., both manufacturers are more profitable than those in strategy profile (R,R). Each equilibrium strategy profile (S_1, S_2) represents the competing manufacturers' channel strategy at Nash equilibrium; the fractions of the brand-driven component of total demand that is captured by the competing manufacturers are θ_1 and θ_2 $(\theta_1+\theta_2=1)$, respectively. Let $\pi_M^{\theta_1}(S_1,S_2)$ denote the profit of the manufacturer with strategy S_1, demand fraction θ_1, and facing a competitor with strategy S_2; similarly, let $\pi_M^{\theta_2}(S_2,S_1)$ denote the profit of the manufacturer with strategy S_2, demand fraction θ_2 and facing a competitor with strategy S_1.

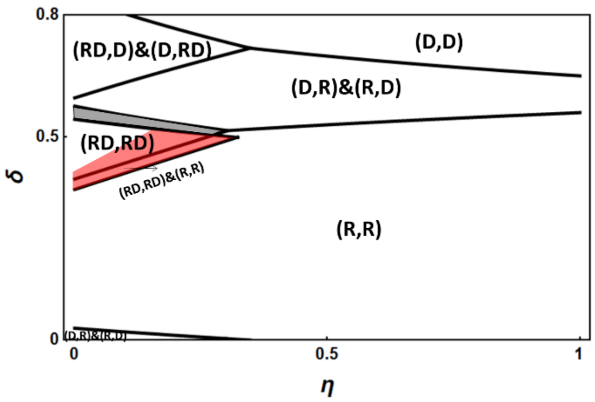
Proposition 4. *Nash equilibria between the manufacturers can be Pareto optimal:*
(1) when $\pi_M^{\theta_1}(D,D)>\pi_M^{\theta_1}(R,R)$ *and* $\pi_M^{\theta_2}(D,D)>\pi_M^{\theta_2}(R,R)$*, the equilibrium strategy profile (D,D) is Pareto optimal;*
(2) when $\pi_M^{\theta_1}(RD,RD)>\pi_M^{\theta_1}(R,R)$ *and* $\pi_M^{\theta_2}(RD,RD)>\pi_M^{\theta_2}(R,R)$*, the equilibrium strategy profile (RD,RD) is Pareto optimal;*
(3) when $\pi_M^{\theta_1}(R,D)>\pi_M^{\theta_1}(R,R)$*, the equilibrium strategy profile (R,D) is Pareto optimal;*
(4) when $\pi_M^{\theta_2}(R,D)>\pi_M^{\theta_2}(R,R)$*, the equilibrium strategy profile (D,R) is Pareto optimal;*
(5) when $\pi_M^{\theta_1}(D,RD)>\pi_M^{\theta_1}(R,R)$ *and* $\pi_M^{\theta_2}(RD,D)>\pi_M^{\theta_2}(R,R)$*, the equilibrium strategy profile (D,RD) is Pareto optimal;*
(6) when $\pi_M^{\theta_1}(RD,D)>\pi_M^{\theta_1}(R,R)$ *and* $\pi_M^{\theta_2}(D,RD)>\pi_M^{\theta_2}(R,R)$*, the equilibrium strategy profile (RD,D) is Pareto optimal;*
(7) when $\pi_M^{\theta_1}(R,RD)>\pi_M^{\theta_1}(R,R)$*, the equilibrium strategy profile (R,RD) is Pareto optimal;*
(8) when $\pi_M^{\theta_2}(R,RD)>\pi_M^{\theta_2}(R,R)$*, the equilibrium strategy profile (RD,R) is Pareto optimal.*

In Corollary 3, a special case is considered in the symmetric market where $\theta_1=\theta_2=0.5$. We introduce $\delta_{(S,S)}^R$ to represent the threshold of cost structure that manufacturers in strategy profile (S,S) and strategy profile (R,R) have the same performance ($S\epsilon\{D,RD\}$). Thus, in the symmetric market, $\delta>\delta_{(S,S)}^R$ indicates that symmetric manufacturers in strategy profile (S,S) outperform manufacturers in strategy profile (R,R), whereas $\delta<\delta_{(S,S)}^R$ indicates that symmetric manufacturers in strategy profile (R,R) outperform manufacturers in strategy profile (S,S).

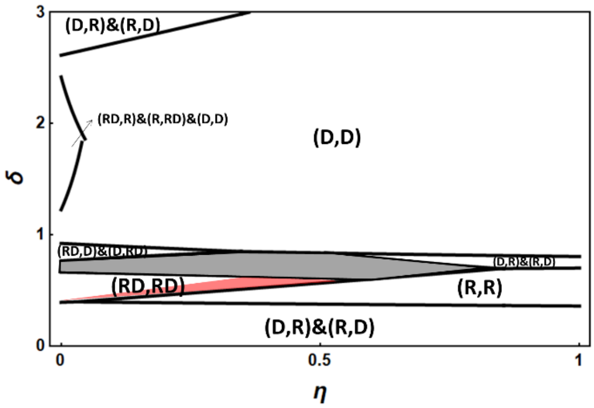
Corollary 3. *In the symmetric market where* $\theta_1=\theta_2=0.5$*: if* $\delta>\delta_{(RD,RD)}^R$*, all of the equilibrium strategy profile (RD,R), (R,RD), and (RD,RD) are Pareto optimal; if* $\delta>\delta_{(D,D)}^R$*, all of the equilibrium strategy profile (R,D), (D,R), and (D,D) are Pareto optimal; if* $\delta>max\left(\delta_{(RD,RD)}^R,\delta_{(D,D)}^R\right)$*, both the equilibrium strategy profile (RD,D) and (D,RD) are Pareto optimal, where* $\delta_{(RD,RD)}^R=\delta_{RD,R}=\frac{\sqrt{(\alpha\eta+1)(\alpha+1)}-1}{\alpha}$ *and* $\delta_{(D,D)}^R=\delta_{D,R}=\frac{\sqrt{\alpha\eta+1}}{2\sqrt{\alpha+\eta}}$*.*

The threshold of cost structure $\delta_{(S,S)}^R$ compares the symmetric equilibria (D,D) and (RD,RD) with the initial strategy profile (R,R); Corollary 3 connects this threshold in symmetric equilibria with other asymmetric equilibria and examines how this threshold explains the optimality of asymmetric equilibria. The definition of $\delta_{(S,S)}^R$ represents that, in the symmetric market, $\delta>\delta_{(S,S)}^R$ is a necessary and sufficient condition of the equilibrium strategy profile (S,S)'s Pareto optimality. The results in Corollary 3 extend this and show that $\delta>\delta_{(S,S)}^R$ is a sufficient condition of the Pareto optimality of the equilibrium strategy profile (S,R) and (R,S) $(S\epsilon\{D,RD\})$, and the intersection of $\delta>\delta_{(RD,RD)}^R$ and $\delta>\delta_{(D,D)}^R$ is a sufficient condition of the Pareto optimality of the equilibrium strategy profile (RD,D) and (D,RD). A key implication of Corollary 3 is that Nash equilibria are more likely to be Pareto optimal if the operating cost in the retail channel is relatively larger than that in the direct channel. This is easily interpretable as seeking for alternative channel strategies (e.g., strategy D and strategy RD) might bring more profits under the condition that operating in the retail channel is costly.

Of course, this does not explicate that Nash equilibria cannot be Pareto optimal if the operating cost in the retail channel is relatively lower than that in the direct channel. Further conditions provided in Proposition 4 is required for a comprehensive discussion. Figure 10 illustrates the results from both Proposition 4 and Corollary 3 for the same parameter values as in Figure 9(a) and Figure 9(d). Although the equilibrium strategy profile (RD,RD) is not always Pareto optimal when the operating cost in the retail channel is relatively lower than that in the direct channel, the equilibrium strategy profile (D,R) or (R,D) is more efficient for manufacturers under a low level of the cost structure. As such, when the relative operating cost in the retail channel is low, both manufacturers may select strategy R at equilibrium; when this cost is getting lower, selecting different single-channel strategies, i.e., strategy profile (D,R) or (R,D), can make both manufacturers better off (as Pareto optimality).



(a) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$



(b) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.9,\ \lambda = 0.7$

Note. Strategy portfolio (S_1, S_2) $(S_1, S_2 \epsilon \{D, R, RD\})$ *indicates the Nash equilibrium in a segment. Grey segments indicate that there is no Nash equilibrium in these segments, whereas red segments indicate that the equilibrium strategy profile (RD,RD) are not Pareto optimal in these segments.*

Figure 10 Pareto optimality

4.3. Manufacturer-Stackelberg

In this section, we extend our model by investigating the case of Manufacturer-Stackelberg where the manufacturers are the Stackelberg leaders and the retailer is the follower (Choi, 1991). We intend to see if the manufacturers can reach Nash equilibria when they are more powerful in the market. The game is constructed with the following sequence of moves. If a manufacturer uses strategy RD, this manufacturer follows the retail price as the direct price; if a manufacturer uses strategy D, this manufacturer decides its direct price. As such, if both manufacturers select the same channel strategy, they set the wholesale prices (in strategy R or RD) or direct prices (in strategy D) simultaneously. Otherwise, if the manufacturers select different strategies, they set the wholesale price(s) and the direct price simultaneously before the retailer sets the retail price(s). Figure 11 illustrates the sequence of the game.

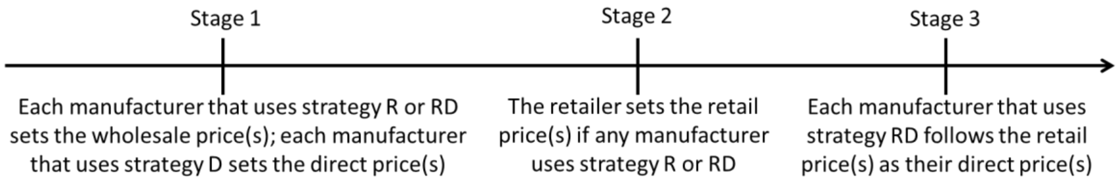
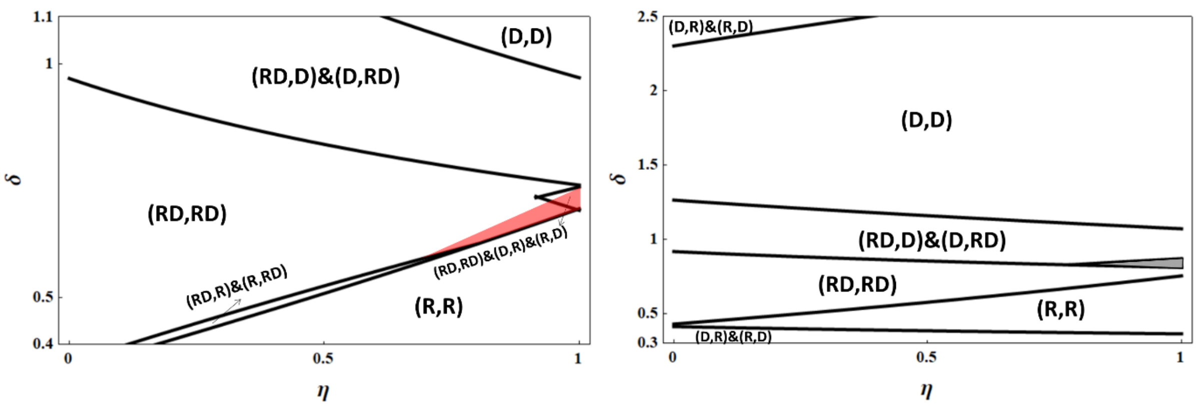


Figure 11 Sequence of events

Based on the same rationale that both manufacturers are seeking profit maximization, we obtain the threshold of cost structure that strategy S_a and strategy S_b have the same performance (see $\delta_{S_a,S_b}^{S_c}$ in Appendix, $S_a, S_b, S_c \epsilon \{D, R, RD\}$) in the case of Manufacturer-Stackelberg. With this threshold, the conditions of Nash equilibria (following Proposition 2 and Proposition 3) and Pareto optimality (following Proposition 4) are derived. Figure 12 illustrates the results for the same parameter values as in Figure 12(a) and Figure 12(b). The red segment in Figure 12(a) shows that the manufacturers may reach any of the equilibrium strategy profile (RD,RD), (D,R), and (R,D), while only strategy profile (D,R) and (R,D) are Pareto optimal; Figure 12(b) shows the case that all the equilibrium strategy profiles are Pareto optimal. A key observation is the similarity of these equilibria to that displayed in Figure 10, i.e., symmetric manufacturers can adopt symmetric or even asymmetric strategies as Nash equilibria and also that there are situations where no Nash equilibrium exists regardless of the sequence of the game. Another observation is that although the equilibrium strategy profile (RD,RD) is not always Pareto optimal when the operating cost in the retail channel is relatively lower than that in the direct channel, the equilibrium strategy profile (D,R) or (R,D) is more efficient for manufacturers under a low level of the cost structure.



(a) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.7,\ \lambda = 0.7$ (b) $\theta_1 = \theta_2 = 0.5,\ \alpha = 1,\ \beta = 0.9,\ \lambda = 0.7$

Note. Strategy portfolio (S_1, S_2) $(S_1, S_2 \epsilon \{D, R, RD\})$ *indicates the Nash equilibrium in a segment. Grey segments indicate that there is no Nash equilibrium in these segments, whereas red segments indicate that the equilibrium strategy profile (RD,RD) are not Pareto optimal in these segments.*

Figure 12 Pareto optimality in Manufacturer-Stackelberg

5. Conclusions

New selling platforms have brought about opportunities, as well as challenges, for upstream manufacturers. Although the dual-channel strategy that integrates both retail platforms and direct selling seems to be more profitable for manufacturers, different channel strategies have been adopted by manufacturers from various industries selling different products. To discover the feasibility of different channel strategies and explore their range of applications, we develop a model to analyze manufacturer's channel selections between single-channel strategies and a dual-channel strategy. Apart from a single manufacturer's decision, we also add the action of a competitor and compare the change of a manufacturer's channel preference. The game in this paper is described through the subgame perfect Nash equilibrium and we provide the equilibrium analysis.

Manufacturers' decisions to adopt a single-channel or multi-channel strategy are the main focus of this paper. There is not a single best channel strategy in different scenarios. According to the comparison between the case of a single manufacturer and the case of two competing manufacturers, we find that although consumers' channel preferences and cost structures play different roles when the manufacturer is facing a competitor with distinct strategies, it is difficult to capture these roles thoroughly if only considering a single manufacturer's channel strategy. A manufacturer may prefer a direct-channel strategy when the direct operating cost is much lower than the retail operating cost. When the manufacturer is facing a single retail-channel competitor, however, the manufacturer may consider the competitor's influence and switch to a dual-channel strategy even when the direct operating cost is much lower than the retail operating cost. This implies that bias may exist when the manufacturer only considers the interaction with the retailer; in fact, things have changed dramatically when competitors exist. Therefore, apart from the interaction with downstream retailers, it is necessary for manufacturers to consider horizontal competitors' actions when making decisions.

Competing manufacturers can reach different Nash equilibria under a variety of exogenous parameters, and also there are situations where no Nash equilibrium exists. Symmetric or asymmetric strategies are not an exclusive result from the symmetric or asymmetric environment. That is, symmetric strategies can arise under an asymmetric environment and asymmetric strategies can arise even under a symmetric environment. The analysis of Pareto efficiency adds to this and shows that both manufacturers can be better off with different equilibrium strategies. This applies to both a retailer-leading setting and a manufacturer-leading setting where the manufacturers are the Stackelberg leaders or followers in the game with the retailer. The manufacturers' channel strategy is thus a function of exogenous parameters, such as customers' channel preference, channels' cost structure, and competitors' channel strategy, which may vary over time. Manufacturers must continuously adjust their distribution channels in order to satisfy the industrial environmental changes.

Several possible directions for future research follow this study. Although we have considered a consistent pricing scenario in this paper, there are still some companies that distinguish the pricing decision between channels as swim lanes instead of integration. Future work could consider the impact of different pricing schemes on manufacturers' channel preferences, and other factors such as return policies and product characteristics could also be considered as factors that affect their channel decisions. In addition, the main concern in this paper is the role of competition. Future research could also consider the roles of both competition and cooperation within manufacturers' channel strategies.

Appendix

Notations

Table Appx 1. Notations

Notation	Explanation
α^D	The number of the consumers who prefer the direct channel ($\alpha^D > 0$).
α^R	The number of the consumers who prefer the retail channel ($\alpha^R > 0$).
α	$\alpha = \alpha^D/\alpha^R > 0$, reflecting the difference of the consumers' size in the direct and the retail channels.
η	The discount coefficient of demand due to consumers' channel mismatch ($\eta\epsilon[0,1]$), describing the degree of consumers' acceptance of their less preferred channels.
θ_i	The fraction of the brand-driven component of total demand that is captured by manufacturer $i(i = 1,2)$, where $\theta_i \in [0,1]$ and $\theta_1 + \theta_2 = 1$. Therefore, θ_1 of the consumers will prefer the product from one manufacturer and θ_2 of the consumers will prefer that from another manufacturer.
λ	The consumers' acceptance of their less preferred products due to the lack of another product ($\lambda \in [0,1]$). A low (high) parameter λ denotes a high (low) level of consumer loyalty towards their preferred brand.
β	The degree to which the two manufacturers' products are substitutable ($\beta \in (0,1)$).
p_i	Selling price in the market ($p_i \in [0,1], i = 1,2$).
w_i	The manufacturer(s)' wholesale price ($w_i \in [0,1], i = 1,2$).
c^R	The operating cost in the retail channel ($c^R \in (0,1)$).
c^D	The operating cost in the direct channel ($c^R \in (0,1)$).
δ	The relative cost structure in direct and indirect channels.
π_M	The profit of the manufacturer.
π_R	The profit of the retailer.

Proof of payoffs in Table 2

When the manufacturer adopts strategy RD, the manufacturer and the retailer's profit functions are:

$$\pi_M(RD) = (p - c^D)d^D(RD) + wd^R(RD) = [\alpha^D(p - c^D) + w\alpha^R](1 - p);$$

$$\pi_R(RD) = (p - w - c^R)d^R(RD) = \alpha^R(p - w - c^R)(1 - p).$$

Let m denote the retailer's margin, i.e., $m = p - w - c^R$. We have $d\pi_M(RD)/dw = \alpha^R(1 - c^R - m - 2w + \alpha + \alpha c^D - 2\alpha c^R - 2m\alpha - 2w\alpha)$. Thus, if $d\pi_M(RD)/dw = 0$, the optimal wholesale price is $w = (1 - c^R - m + \alpha + \alpha c^D - 2\alpha c^R - 2m\alpha)/[2(1 + \alpha)]$ where $d^2\pi_M(RD)/dw^2 = -2(\alpha^D + \alpha^R) < 0$. Thus, the manufacturer's profit function is concave, and there exists an optimal wholesale price. Substitute the above equation into the manufacturer's profit function, and we have $d\pi_R(RD)/dm = \alpha^R(1 - c^R - 2m + \alpha - \alpha c^D)/[2(1 + \alpha)]$, $d^2\pi_R(RD)/dm^2 < 0$. Thus, the retailer's profit function is concave, and the best response of the selling price is $m = (1 - c^R + \alpha - \alpha c^D)/2$. Substitute the above optimal prices into the wholesale price's function, the selling price's function and the manufacturer's profit function, and we have the optimal prices and profits. Thus, solving the first-order condition gives the optimal solutions under strategy D, R, and RD, as shown in Table 2.

Proof of Proposition 1

The results in Proposition 1 follow directly from a pair-wise comparison of the profits in different channel strategies listed in Table 2. For example, comparing the manufacturer's profits in strategy D and

R, we have $\Delta\pi_M(R-D) = \pi_M(R) - \pi_M(D) = \alpha_R(1-c_R)^2[-4(\alpha+\eta)\delta^2 + \alpha\eta + 1]/16$. Thus, we have $\pi_M(R) > \pi_M(D)$ when $0 < \delta < \sqrt{(1+\alpha\eta)/[4(\alpha+\eta)]} = \delta_{D,R}$, and $\pi_M(R) < \pi_M(D)$ when $\delta > \delta_{D,R}$. Similarly, we have $\delta_{RD,R}$ and $\delta_{D,RD}$:

$$\delta_{D,RD} = \frac{\alpha+2\sqrt{(\alpha+\eta)(\alpha+1)}}{3\alpha^2+4\alpha+4\eta+4\alpha\eta}; \ \delta_{RD,R} = \frac{\sqrt{(\alpha\eta+1)(\alpha+1)}-1}{\alpha}; \ \delta_{D,R} = \frac{\sqrt{\alpha\eta+1}}{2\sqrt{\alpha+\eta}}.$$

Then, the manufacturer would choose: strategy R when $\delta < \delta_{RD,R}$ and $\delta < \delta_{D,R}$; strategy D when $\delta > \delta_{D,RD}$ and $\delta > \delta_{D,R}$; strategy RD when $\delta_{RD,R} < \delta < \delta_{D,RD}$, if $\delta_{RD,R} < \delta_{D,RD}$.

Proof of Corollary 1

$\delta_{RD,R} - 1 = \frac{\sqrt{(\alpha\eta+1)(\alpha+1)}-1}{\alpha} - 1 = \frac{[\sqrt{\alpha\eta+1}-\sqrt{\alpha+1}]\sqrt{(\alpha+1)}}{\alpha}$. Thus $\delta_{RD,R} = 1$ if $\eta = 1$; $\delta_{RD,R} < 1$ if $0 \le \eta < 1$

Proof of Proposition 2

(1) Calculation of the manufacturer's optimal profits

We begin with the case when the competitor is adopting strategy RD and the manufacturer is adopting strategy RD since the calculations in the other cases are similar. The competitor, the manufacturer and the retailer's profit functions are:

$\pi_C(RD,R) = (p_2 - c^D)d_2^D(RD,RD) + w_2 d_2^R(RD,RD) = (p_2 - c^D)\alpha^D\theta_2(1-p_2+\beta p_1) + w_2\alpha^R\theta_2(1-p_2+\beta p_1)$,

$\pi_M(RD,R) = (p_1 - c^D)d_1^D(RD,RD) + w_1 d_1^R(RD,RD) = (p_1 - c^D)\alpha^D\theta_1(1-p_1+\beta p_2) + w_1\alpha^R\theta_1(1-p_1+\beta p_2)$,

$\pi_R(RD,R) = (p_1 - w_1 - c^R)d_1^R(RD,RD) + (p_2 - w_2 - c^R)d_2^R(RD,RD) = (p_1 - w_1 - c^R)\alpha^R\theta_1(1-p_1+\beta p_2) + (p_2 - w_2 - c^R)\alpha^R\theta_2(1-p_2+\beta p_1)$.

Let m_i denote the retailer's margin, i.e., $m_i = p_i - w_i - c^R$, $i = 1,2$. We have $d^2\pi_C/d{w_2}^2 = d^2\pi_M/d{w_1}^2 = -2(\alpha^D + \alpha^R) < 0$. Thus, the manufacturer's profit function is concave in w_1 and the competitor's profit function is concave in w_2. When $d\pi_M/dw_1 = d\pi_C/dw_2 = 0$, the optimal wholesale prices are

$$w_1 = \frac{2+2\alpha+2\alpha c^D+\beta(1+m_2+\alpha+\alpha c^D)+c^R(2+\beta)(-1-2\alpha+\alpha\beta+\beta)+m_1(-2+\beta^2-4\alpha+\alpha\beta^2)}{(1+\alpha)(4-\beta^2)};$$

$$w_2 = \frac{2+2\alpha+2\alpha c^D+\beta(1+m_1+\alpha+\alpha c^D)+c^R(2+\beta)(-1-2\alpha+\alpha\beta+\beta)+m_2(-2+\beta^2-4\alpha+\alpha\beta^2)}{(1+\alpha)(4-\beta^2)}.$$

Substitute the above equations into the retailer's profit function, we have

$$\frac{\partial^2\pi_R}{\partial {m_1}^2}\frac{\partial^2\pi_R}{\partial {m_2}^2} - \left(\frac{\partial^2\pi_R}{\partial m_1 m_2}\right)^2 = \left[\frac{\alpha^R}{(1+\alpha)(4-\beta^2)}\right]^2 [16\theta_1\theta_2 + 4\beta^4\theta_1\theta_2 - \beta^2(1+16\theta_1\theta_2)].$$

Thus, the retailer's profit function is concave if $16\theta_1\theta_2 + 4\beta^4\theta_1\theta_2 - \beta^2(1+16\theta_1\theta_2) > 0$. When $\partial\pi_R/\partial m_1 = \partial\pi_R/\partial m_2 = 0$, we have

$$m_1 = \frac{(2+\beta)\theta_2(1+\alpha-\alpha c^D-c^R+c^R\beta+\alpha c^D\beta)(4\theta_1+\beta\theta_1-2\theta_1\beta^2+\beta\theta_2)}{16\theta_1\theta_2+4\beta^4\theta_1\theta_2-\beta^2(1+16\theta_1\theta_2)};$$

$$m_2 = \frac{(2+\beta)\theta_1(1+\alpha-\alpha c^D-c^R+c^R\beta+\alpha c^D\beta)(4\theta_2+\beta\theta_2-2\theta_2\beta^2+\beta\theta_1)}{16\theta_1\theta_2+4\beta^4\theta_1\theta_2-\beta^2(1+16\theta_1\theta_2)}.$$

Substitute the above equations into the price and profit functions, we have the manufacturer's optimal profits. The calculation in the other cases are similar and the profit functions are always concave, except the strategy profile (R,R) where the retailer's profit function is concave if $16\theta_1\theta_2 + 4\beta^4\theta_1\theta_2 - \beta^2(1 + 16\theta_1\theta_2) > 0$.

(2) Calculation of the boundary $\delta_{S_a,S_b}^{S_c}$

The above calculation results show that, in each case, the manufacturer's optimal profits follow the format of $\pi_M(S_a,S_c) = [M(S_a,S_c) + N(S_a,S_c)\delta]^2$. Thus, $\pi_M(S_a,S_c) - \pi_M(S_b,S_c) = [M(S_a,S_c) + N(S_a,S_c)\delta]^2 - [M(S_b,S_c) + N(S_b,S_c)\delta]^2 = [N(S_a,S_c)^2 - N(S_b,S_c)^2]\delta^2 + 2[M(S_a,S_c)N(S_a,S_c) - M(S_b,S_c)N(S_b,S_c)]\delta + [M(S_a,S_c)^2 - M(S_b,S_c)^2]$. When $\pi_M(S_a,S_c) - \pi_M(S_b,S_c) = 0$,

$$\delta = \frac{-M(S_a,S_c)N(S_a,S_c)+M(S_b,S_c)N(S_b,S_c)\pm|M(S_a,S_c)N(S_b,S_c)-M(S_b,S_c)N(S_a,S_c)|}{N(S_a,S_c)^2-N(S_b,S_c)^2}.$$

Thus, if $N(S_a,S_c)^2 \neq N(S_b,S_c)^2$ and $M(S_a,S_c)N(S_b,S_c) > M(S_b,S_c)N(S_a,S_c)$,

$$\delta_{S_a,S_b}^{S_c} = -\frac{M(S_a,S_c)+M(S_b,S_c)}{N(S_a,S_c)+N(S_b,S_c)},\ \delta_{S_b,S_a}^{S_c} = -\frac{M(S_a,S_c)-M(S_b,S_c)}{N(S_a,S_c)-N(S_b,S_c)}.$$

We thus have:

$$M(D,D) = 0;\ N(D,D) = \frac{\sqrt{(\alpha+\eta)\theta_1}}{2-\beta};$$

$$M(R,D) = -\frac{(2-\beta^2)\sqrt{2+\alpha\eta\theta_1(2-\lambda)-\theta_2(2-2\lambda+\eta\lambda)}}{2\sqrt{2}(1-\beta)(4-\beta^2)};\ N(R,D) = \frac{\beta\sqrt{2+\alpha\eta\theta_1(2-\lambda)-\theta_2(2-2\lambda+\eta\lambda)}}{2\sqrt{2}(1-\beta)(4-\beta^2)};$$

$$M(RD,D) = \frac{\theta_1\left(4-2\beta^2-4\lambda+2\eta\lambda+2\beta^2\lambda-\eta\lambda\beta^2\right)+\left(2-\beta^2\right)(2-\eta)\lambda}{2\sqrt{2}(1-\beta)(4-\beta^2)\sqrt{2\lambda-\eta\lambda+\theta_1(2+2\alpha-2\lambda+\eta\lambda)}};$$

$$N(RD,D) = \frac{\theta_1\left(4\alpha-2\alpha\beta^2-2\beta-2\alpha\beta+2\beta\lambda-\beta\eta\lambda\right)-\beta(2-\eta)\lambda}{2\sqrt{2}(1-\beta)(4-\beta^2)\sqrt{2\lambda-\eta\lambda+\theta_1(2+2\alpha-2\lambda+\eta\lambda)}};$$

$$M(D,R) = \frac{\beta\sqrt{\alpha\eta\theta_1(2-\lambda)-\alpha\theta_1(2-2\lambda+\eta\lambda)+\alpha\lambda(2-\eta)}}{2\sqrt{2}(1-\beta)(4-\beta^2)};$$

$$N(D,R) = \frac{\left(8-9\beta^2+2\beta^4\right)\sqrt{\alpha\eta\theta_1(2-\lambda)-\alpha\theta_1(2-2\lambda+\eta\lambda)+\alpha\lambda(2-\eta)}}{2\sqrt{2}(1-\beta)(4-\beta^2)(2-\beta^2)};$$

$$M(R,R) = (1+\beta)\theta_2\sqrt{\frac{(1+\alpha\eta)\theta_1(\beta-4\theta_1+2\theta_1\beta^2)^2}{[16\theta_1\theta_2+4\beta^4\theta_1\theta_2-\beta^2(1+16\theta_1\theta_2)]^2}};\ N(R,R) = 0;$$

$$M(RD,R) = \frac{(1+\beta)\theta_2(2+2\alpha\eta-\alpha\eta\lambda)\left[-4\theta_1+2\beta^2\theta_1+\beta+\alpha\beta(\theta_1+\eta\theta_2-\eta\theta_2\lambda+\theta_2\lambda)\right]\sqrt{2\theta_1+2\alpha\theta_1+2\alpha\lambda\theta_2-\alpha\eta\lambda\theta_2}}{2\sqrt{2}\sqrt{\left\{\begin{array}{c}(4+\beta^4)\theta_2(2+2\alpha\eta-\alpha\eta\lambda)(2\theta_1+2\alpha\theta_1+2\alpha\lambda\theta_2-\alpha\eta\lambda\theta_2)-\beta^2\left(1+16\theta_2-16{\theta_2}^2\right)\\+2\alpha\beta^2\left(9\theta_1-8{\theta_1}^2+\eta\theta_2+8\eta\theta_1\theta_2+9\theta_2\lambda-5\eta\theta_2\lambda-8\theta_1\theta_2\lambda\right)+8\alpha^2\beta^2\\-2\theta_2\alpha^2\beta^2(1-\lambda+\eta(-9+5\lambda))+{\theta_2}^2\alpha^2\beta^2[(1-\lambda)(1-18\eta-\lambda+10\eta\lambda)+\eta^2(1-10\lambda+5\lambda^2)]\end{array}\right\}^2}};$$

$$N(RD,R) = \frac{(1+\beta)\theta_2(2+2\alpha\eta-\alpha\eta\lambda)\alpha(-2+\beta^2)(2\theta_1+2\theta_1\lambda-\theta_2\eta\lambda)\sqrt{2\theta_1+2\alpha\theta_1+2\alpha\lambda\theta_2-\alpha\eta\lambda\theta_2}}{2\sqrt{2}\sqrt{\left\{\begin{array}{c}(4+\beta^4)\theta_2(2+2\alpha\eta-\alpha\eta\lambda)(2\theta_1+2\alpha\theta_1+2\alpha\lambda\theta_2-\alpha\eta\lambda\theta_2)-\beta^2\left(1+16\theta_2-16{\theta_2}^2\right)\\+2\alpha\beta^2\left(9\theta_1-8{\theta_1}^2+\eta\theta_2+8\eta\theta_1\theta_2+9\theta_2\lambda-5\eta\theta_2\lambda-8\theta_1\theta_2\lambda\right)+8\alpha^2\beta^2\\-2\theta_2\alpha^2\beta^2(1-\lambda+\eta(-9+5\lambda))+{\theta_2}^2\alpha^2\beta^2[(1-\lambda)(1-18\eta-\lambda+10\eta\lambda)+\eta^2(1-10\lambda+5\lambda^2)]\end{array}\right\}^2}};$$

$$M(D,RD) = \frac{-\left[2\alpha\left(8-2\beta-9\beta^2+\beta^3+2\beta^4\right)\theta_2+\left(8-9\beta^2+2\beta^4\right)(2\theta_2+2\theta_1\lambda-\eta\theta_1\lambda)\right]\sqrt{\theta_1(2\alpha+2\eta-\eta\lambda)}}{2\sqrt{2}(1-\beta)(4-\beta^2)(2\theta_2+2\alpha\theta_2+2\theta_1\lambda-\eta\theta_1\lambda)};$$

$$N(D,RD) = \frac{\beta(2\theta_2+2\theta_1\lambda-\eta\theta_1\lambda)\sqrt{\theta_1(2\alpha+2\eta-\eta\lambda)}}{2\sqrt{2}(1-\beta)(4-\beta^2)(2-\beta^2)(2\theta_2+2\alpha\theta_2+2\theta_1\lambda-\eta\theta_1\lambda)};$$

$$M(R,RD) =$$

$$\frac{\left[2\beta\theta_2(1+\alpha\theta_2+\alpha\eta\theta_1+\alpha\theta_1\lambda-\alpha\eta\theta_1\lambda)-(2-\beta^2)\theta_1(2+2\alpha\eta-\alpha\eta\lambda)(2\alpha\theta_2+2\theta_2+2\alpha\theta_1\lambda-\alpha\eta\theta_1\lambda)\right](1+\beta)\sqrt{\theta_1(2+2\alpha\eta-\alpha\eta\lambda)}}{2\sqrt{2}\sqrt{\left\{\begin{matrix}(4+\beta^4)\theta_1(2+2\alpha\eta-\alpha\eta\lambda)(2\theta_2+2\alpha\theta_2+2\alpha\theta_1\lambda-\alpha\eta\theta_1\lambda)-\beta^2-16\theta_1\beta^2+16{\theta_1}^2\beta^2\\+2\alpha\beta^2\left(-1-7\theta 1-9\eta\theta_1+8{\theta_1}^2+8\eta{\theta_1}^2-\theta_1\lambda+5\eta\theta_1\lambda-8{\theta_1}^2\lambda\right)-\alpha^2\beta^2\\+2\theta_1\alpha^2\beta^2(1-9\eta-\lambda+5\eta\lambda)-{\theta_1}^2\alpha^2\beta^2[(1-\lambda)(1-18\eta-\lambda+10\eta\lambda)+\eta^2(1-10\lambda+5\lambda^2)]\end{matrix}\right\}^2}};$$

$$N(R,RD)=\frac{\alpha\beta(1+\alpha\theta_2+\alpha\eta\theta_1+\alpha\theta_1\lambda-\alpha\eta\theta_1\lambda)(2\theta_2+2\theta_1\lambda-\eta\theta_1\lambda)(1+\beta)\sqrt{\theta_1(2+2\alpha\eta-\alpha\eta\lambda)}}{2\sqrt{2}\sqrt{\left\{\begin{matrix}(4+\beta^4)\theta_1(2+2\alpha\eta-\alpha\eta\lambda)(2\theta_2+2\alpha\theta_2+2\alpha\theta_1\lambda-\alpha\eta\theta_1\lambda)-\beta^2-16\theta_1\beta^2+16{\theta_1}^2\beta^2\\+2\alpha\beta^2\left(-1-7\theta 1-9\eta\theta_1+8{\theta_1}^2+8\eta{\theta_1}^2-\theta_1\lambda+5\eta\theta_1\lambda-8{\theta_1}^2\lambda\right)-\alpha^2\beta^2\\+2\theta_1\alpha^2\beta^2(1-9\eta-\lambda+5\eta\lambda)-{\theta_1}^2\alpha^2\beta^2[(1-\lambda)(1-18\eta-\lambda+10\eta\lambda)+\eta^2(1-10\lambda+5\lambda^2)]\end{matrix}\right\}^2}};$$

$$M(RD,RD)=(1+\beta)\theta_2\sqrt{\frac{\theta_1(\beta-4\theta_1+2\theta_1\beta^2)^2}{(1+\alpha)[16\theta_1\theta_2+4\beta^4\theta_1\theta_2-\beta^2(1+16\theta_1\theta_2)]^2}};$$

$$N(RD,RD)=(1+\beta)\alpha\theta_2\sqrt{\frac{\theta_1(\beta-4\theta_1+2\theta_1\beta^2)^2}{(1+\alpha)[16\theta_1\theta_2+4\beta^4\theta_1\theta_2-\beta^2(1+16\theta_1\theta_2)]^2}}.$$

Proof of Proposition 3

If two manufacturers, i.e., the fractions of the brand-driven component of total demand that is captured by the competing manufacturers are θ_1 and θ_2, reaches the Nash equilibrium at strategy profile (S_1,S_2) $(S_1,S_2\epsilon\{D,R,RD\})$, two conditions are satisfied simultaneously: (1) strategy S_1 is the best strategy facing a competitor with θ_2 of total demand and strategy S_2; and (2) strategy S_2 is the best strategy facing a competitor with θ_1 of total demand and strategy S_1.

Symmetric equilibria (i.e., $S_1=S_2$) thereby exist when strategy $S_1(=S_2)$ is the best strategy facing a competitor (no matter with θ_1 or θ_2 of total demand) with strategy $S_1(=S_2)$. We can thus conclude the conditions of symmetric equilibria through Proposition 2. For example, strategy profile (D,D) is a Nash equilibrium both when strategy D is the best strategy facing a competitor with θ and strategy D (i.e., $\delta\epsilon Z_{D>R}^{(D,\theta_2)}\cap Z_{D>RD}^{(D,\theta_2)}$) and when strategy D is the best strategy facing a competitor with $1-\theta$ and strategy D (i.e., $\delta\epsilon\ Z_{D>R}^{(D,\theta_1)}\cap Z_{D>RD}^{(D,\theta_1)}$). Therefore, when $\delta\epsilon\ Z_{D>R}^{(D,\theta_1)}\cap Z_{D>RD}^{(D,\theta_1)}\cap Z_{D>R}^{(D,\theta_2)}\cap Z_{D>RD}^{(D,\theta_2)}$, (D,D) is a Nash equilibrium.

Asymmetric equilibria (i.e., $S_1\neq S_2$) exist when strategy profile (S_1,S_2) satisfies the two conditions above. For example, strategy profile (R,D) is a Nash equilibrium both when strategy D is the best strategy facing a competitor with θ_1 and strategy R (i.e., $\delta\epsilon Z_{D>R}^{(R,\theta_2)}\cap Z_{D>RD}^{(R,\theta_2)}$) and when strategy R is the best strategy facing a competitor with θ_2 and strategy D (i.e., $\delta\epsilon\ Z_{R>D}^{(R,\theta_1)}\cap Z_{R>RD}^{(R,\theta_1)}$). Therefore, when $\delta\epsilon Z_{R>D}^{(D,\theta_1)}\cap Z_{R>RD}^{(D,\theta_1)}\cap Z_{D>R}^{(R,\theta_2)}\cap Z_{D>RD}^{(R,\theta_2)}$, (R,D) is a Nash equilibrium.

If the intersection between the two conditions does not exist, there is no Nash equilibrium.

Proof of Corollary 2

Corollary 2 is a special case of Proposition 3, i.e., $\theta_1=\theta_2=0.5$. Thus the conditions of θ or $1-\theta$ don't limit the Nash equilibria. If the competition reaches the Nash equilibrium at strategy profile (S_1,S_2) $(S_1,S_2\epsilon\{D,R,RD\})$, two conditions are satisfied simultaneously: (1) strategy S_1 is the best strategy facing a competitor with strategy S_2; and (2) strategy S_2 is the best strategy facing a competitor with strategy S_2.

Symmetric equilibria (i.e., $S_1 = S_2$) thereby exist when strategy $S_1 (= S_2)$ is the best strategy facing a competitor with strategy $S_1 (= S_2)$. We can thus conclude the conditions of symmetric equilibria through Proposition 2. For example, strategy profile (D,D) is a Nash equilibrium when $\delta \epsilon \ Z_{D>R}^{D} \cap Z_{D>RD}^{D}$;

Asymmetric equilibria (i.e., $S_1 \neq S_2$) exist when strategy profile (S_1, S_2) satisfies the two conditions above. For example, Nash equilibrium (D,R) or (R,D) exists when $\delta \epsilon Z_{R>D}^{D} \cap Z_{R>RD}^{D}$ and $\delta \epsilon \ Z_{D>R}^{R} \cap Z_{D>RD}^{R}$, i.e., when $\delta \epsilon Z_{R>D}^{D} \cap Z_{R>RD}^{D} \cap Z_{D>R}^{R} \cap Z_{D>RD}^{R}$.

If the intersection between the two conditions does not exist, there is no Nash equilibrium.

Proof of Proposition 4

If the equilibrium strategy profile (S_1, S_2) is Pareto optimal, two conditions need to be satisfied simultaneously: $\pi_M^{\theta_1}(S_1, S_2) > \pi_M^{\theta_1}(\mathrm{R}, \mathrm{R})$ and $\pi_M^{\theta_2}(S_2, S_1) > \pi_M^{\theta_2}(\mathrm{R}, \mathrm{R})$.

If strategy profile (D,R) reached Nash equilibrium, strategy D is the best-performed one when facing a competitor with strategy R. Therefore, one of the conditions, i.e., $\pi_M^{\theta_1}(D, R) > \pi_M^{\theta_1}(\mathrm{R}, \mathrm{R})$, has been satisfied. The equilibrium strategy profile (D,R) only needs to satisfy the other condition, i.e., $\pi_M^{\theta_2}(\mathrm{R}, \mathrm{D}) > \pi_M^{\theta_2}(\mathrm{R}, \mathrm{R})$, to be Pareto optimal. The similar conditions apply for the equilibrium strategy profile (R,D), (RD,R), and (R,RD) where one manufacturer selects strategy R.

For equilibrium strategy profile (D,D), (RD,RD), (RD,D) and (D,RD) where none of the manufacturers selects strategy R, they need to satisfy both conditions, i.e., $\pi_M^{\theta_1}(S_1, S_2) > \pi_M^{\theta_1}(\mathrm{R}, \mathrm{R})$ and $\pi_M^{\theta_2}(S_2, S_1) > \pi_M^{\theta_2}(\mathrm{R}, \mathrm{R})$, simultaneously.

Proof of Corollary 3

In the symmetric market where $\theta_1 = \theta_2 = 0.5$, when $\pi_M(D, D) = \pi_M(\mathrm{R}, \mathrm{R})$, we have $\delta_{(\mathrm{D,D})}^{\mathrm{R}} = \frac{\sqrt{\alpha\eta+1}}{2\sqrt{\alpha+\eta}} = \delta_{\mathrm{D,R}}$; when $\pi_M(RD, RD) = \pi_M(\mathrm{R}, \mathrm{R})$, we have $\delta_{(\mathrm{RD,RD})}^{\mathrm{R}} = \frac{\sqrt{(\alpha\eta+1)(\alpha+1)}-1}{\alpha} = \delta_{\mathrm{RD,R}}$.

If strategy profile (D,R) reached Nash equilibrium, strategy D outperforms strategy R when facing a competitor with strategy R and strategy R outperforms strategy D when facing a competitor with strategy D, i.e., we have $\pi_M(D, R) > \pi_M(R, R)$ and $\pi_M(R, D) > \pi_M(D, D)$. Then if the equilibrium strategy profile (D,R) is Pareto optimal, the additional condition is that $\pi_{\mathrm{M}}(\mathrm{R}, \mathrm{D}) > \pi_{\mathrm{M}}(\mathrm{R}, \mathrm{R})$. If the equilibrium strategy profile (RD,RD) is Pareto optimal, we have $\delta > \delta_{(D,D)}^{M}$, i.e., $\pi_M(D, D) > \pi_M(R, R)$; thus when $\pi_M(D, D) > \pi_M(R, R)$, we have $\pi_M(R, D) > \pi_M(D, D) > \pi_M(\mathrm{R}, \mathrm{R})$, i.e., the additional condition of the equilibrium strategy profile (D,R)'s Pareto optimality is satisfied. Thus, if $\delta > \delta_{(D,D)}^{M}$, all of the equilibrium strategy profile (R,D), (D,R), and (D,D) are Pareto optimal. The similar derivation applies to $\delta_{(RD,RD)}^{M}$, i.e., if $\delta > \delta_{(RD,RD)}^{M}$, all of the equilibrium strategy profile (RD,D), (D,RD), and (RD,RD) are Pareto optimal; if $\delta > max\left(\delta_{(RD,RD)}^{M}, \delta_{(D,D)}^{M}\right)$, both the equilibrium strategy profile (RD,D) and (D,RD) are Pareto optimal.

Derivations for the Manufacturer-Stackelberg case

We derive the analytical results in the case of Manufacturer-Stackelberg. Similar to the case of Retailer-Stackelberg, the optimal solutions in each strategy profile are obtained through backward induction. We thus have $\delta_{S_a,S_b}^{S_c} = -\frac{M(S_a,S_c)+M(S_b,S_c)}{N(S_a,S_c)+N(S_b,S_c)}$ and $\delta_{S_b,S_a}^{S_c} = -\frac{M(S_a,S_c)-M(S_b,S_c)}{N(S_a,S_c)-N(S_b,S_c)}$ if $N(S_a,S_c)^2 \neq N(S_b,S_c)^2$ and $M(S_a,S_c)N(S_b,S_c) > M(S_b,S_c)N(S_a,S_c)$. $Z_{S_a>S_b}^{S_c}$ can thus be derived. In the symmetric market where $\theta_1 = \theta_2 = 0.5$, we have:

$$M(D,D) = 0;\ N(D,D) = \frac{\sqrt{\alpha+\eta}}{\sqrt{2}(2-\beta)};\ M(R,R) = \frac{\sqrt{1+\alpha\eta}}{2(2-\beta)};\ N(R,R) = 0;$$

$$M(R,D) = \frac{(4-3\beta^2)\sqrt{2+2\lambda-\eta\lambda+2\alpha\eta-\alpha\eta\lambda}}{2\sqrt{2}(1-\beta)(8-5\beta^2)};\ N(R,D) = -\frac{\beta(2-\beta^2)\sqrt{2+2\lambda-\eta\lambda+2\alpha\eta-\alpha\eta\lambda}}{2\sqrt{2}(1-\beta)(8-5\beta^2)};$$

$$M(RD,D) = \frac{(4-3\beta^2)(2+2\lambda-\eta\lambda)\sqrt{2+2\lambda-\eta\lambda+\alpha}}{2\sqrt{2}(1-\beta)[4\alpha(2-\beta^2)+(8-5\beta^2)(2+2\lambda-\eta\lambda)]};\ M(RD,RD) = \frac{1}{(2-\beta)\sqrt{2(2+\alpha)}};$$

$$N(RD,D) = \frac{[2\alpha(4-2\beta-3\beta^2+\beta^3)-\beta(2-\beta^2)(2+2\lambda-\eta\lambda)]\sqrt{2+2\lambda-\eta\lambda+\alpha}}{2\sqrt{2}(1-\beta)[4\alpha(2-\beta^2)+(8-5\beta^2)(2+2\lambda-\eta\lambda)]};\ N(RD,RD) = \frac{\alpha}{(2-\beta)\sqrt{2(2+\alpha)}};$$

$$M(D,R) = \frac{\beta\sqrt{[\eta(2-\lambda)+\alpha(2+2\lambda-\eta\lambda)](2-\beta^2)}}{2\sqrt{2}(1-\beta)(8-5\beta^2)};\ N(D,R) = -\frac{(4-3\beta^2)\sqrt{[\eta(2-\lambda)+\alpha(2+2\lambda-\eta\lambda)](2-\beta^2)}}{2\sqrt{2}(1-\beta)(8-5\beta^2)};$$

$$M(RD,R) = \frac{\left\{\begin{array}{c}-\beta^2(4+2\alpha\eta-\alpha\eta\lambda)^2+16(2+2\alpha\eta-\alpha\eta\lambda)\\ -4\beta\left[\begin{array}{c}4+2\alpha(3\eta-2\eta\lambda+1+\lambda)\\ +\alpha^2\eta(2-\lambda)(1+\lambda+\eta-\eta\lambda)\end{array}\right]\end{array}\right\}\sqrt{(1+\beta)(2+2\alpha\eta-\alpha\eta\lambda)\left\{\begin{array}{c}(2+2\alpha\eta-\alpha\eta\lambda)(4+2\alpha+2\alpha\lambda-\alpha\eta\lambda)\\ -\beta^2\left[\begin{array}{c}8+\alpha^2\eta(1+\lambda+\eta-\eta\lambda)(2-\lambda)\\ +\alpha(4+4\lambda+8\eta-6\eta\lambda)\end{array}\right]\end{array}\right\}}}{4\sqrt{(1-\beta)\left\{\begin{array}{c}\beta^4[2+\alpha(1+\eta-\eta\lambda+\lambda)](4+2\alpha\eta-\alpha\eta\lambda)^3+32(2+2\alpha\eta-\alpha\eta\lambda)^2(4+2\alpha+2\alpha\lambda-\alpha\eta\lambda)\\ -2\beta^2(2+2\alpha\eta-\alpha\eta\lambda)\left[\begin{array}{c}4\alpha^2\eta(2-\lambda)(5\eta-6\eta\lambda+7+7\lambda)+\alpha^3\eta^2(2-\lambda)^2(2+2\lambda-\eta\lambda)\\ +160+40\alpha(4\eta-3\eta\lambda+2+2\lambda)\end{array}\right]\end{array}\right\}^2}};$$

$$N(RD,R) = \frac{\alpha(2+2\lambda-\eta\lambda)\left[\begin{array}{c}32+16\alpha\eta(2-\lambda)\\ -\beta^2(4+2\alpha\eta-\alpha\eta\lambda)^2\end{array}\right]\sqrt{(1+\beta)(2+2\alpha\eta-\alpha\eta\lambda)\left\{\begin{array}{c}(2+2\alpha\eta-\alpha\eta\lambda)(4+2\alpha+2\alpha\lambda-\alpha\eta\lambda)\\ -\beta^2\left[\begin{array}{c}8+\alpha^2\eta(1+\eta-\eta\lambda+\lambda)(2-\lambda)\\ +\alpha(4+4\lambda+8\eta-6\eta\lambda)\end{array}\right]\end{array}\right\}}}{8\sqrt{(1-\beta)\left\{\begin{array}{c}\beta^4[2+\alpha(1+\eta-\eta\lambda+\lambda)](4+2\alpha\eta-\alpha\eta\lambda)^3-32(2+2\alpha\eta-\alpha\eta\lambda)^2(4+2\alpha+2\alpha\lambda-\alpha\eta\lambda)\\ -2\beta^2(2+2\alpha\eta-\alpha\eta\lambda)\left[\begin{array}{c}4\alpha^2\eta(2-\lambda)(5\eta-6\eta\lambda+7+7\lambda)+\alpha^3\eta^2(2-\lambda)^2(2+2\lambda-\eta\lambda)\\ +160+40\alpha(4\eta-3\eta\lambda+2+2\lambda)\end{array}\right]\end{array}\right\}^2}};$$

$$M(D,RD) = -\frac{\beta(2+2\lambda-\eta\lambda)\sqrt{(2-\beta^2)(2\alpha+2\eta-\eta\lambda)}}{2\sqrt{2}(1-\beta)[4\alpha(2-\beta^2)+(8-5\beta^2)(2+2\lambda-\eta\lambda)]};$$

$$N(D,RD) = \frac{[2\alpha(2-\beta-\beta^2)+(4-3\beta^2)(2+2\lambda-\eta\lambda)]\sqrt{(2-\beta^2)(2\alpha+2\eta-\eta\lambda)}}{2\sqrt{2}(1-\beta)[4\alpha(2-\beta^2)+(8-5\beta^2)(2+2\lambda-\eta\lambda)]};$$

$$M(R,RD) = \frac{\begin{array}{c}-\{\alpha\eta(2-\lambda)[2\alpha(2+2\lambda-\eta\lambda)-\alpha\beta^2(1+\eta-\eta\lambda+\lambda)-2\beta]+(2-\beta^2)[2\alpha(2+2\lambda+4\eta-3\eta\lambda)+8]-8\beta\}\\ (2+2\alpha\eta-\alpha\eta\lambda)\sqrt{(1+\beta)[16-\beta^2(4+2\alpha\eta-\alpha\eta\lambda)^2+8\alpha\eta(2-\lambda)]}\end{array}}{\sqrt{(1-\beta)\left\{\begin{array}{c}32[4+\alpha(2+2\lambda+8\eta-5\eta\lambda)](4-\beta^2)(1-\beta^2)-\alpha^4\beta^2\eta^3(2-\lambda)^3[4+2(2-\eta)\lambda-\beta^2(1+\eta-\eta\lambda+\lambda)]\\ +2\alpha^3\eta^2(2-\lambda)^2[16(2+2\lambda-\eta\lambda)-2\beta^2(10\eta-13\eta\lambda+16+16\lambda)+\beta^4(6+6\lambda+8\eta-7\eta\lambda)]\\ +8\alpha^2\eta(2-\lambda)[32(1+\lambda+\eta-\eta\lambda)-2\beta^2(25\eta-21\eta\lambda+17+17\lambda)+3\beta^4(2+2\lambda+4\eta-3\eta\lambda)]\end{array}\right\}^2}};$$

$$N(R,RD) = \frac{\alpha\beta(4+2\alpha\eta-\alpha\eta\lambda)(2+2\lambda-\eta\lambda)(2+2\alpha\eta-\alpha\eta\lambda)\sqrt{(1+\beta)[16-\beta^2(4+2\alpha\eta-\alpha\eta\lambda)^2+8\alpha\eta(2-\lambda)]}}{\sqrt{(1-\beta)\left\{\begin{array}{c}32[4+\alpha(2+2\lambda+8\eta-5\eta\lambda)](4-\beta^2)(1-\beta^2)-\alpha^4\beta^2\eta^3(2-\lambda)^3[4+2(2-\eta)\lambda-\beta^2(1+\eta-\eta\lambda+\lambda)]\\ +2\alpha^3\eta^2(2-\lambda)^2[16(2+2\lambda-\eta\lambda)-2\beta^2(10\eta-13\eta\lambda+16+16\lambda)+\beta^4(6+6\lambda+8\eta-7\eta\lambda)]\\ +8\alpha^2\eta(2-\lambda)[32(1+\lambda+\eta-\eta\lambda)-2\beta^2(25\eta-21\eta\lambda+17+17\lambda)+3\beta^4(2+2\lambda+4\eta-3\eta\lambda)]\end{array}\right\}^2}}.$$

Also, similar to Corollary 3, the necessary and sufficient conditions of the symmetric equilibrium strategy profile (RD,RD) and (D,D) are $\delta_{(RD,RD)}^{R} = \frac{\sqrt{2(\alpha\eta+1)(\alpha+2)}-2}{2\alpha}$ and $\delta_{(D,D)}^{R} = \frac{\sqrt{\alpha\eta+1}}{2\sqrt{\alpha+\eta}}$. As such, we can illustrate the numerical examples in Figure 12.

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