



Channel Selection with Symmetric Manufacturers' Competition in Multi-Channel Supply Chains

by

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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 success and failure of manufacturers with different channel strategies. To explore the rationale of different channel strategies in different business contexts, we develop a linear demand model to analyze a manufacturer's channel selection between two single-channel strategies (i.e., direct-channel strategy and retail-channel strategy) and a dual-channel strategy (i.e., strategy with both direct and retail channels) resting on consumers' preference and cost levels of the differentiation between retail and direct channels, which centres the conflict in the nature of channel differentiation both in the cost side and in the market side. Specifically, we incorporate the behavior of a symmetric competitor and track down the change of the focal manufacturer's channel preference, which has been surprisingly neglected in the literature since previous researchers mainly focus on a single manufacturer's decision-making scenario. Comparing this new scenario with the single manufacturer's channel selection in previous literature clarifies the effects of network positions in the same market segment and offers insights into the current intertwined business relationships in practice. Our finding shows that the channel preference is a dynamic choice depending on the channels' operating costs and market factors of consumers' purchasing attitude. In addition, our results show that the impacts of consumer's channel preference can be either overestimated or underestimated in deciding the focal manufacturer's channel selection strategy if the manufacturer considers itself as the only decision maker in the upstream. Actually, the competitor needs to compete with the manufacturer for customers, which significantly changes the focal manufacturer's decision making on channel strategy. Finally, we summarize the equilibria in the game between two manufacturers and show that the asymmetric channel structure cannot be a Nash equilibrium in this game.

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1. Introduction

The role of internet in marketing and retailing has expanded significantly in the last two decades. In 2016, online sales account for approximately 14.7% of all retail spending in Great Britain (Office-of-National-Statistics, 2017), and 8.7% in the worldwide (Statista, 2017). To be specific, this impact varies from industry to industry. The portion of online sales is significant in industries such as travel, books and fashion. For example, Booking.com and Tripadvisor are two online travel servicers against traditional travel intermediaries (Verhoef et al., 2015); Amazon contributes a lot to book sales due to the Kindle e-book reader; and Everlane and Tiefs are online fashion brands who are selling exclusively through their websites. Although other industries such as food stores are less influenced by online retailing (Office-of-National-Statistics, 2017), there are also grocery retailers such as Tesco and Sainsbury's in the UK who offer the online shopping options. In these examples, online selling has become an option for the companies to boost their business and increase customer touch points.

Strategies about how to manage and conciliate the market requirements as well as online resources changed through the retail mix in supply chains play an important role in channel members' decision making (Sorescu et al., 2011). A number of retailers are trying a retail mix through both online and offline channels, or acting as pure web-based players as alternatives to the traditional brick-and-mortar retailing (Wang et al., 2016). This can also be considered as a decision region for the upstream manufacturers; and introducing a new direct channel has become an optional channel strategy for top manufacturers in various industries, e.g., Hewlett Packard, Procter & Gamble and Estee Lauder. In this case, however, dual-channel manufacturers become vertical as well as horizontal competitors to retailers, and cannibalize their sales due to the horizontal substitutability (Shipley et al., 1991). Choi (2003) finds that the entry barrier in a direct channel against latecomers is another reason that cuts off the extension of dual-channel manufacturers. Nevertheless, other literature on this topic has shown that manufacturers' additional direct channel is not necessarily detrimental to retailers given certain relations on channel power or cost structure, and channel conflict here can be mitigated by coordination schemes (Cai, 2010; Chiang et al., 2003). In addition, pure direct sales can be a proper strategy for manufacturers as well, e.g., Everlane, Dollar Shave Club and Tiefs. Although the intermediaries such as retailers and distributors seem to deprive manufacturers of profits and potential customers, we cannot deny the value of intermediaries' functions such as market coverage and information collection (Tsay and Agrawal,

2004a). Therefore, a balance also exists here between the advantages and disadvantages of intermediaries.

Although the manufacturer's channel selection has been discussed in the literature, most research considers the situation with only one manufacturer as well as the dyad supply chain with one manufacturer and one retailer (Cattani et al., 2006; Tsay and Agrawal, 2004a). Companies nowadays, however, are embedded in networks typically consisting of multiple retailers, manufacturers, distributors and other channel agents, thus the dyadic view should be extended to a more complex scenario such as a triad in some situations (Achrol, 1997; Havila et al., 2004; Zaheer et al., 2000). Through the connection with another manufacturer as well as a retailer, a manufacturer is more likely to learn and upgrade in a triadic (e.g., retailer-manufacturer-manufacturer) relationship than an isolated dyadic one (Håkansson et al., 1999). Considering a network environment (Möller and Halinen, 1999; Watson et al., 2015), we develop a model consisting of two competing manufacturers and one common retailer, in which the additional channel competition exists between the two symmetric manufacturers. Taking into account competing manufacturers is crucial to investigate the channel selection phenomenon. For example, Coca-Cola and Pepsi are two leading companies manufacturing cola and other soft drinks. They inevitably share mutual retailers such Wal-Mart and Amazon. The portfolio of Unilever and Procter & Gamble is another example to highlight the competing position of certain manufacturers. However, this issue is ignored in literature and we mention specific papers in the literature review section.

Considering the research gap in extant literature, i.e., how interactions between competing manufacturers influence their channel preference, we aim to answer following research questions: (1) What is the manufacturer's channel selection with and without competitors? (2) How do differentiation between direct and retail channels affects manufacturers' channel preference? (3) What is the Nash equilibrium in channel selection between competing manufacturers? Answering these questions would contribute to the literature by providing important insights into the structural equivalence of manufacturers and by clarifying its potential effects on manufacturers' channel preference. In addition, answering these questions would contribute to a better understanding of different channel strategies and offer insights into their distinctions and competitions. Finally, it would clarify the potential Nash equilibria in the market with two similar manufacturers.

We develop a mathematical model to address these questions. First, we examine the case with only one manufacturer and one retailer. Using the concept of subgame perfect Nash equilibrium, we compare

three channel strategies for the manufacturer: direct channel only (strategy D), retail channel only (strategy R), and mix channel consisting of both the direct channel and the retail channel (strategy RD). Although Tsay and Agrawal (2004a) and Cai (2010) compare the similar strategies, Tsay and Agrawal (2004a) focus on the optimal sales effort with exogenous pricing and Cai (2010) discusses the channel selection based on segmentation of the relative channel power of dual channels. We aim to model pricing decisions and channel selections under different levels of channel distinction, thus, we have different findings which are inconsistent with that in Cai (2010). Then we extend the case to a more comprehensive one which explores the scenarios with two competing manufacturers and one common retailer. The manufacturers here are assumed to produce highly substitutable products and be symmetric, i.e., they have identical cost structure of the retail and direct channels and the identical pricing strategy is adopted. Each manufacturer has three channel strategies (i.e., strategy D, strategy R, and strategy RD) to choose, thus considering the symmetry, there are six distinct channel structures in total. Finally, we compare the manufacturer's channel selection and present our findings about how the competition effects the manufacturer's channel selection and demonstrate the Nash equilibria in our game.

We thus find that there is not a strategy for the manufacturer that is always the best, i.e., the channel preference is a dynamic choice that depends on the channels' cost structure and market factors of consumers' purchasing attitude. If the consumers would easily change their purchasing channel when their preferred channel is not offered in the market, the single manufacturer in the market tends to select a single-channel strategy instead of the dual-channel strategy, probably due to the complexity of running multiple channels simultaneously. The dual-channel strategy can act as a balance strategy when more consumers would stick to their initial channel selection and the costs of direct and retail channels are relatively similar. In addition, we explore impacts of the competing manufacturer's channel selection, which shows that the competitor's single- or dual-channel strategy can change the focal manufacturer's channel preference significantly. An interesting finding in this part illustrates that market factors and cost structures play different roles when the manufacturer is facing a competitor. Finally, we summarize the Nash equilibria in the game between two manufacturers and explain the impacts of cost structure and market factors on the equilibrium. The Nash equilibria are highly influenced by the cost structure: both manufacturers would benefit and balance their strategies to concentrate on the single channel with relatively low operating cost in one channel. The exceptions may exist when the consumer's acceptance of less preferred channel is high, which to some extent reduces the fierce channel competition.

Asymmetric strategy profiles cannot become Nash equilibria.

The reminder of this paper is organized as follows. Section 2 discusses the literature on channel competition and presents the distinctions of our model, while Section 3 reviews the demand functions and games adopted in related literature. Section 4 introduces the channel strategy of a single manufacturer, and Section 5 compares the channel selection when the manufacturer is competing with a symmetric manufacturer. Numerical analysis is developed in both Section 4 and Section 5. A summary of our results and managerial implications are provided in Section 6.

2. Literature Review

There is rich literature on channel competition in multi-channel supply chains due to the rapid growth of digitalization and globalization (Tsay and Agrawal, 2004b). Competition discussed in literature is caused by competing channel members or multiple marketing platforms which are mainly embedded in different channel structures. In this section, we first review the literature discussing the channel competition with regard to multiple horizontal channel members and various channel platform, including brick-and-mortar stores and e-business, in the first two parts. Literature on comparison of different channel structures is discussed in the third part.

2.1. Competition caused by multiple firms

We discuss two streams in this subsection: multiple intermediaries with one single product and substitutable products produced by competing manufacturers. In the first stream, competition as well as cooperation in supply chains with multiple retailers is the focus of much of the channel competition literature. Ingene and Parry (1995a) and Ingene and Parry (1995b) explore channel coordination within a vertical channel consisting of a common manufacturer and multiple independent retailers. They find that the distinct relationships among retailers, e.g., competing or noncompeting, can differentiate the appropriate contracts coordinating the supply chains. Bernstein and Federgruen (2004) consider the inventory and pricing problems in a periodic review, infinite-horizon model with competing retailers and illustrate that retailer competition can break down certain monotonicity properties in centralized systems. They further demonstrate that retailer competition can affect one retailer's distribution of random demands through its own price as well as those of the other retailers (Bernstein and Federgruen, 2005). Savaskan and Van Wassenhove (2006) extend the case of retailer competition into the reverse supply chain, their results show that the competitive interaction between the retailers has a significant

impact on supply chain profits when the retailers act as product return points in the reverse channel. In addition, some literature has recently focused on the pricing competition within a duopoly-retailer supply chain (Huang et al., 2016; Wu et al., 2012; Xiao and Qi, 2008; Yang and Zhou, 2006). They explore how the pricing decisions would be affected by channel members' power structures and retailers' competitive behaviours (e.g., Cournot, Bertrand, Collusion or Stackelberg). Their main results indicate that the cooperation between retailers raises the selling price, and Wu et al. (2012) find the performance of the supply chain is similar under the above structures if the retailers are highly substitutable. Similarly, Xiao and Qi (2008) model price competition and two coordination schemes under the cost and demand disruptions. Apart from pricing decisions, Wang et al. (2011) consider coordination and cooperative advertising issues in this channel structure (i.e., one manufacturer and duopoly retailers) and discuss the game models in four scenarios, including Stackelberg–Cournot, Stackelberg–Collusion, Nash–Cournot and Nash–Collusion.

A second category of literature considers the competition within multiple manufacturers in a supply chain, where substitutability of products from distinct manufacturers is the main reason that causes competition as well as conflict. In the supply chain with two manufacturers and one common retailer, Choi (1991) first differentiates the products sold by manufacturers and explore the impacts of different power structures on channel members' performance. Building upon Choi (1991)'s initial work, increasing literature has extended it by considering coordination schemes (Sinha and Sarmah, 2010) and manufacturer's pricing strategies (Wei and Zhao, 2016; Zhao et al., 2014). To be specific, Sinha and Sarmah (2010) model price competition of two differentiated products and compare the equilibrium and customers' circumstances with and without coordination. Zhao et al. (2014) develop one centralized pricing model and seven decentralized pricing models under different power structures and pricing strategies. Along similar lines, Wei and Zhao (2016) extend this work by considering the manufacturing cost and the customer demand for each product as fuzzy variables. All papers discussed above assume a single retailer in the supply chain, while other literature also develops models with competing manufacturers as well as retailers. For example, Choi (1996) and Trivedi (1998) consider the case when duopoly manufacturers share two common retailers and demonstrate the effect of two types of horizontal competition, i.e., product differentiation and store differentiation. Xia (2011) explores pricing strategies in the supply chain with two suppliers and multiple downstream buyers.

Another channel structure that considers product substitutability is discussed as chain-to-chain

competition (Huang et al., 2016), which is generally modelled as each of duopoly manufacturers have an exclusive retailer. Much of the related literature has focused on manufacturers' strategic attitude towards intermediaries, i.e., whether to sell their products indirectly through retailers or directly to customers through vertical integration (Anderson and Bao, 2010; Coughlan, 1985; McGuire and Staelin, 1983). Recently, this literature has been extended by considering the pricing and quantity decisions under demand uncertainty (Wu et al., 2009), comparison of symmetric and asymmetric relative channel status (Zhang et al., 2012), advertising strategies (Liu et al., 2014) and two asymmetric characteristics of products (Yang et al., 2015). Their results demonstrate that the competition between differentiated products has significant impacts on manufacturers' integration preference.

2.2. Competition caused by marketing platforms

We have discussed the channel competition in supply chains when multiple channel members competing in the same channel levels including upstream and downstream positions. When there are not horizontal competitors, however, competition can also be raised through the conflict between traditional channels and new channel forms based on 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. Some literature considers a multi-channel retailer who sells to customers through both physical and online stores. For example, Huang and Swaminathan (2009) study four prevalent pricing strategies of a dual-channel retailer. Yan and Ghose (2010) examine the impact of forecast information about customers' willingness to pay on each channel's performance. Specifically, Chen and Bell (2012) model the pricing and quantity decisions when a retailer is selling a single product through a returnable channel and a nonreturnable channel.

A large number of papers focusing on the manufacturers' dual-channel strategy have arisen significantly. Chiang et al. (2003) and Tsay and Agrawal (2004a), as two seminal papers, initially introduce the manufacturer's additional direct selling strategy. They demonstrate that there exists Pareto zone that benefits both the manufacturer and the retailer under a manufacturer's dual-channel strategy. Their work has been extended in several directions. Boyaci (2005) studies the stocking levels in two channels, then Yao et al. (2009) and Moon et al. (2010) compare several inventory strategies of a dual-channel manufacturer. Chen et al. (2008), Yan and Pei (2009) and Dan et al. (2012) focus on the retail service as the retailer's value adding when competing with the manufacturer's direct channel, while the

direct channel is competing on its delivery lead time and pricing (Chen et al., 2008; Hua et al., 2010).

Above papers examine the channel members' individual strategies against the vertical and horizontal competition raised by a dual-channel manufacturer. Moreover, in order to address the competition and increase performance of the supply chain, channel members can mitigate or even eliminate conflicts through proper interactions between each other. First, information sharing can be considered as a proper way to bridge between the manufacturer and the retailer, and its value is also studied in a dual-channel supply chain in which the types of information include demand forecast (Yue and Liu, 2006), producing or service cost (Cao et al., 2013; Mukhopadhyay et al., 2008) and channel members' risk-averse attitude (Liu et al., 2016). They quantify the value of information sharing in different scenarios, and results reveal that information sharing can be beneficial to the dual-channel manufacturer as well as the retailer under some conditions. Apart from information sharing, channel coordination has been intensively studied in related literature. As discussed in Cachon (2003), there are various contracts that can coordinate a single-channel supply chain, however, Boyaci (2005) argues that these simple contracts fail to coordinate a supply chain in a more complex dual-channel setting. In line with these, many papers have developed new coordinating schemes to achieve win-win results for a supply chain with a dual-channel manufacturer and a retailer, such as a two-part compensation-commission contract (Boyaci, 2005), a profit sharing contract (Chen et al., 2012; Yan, 2008), price-discount contracts (Cai et al., 2009), and a two-part tariff agreement (Chen et al., 2012). Specifically, David and Adida (2015) propose a linear quantity-discount contract to perfectly coordinate the supply chain with symmetric retailers and a multi-channel manufacturer who also operates an additional direct channel. More recently, many papers have focused on the coordination contracts in a supply chain with a risk-averse retailer who is sourcing from a dual-channel manufacturer. These include Li et al. (2014), which examine the effect of the retailer's risk-averse degree on the optimal selling price and channel members' performance, and Xu et al. (2014) and Li et al. (2016), which develop a two-way revenue-sharing contract and a risk-sharing contract, respectively.

2.3. Comparison of channel structures

According to our previous review, there are different channel structures that the channel members can choose. Related papers have discussed whether adding a new channel can benefit the channel members (Chiang et al., 2003; Dumrongsiri et al., 2008; Huang and Swaminathan, 2009; Lu and Liu,

2015). Furthermore, Wang et al. (2016) explore the leading retailer's preference among online channel, offline channel and combination of two channels when facing a dual-channel manufacturer with another direct channel. Other papers also study the channel selection of manufacturers in a manufacturer-leading supply chain. Based on the manufacturer and the retailer's optimal sales effort, Tsay and Agrawal (2004a) compare the manufacturer's three distribution strategies, i.e., direct sales, reseller-only, and combination of both channels, and discuss two coordinating schemes. Apart from these three channel strategies, Cai (2010) considers an additional structure where a manufacturer is selling a single product through two symmetric retailers. They focus on the pricing decisions and examine both the channel-adding Pareto zone and the contract-implementing Pareto zone in the supply chain. More recently, a game between two manufacturers and their exclusive retailers has been introduced by Matsui (2016) which studies six distribution strategies according to each manufacturer's channel strategy. The equilibria reveal that a symmetric distribution policy is not optimal under price competition. However, Matsui's work 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 wholesale price thus retailers have no margin profit.

In this paper, we focus on the duopoly manufacturers' channel strategy with a common retailer. One distinction of our model is that the manufacturer is deciding on channel selection under the competition with another similar manufacturer. Comparing this new scenario with the single manufacturer's channel selection in previous literature clarifies the effects of network positions 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, and we also introduce consumers' channel preference between retail and direct channels. This assumption centres the conflict in the nature of channel differentiation both in the cost side and in the market side.

3. Model Review

3.1. Demand Functions

There are different kinds of demand functions in the area of dual-channel supply chain management which is more complicated than the case with only one channel. The dual channels or multiple channels discussed in the literature are caused by the multi-channel strategy of one company or the channels from

several competitive companies. The linear demand functions are the most popular functions used in the multi-channel analysis, and the linear models reviewed in this section are derived from three various types: utility maximization, customer segments and customer choice. In addition, there are some nonlinear models as well.

3.1.1. Utility maximization

In the first type, the linear functions are initially derived from maximizing the utility function for a representative customer, which is defined as follow (Ingene and Parry, 2004; Singh and Vives, 1984)

$$U = \sum_{i=1,2} \left(a_i D_i - \frac{b_i D_i^2}{2} \right) - \theta D_1 D_2 - \sum_{i=1,2} p_i D_i \quad (3.1)$$

where a_i denotes the base demand of good i ($i=1,2$), b_i denotes the rate of change of marginal utility, D_i represents demand of channel i and p_i represents the price in channel i . The demand functions are derived from the maximization of (3.1), then the demand for each channel is

$$D_i = \frac{a_i b_j - \theta a_j}{b_1 b_2 - \theta^2} - \frac{b_j}{b_1 b_2 - \theta^2} p_i + \frac{\theta}{b_1 b_2 - \theta^2} p_j, \quad i, j = 1, 2 \quad \text{and} \quad i \neq j, \quad (3.2)$$

where $a_i > 0$, $b_i > 0$. $b_1 b_2 - \theta^2 > 0$ is assumed to ensure the concavity of (3.2), and $a_i b_j - \theta a_j > 0$ ensures positive demand. The parameter θ indicates the relationship between two products as a measure of substitutability and complementarity. When $\theta > 0$, demand for product i decreases in the price of product i and increases in the price of its competitor (product j), which means the product may be replaced by its competitor and they are substitutes. In this case, the products become perfect substitutable if $a_i = a_j$ and $b_1 = b_2 = \theta$ (Singh and Vives, 1984), and Coca-Cola or Pepsi would be an example of homogenous products. The products are independent when the price of competitor cannot influence a product's demand, i.e., $\theta = 0$. This may happen when two products are unrelated types of goods; however, this setting is rare in literature since the interaction between similar products or channels is an important point. Thus, $\theta^2/b_1 b_2$ captures the degree of product differentiation when $\theta \geq 0$, ranging from zero when products are independent to one when the products are perfect substitutes. In addition, the products would be complements when $\theta < 0$.

This demand settings also show that the customer utility decreases in the degree of substitutability and increases in the degree of complementarity. Furthermore, in order to ensure that the demand decreases in the product prices, $b_i > |\theta|$ ($i=1,2$) is assumed, which also indicates that the product is

more sensitive on its own price change than the competitor's price change (Lus and Muriel, 2009).

The quadratic utility function is commonly used in operation management study (Liu et al., 2014; Lus and Muriel, 2009), and is derived from initial application to economics study (Röller and Tombak, 1990, 1993). As examples, Lus and Muriel (2009) consider two substitutable products and study the optimal investment mix of flexible and dedicated capacities in both monopoly and oligopoly settings. They find that the higher substitutability decreases the optimal investment in manufacturing flexibility. Liu et al. (2014) consider two partially substitutable products and explore the effect of advertising with cost sharing scheme, and they consider two dummy variables which indicate the impact of advertising on base demand. Their results show that the higher substitutability erodes the supply chain efficiency, while manufacturer advertising can facilitate the efficiency.

When $i(i=1,2)$ represents different channels, (3.2) can also explain the demands for two competing channels. In this case, the channels are assumed to be substitutable, i.e., $\theta \geq 0$, and the parameters in (3.1) are simplified in the sequel for brevity (Cai, 2010; Matsui, 2016). Cai (2010) compare four different supply chain structures with different channel scenarios, and the demand function in each structure is derived from the customer utility (3.1) with $b_1 = b_2 = 1$. Matsui (2016) attempt to solve a multi-channel and multi-product situation through maximizing the customer utility with $a_1 = a_2 = a$, but the complex situation with four channels cannot be fully explained based on (3.2).

Letting $\alpha_i = (a_i b_j - \theta a_j) / (b_1 b_2 - \theta^2)$, $\beta_i = b_i / (b_1 b_2 - \theta^2)$ and $\gamma = \theta / (b_1 b_2 - \theta^2)$, $i, j = 1, 2$ and $i \neq j$, (3.2) can be written as

$$D_i = \alpha_i - \beta_i p_i + \gamma p_j, \quad i, j = 1, 2 \quad \text{and} \quad i \neq j. \quad (3.3)$$

The parameter $\alpha_i > 0$ represents the market size of product/channel i , and $\alpha_1 + \alpha_2$ represents the total market size. $\beta_i > 0$ and γ denote the price and cross-price sensitivity, respectively, and are related to the product/channel substitutability. As mentioned above, $\gamma > 0$, $\gamma = 0$ and $\gamma < 0$ can be interpreted as substitutable, independent and complementary products, respectively, and the relation $\beta_i > |\gamma|$ ensures that the price sensitivity exceeds the cross-price sensitivity and the total demand should decrease in the prices. Although the similar relations remain in (3.3), this simplification sacrifices some sensitive explanations on price. As $\beta_i = b_i / (b_1 b_2 - \theta^2)$ increases in θ , customers are more sensitive when the substitutability is higher, thus the speciality of a product can reduce customers' price-sensitivity. The impact of substitutability on the market base is also ignored. Therefore, Lus and Muriel (2009)

compare two types of demand functions discussed above and find that (3.2) is more appropriate when measuring substitutability for linear demand functions and the results of (3.3) tend to be unrealistic based on intuition. However, (3.3) is still a common demand function when describing substitutability among products or channels because of its brevity.

In some literature discussing substitutability, (3.3) can be rewritten as

$$D_i = \alpha_i - \beta_i' p_i + \gamma(p_j - p_i), \quad i, j = 1, 2 \quad \text{and} \quad i \neq j \quad (3.4)$$

where $\beta_i' = \beta_i - \gamma > 0$. According to Chen et al. (2012), γ represents the channel substitutability, and can be interpreted as the number of customers who switch from channel j to channel i per unit price when $p_j > p_i$, and vice versa. (3.3) and (3.4) are the most commonly used demand functions when considering multiple channels (Chen et al., 2012; Lu and Liu, 2015). To be specific, Chen et al. (2012) focus on the coordination schemes in a dual-channel supply chain and Lu and Liu (2015) compare the efficiency of distribution structures under single-channel and dual-channel supply chain.

Apart from the price, other factors are also considered in linear demand functions, including the lead time in the direct channel (Hua et al., 2010) and retail service value added (Tsay and Agrawal, 2000; Yao and Liu, 2005). For example, Hua et al. (2010) assume that demand is linear in lead time in the direct channel and prices under a dual-channel supply chain. They capture the channel substitutability and the diverse impact of the direct channel's lead time on different channels' demand, i.e., the longer lead time increases the demand for the retail channel and decrease that for the direct channel.

Another example is that the demand functions proposed in Tsay and Agrawal (2000) consider both the price level and the service level:

$$D_i = \alpha_i - \beta_p p_i + \gamma_p(p_j - p_i) + \beta_s s_i - \gamma_s(s_j - s_i), \quad i, j = 1, 2 \quad \text{and} \quad i \neq j \quad (3.5)$$

where $s_i > 0$ represents the service level in channel i , $\beta_p(\beta_s) \geq 0$ denotes the price (or service) sensitivity and $\gamma_p(\gamma_s) \geq 0$ measures the intensity of pricing or service competition between the two channels.

3.1.2. Customer segments

In the second type, the customers are divided into different segments. Kumar and Ruan (2006) propose a model with two segments of customers—store loyal and brand loyal. The store loyal customers purchase the products only from the retailer, whereas the brand loyal customers purchase their preferred brand from both retail channel and direct channel. In practice, some customers don't

seem to buy from the online store because they need to touch the products before purchasing and rely on retailers' advice to make decision. Another reason is that shopping online requires additional delivery time, while they can acquire the products in retail store immediately after purchasing and save the waiting time. Thus, the store loyal customers' choice is assumed to rely on the level of sales effort (s) allocated to each brand. Brand loyal customers may switch to the online channel because shopping online is convenient and requires less shopping cost. The prices of different channels are an important factor for customers to make their choice. In this case, the fraction of brand loyal customers purchasing online is $0.5 + \gamma(p_r - p_d)$, where γ plays the same role as parameter γ in (3.4), and can be interpreted as the number of customers who switch from the retail channel (p_r) to the online channel (p_d) per unit price when $p_r > p_d$, and vice versa. In this model, part of the brand loyal customers 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 only includes part of brand loyal customers, while the store loyal customers and other part of the brand loyal customers choose to buy from the retail channel. If the manufacturer doesn't sell the product online, the demand functions for the retail channel (D_r) and the online channel (D_d) are

$$D_d = 0, \quad D_r = \alpha_r s + \alpha_d. \quad (3.6)$$

If the manufacturer owns both retail and online channels, the demand functions are

$$D_d = \alpha_d [0.5 + \gamma(p_r - p_d)], \quad D_r = \alpha_r s + \alpha_d [0.5 + \gamma(p_d - p_r)]. \quad (3.7)$$

where α_r denotes the market size of store loyal and α_d denotes the market size of brand loyal; p_r and p_d denote the price in the retail channel and the direct channel, respectively.

In addition, Cai et al. (2009) develop this model to compare the impact of price discount contracts on the single-retail channel and the dual-channel supply chain competition. They think that the choice of store loyal customers is influenced by the retail price instead of sales efforts. When the supplier only sells through the retailer, the demand functions are

$$D_d = 0, \quad D_r = (\alpha_d + \alpha_r)(1 - \beta p_r). \quad (3.8)$$

After the supplier enters the direct channel, the demand functions are

$$D_d = \alpha_d [\theta(1 - \beta p_d) + \gamma(p_r - p_d)], \quad D_r = \alpha_r (1 - \beta p_r) + \alpha_d [(1 - \theta)(1 - \beta p_r) + \gamma(p_d - p_r)] \quad (3.9)$$

where β and γ denote the price and cross-price sensitivity, respectively; θ represents the initial portion of brand loyal customers that prefer the direct channel, then $1-\theta$ represents the initial portion of brand loyal customers that prefer the retail channel. Under this assumption, the total market size remains the same before or after the supplier enters the direct channel, and all the brand loyal customers will buy from the offline stores when there is no direct channel.

Similarly, Wang et al. (2016) develop a linear demand model based on Kumar and Ruan (2006) and Cai et al. (2009), and discuss the channel selection of a dominant multi-channel retailer. The customers are divided into two types—store preferred customers and web preferred customers. Contrary to previous hypothesis that all the store loyal customers will switch to the online channel when lacking store channels, Wang et al. (2016) assume some store loyal customers will buy nothing in this case, thus they introduce a new parameter to indicate the discount coefficient of demand due to customers' channel mismatch, e.g., some store preferred customers will give up buying when only the online channel exists. Therefore, the demand for different channels is decided by prices, customer' channel preference, customer' product preference and discount coefficient of channel mismatch.

To summarize, researchers can compare the demand variation in different channel scenarios based on the assumption of customer segments, in which the customers' channel and product preference under the different channel structures are important assumptions. We also develop a demand model based on this assumption of customer segments and linear function.

3.1.3. Customer choice

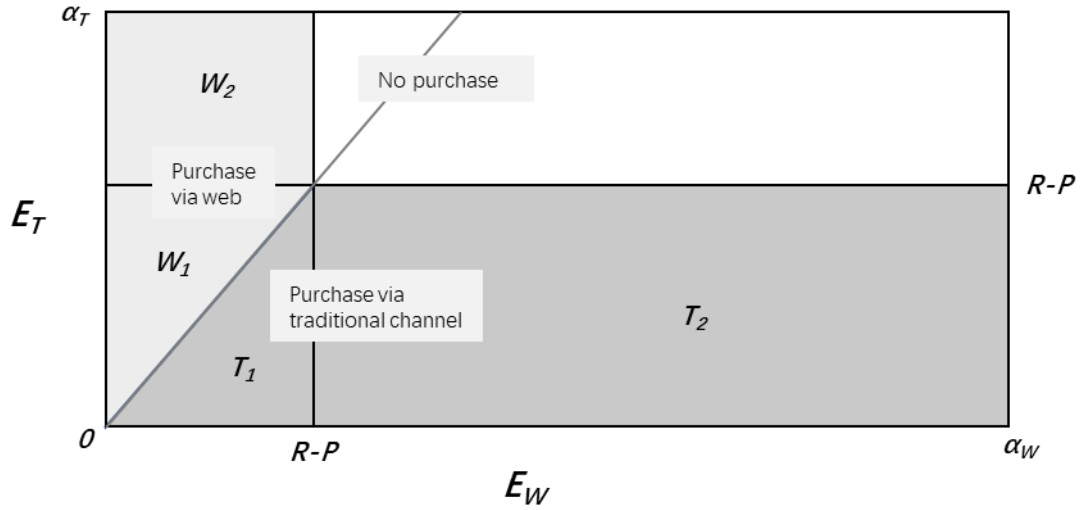
Customer choice is also an important approach to derive the demand functions with multiple channels. According to the empirical studies of Liang and Huang (1998) and Frambach et al. (2007), customers prefer the traditional retail stores more than the online direct channels during their purchasing behaviours. This may be because that customers cannot touch and smell the products before purchasing (Kumar and Ruan, 2006), and they have to wait several days for delivery (Chiang et al., 2003). Based on the literature above, Chiang et al. (2003) introduce the parameter θ to denote the customer acceptance of the direct channel and assume $0 < \theta < 1$. The value of the product in the retail channel is v for customers, and the sale price in the retail channel is p_r , then the customer surplus is $v - p_r$. Similarly, the customer surplus in the direct channel is $\theta v - p_d$, where p_d denotes the sale price in the direct channel. The customers' channel decisions are determined by their individual reservation value (i.e., v) assuming $0 < v < 1$ and uniformly distributed. For example, when $v \in [(p_r - p_d)/(1-\theta), 1]$,

the customers in this interval prefer to buy from the retail channel. Therefore, the piecewise-linear demand functions (Chiang et al., 2003) are based on the probability that customers would choose from two channels:

$$D_r = \begin{cases} 1 - \frac{p_r - p_d}{1 - \theta} \left(\text{if } \frac{p_d}{\theta} \leq p_r \right) \\ 1 - p_r \text{ (otherwise)} \end{cases}, \quad D_d = \begin{cases} \frac{\theta p_r - p_d}{\theta(1 - \theta)} \left(\text{if } \frac{p_d}{\theta} \leq p_r \right) \\ 0 \text{ (otherwise)} \end{cases}. \quad (3.10)$$

As seen in (3.10), the price sensitivity is larger in the retail channel when the retail price exceeds p_d/θ , because more customers will choose the direct channel if the retail price is high. These demand functions are widely used in the literature (Chen and Bell, 2012), and also improved through incorporating the retail service factor (Yan and Pei, 2009), considering the delivery time in the direct channel (Xu et al., 2012), and combining uncertainty in the customers' willing to pay (Yan and Ghose, 2010).

Some literature proposes the similar model but assumes that the reservation value in different channels remains the same. The utility function used in Dumrongsiri et al. (2008) is $U_i = v + \delta s_i - p_i$, $i=1,2$, where v denotes the customer's reservation value, s_i denotes the price service quality in channel i and δ measures the sensitivity to the service level with $\delta \sim U[\delta_{down}, \delta_{up}]$. Assume $\delta^* = (p_1 - p_2)/(s_1 - s_2)$ satisfies $U_1 = U_2$, thus, the demand function for channel 1 equals the probability of $\delta \in [\delta^*, \delta_{up}]$, i.e., $D_1 = (\delta_{up} - \delta^*)/(\delta_{up} - \delta_{down})$. Then, the demand function for channel 2 equals the probability of $\delta \in [\delta_{down}, \delta^*]$, i.e., $D_2 = (\delta^* - \delta_{down})/(\delta_{up} - \delta_{down})$. Another similar form is that Cattani et al. (2006) model the utility function $U_i = v - E_i - p_i$ to derive the demand functions, where $i=1,2$ denotes two different channels, v denotes the customer's reservation value, p_i denotes the price and E_i denoted the customer's effort to buy in channel i with $E_i \sim U[0, \alpha_i]$. Then, the buying effort is the key point to compare the two channels. As shown in Fig. 1, the customer would buy from channel T in Region W_1 and Region W_2 , and would buy from channel W in Region T_1 and Region T_2 . Therefore, the demand functions are calculated from the probability of each region.



Source from: Cattani et al. (2006)

Fig. 1 Customer channel preference based on scaled effort

3.1.4. Other models

Apart from linear models, there are some papers adopting the constant elasticity function when studying the competition between multiple channels:

$$D_i = \alpha_i p_i^{-\beta} p_j^\gamma, \quad i, j = 1, 2 \quad \text{and} \quad i \neq j, \quad (3.11)$$

where $\beta > 1$ and $\gamma \geq 0$ denote the price and cross-price sensitivity, respectively (Choi, 1991; Moorthy, 1988; Wang et al., 2013; Zhao and Shi, 2011). This nonlinear model can be rewritten as $D_i = \alpha_i p_i^{-(\beta-\gamma)} (p_j/p_i)^\gamma$. Note that $\alpha_i p_i^{-(\beta-\gamma)}$ represents the demand without competition with the constant elasticity $\beta - \gamma$, and $(p_j/p_i)^\gamma$ represents the price competition in the dual-channel supply chain. Therefore, the two prices are independent when $\gamma = 0$. As the formulas of linear and nonlinear functions are different, the results based on them can be opposite sometimes, therefore, the choice of the proper demand function is important in research (Choi, 1991).

The deterministic models we have discussed are used in the literature with regard to the pricing scheme and the service level. Some research about the newsvendor problem, inventory management and asymmetric information, however, adopts the stochastic demand function (Dumrongsiri et al., 2008; Yan and Ghose, 2010). If we assume D_i denotes the deterministic demand and ε_i is a random variable with the probability distribution function $f(\cdot)$ and cumulative distribution function $F(\cdot)$ where i represents the different channels, then, the stochastic demand is $\bar{D}_i = D_i + \varepsilon_i$ for the linear model and $\bar{D}_i = D_i \varepsilon_i$ for the nonlinear model (Dumrongsiri et al., 2008; Wang et al., 2013).

3.2. Games

Subgame-perfect equilibrium (SPE) is an important solution concept in games among multiple players. A strategy profile is a SPE if it represents a Nash equilibrium of every subgame of the original game, thus a SPE is a refinement of a Nash equilibrium and a solution concept of a dynamic game (Gibbons, 1992). In the literature on supply chain management, SPE is widely used when different players, e.g., manufacturers, retailers, and distributors, make their own decisions in different stages, and these individual behaviours and decisions are considered as smaller games that form the entire dynamic game together.

The equilibria in these games are highly affected by channel members' position and bargaining powers. Normally in a supply chain consisting of manufacturers and retailers, three channel power structures have been discussed in multi-channel supply chains, namely manufacturer-Stackelberg, retailer-Stackelberg structures and Nash game. In the first scenario, manufacturers may be in the leading position when a manufacturer has the preference and ability to open multiple channels (Cai, 2010; Cattani et al., 2006; Chen et al., 2012; Chen et al., 2008; Chiang et al., 2003; David and Adida, 2015). The manufacturer(s) thereby can choose their channel strategy and wholesale price first, and the retailer(s) can determine the retail price to maximize their profits given the wholesale price. This structure applies to the market with a few large manufacturers or a monopoly manufacturer and relatively small retailers (Choi, 1991). For example, Procter & Gamble and Nestle S.A. are two major companies that manufacturing fast moving consumer goods, and they are collaborating with and leading relatively smaller retailers around the world. Specially, Yue and Liu (2006) also considers the Bayesian Nash equilibrium under information asymmetry in a mixed distribution system.

Second, retailers may be more powerful in the supply chain, e.g., Wal-Mart, when a retailer has the preference and ability to open multiple channels (Wang et al., 2016). The retailer(s) can choose their channel strategy and determine the retail price first, and manufacturer(s) thereby can determine their wholesale price given the retail price. Finally, manufacturers and retailers may have equal bargaining power in some context, thus they move simultaneously, e.g., relatively small to medium sized companies (Choi, 1991). Yao and Liu (2005) explore the Bertrand pricing equilibrium between a dual-channel manufacturer and a retailer. Dumrongsiri et al. (2008) assess the manufacturer's dual-channel strategy under a simultaneous

Previous research on manufacturer's dual-channel strategy mainly considers the manufacturer as

the Stackelberg. One possible reason might be the lower efficiency under the retailer-Stackelberg and Nash games. According to Cai et al. (2009), there is a retailer Stackelberg leadership dilemma that the retailer gains less profits than that in the manufacturer-Stackelberg case. Similar, in the Nash game, the retailer gains zero margin profit if the selling prices in the retail channel and the manufacturer's direct channel are inconsistent, while the Nash game is equivalent to Stackelberg under the consistent pricing strategy. Therefore, we consider the manufacturer-Stackelberg game to explore the manufacturers' channel strategies.

4. One Manufacturer's Multi-Channel Strategy

In this section, we consider the market with one Stackelberg-leading manufacturer (he) and one retailer (she), and the single product here can be sold through three channel strategies (see Fig. 2): (1) the direct channel only (strategy D), (2) the retail channel only (strategy R), (3) multi-channel strategy (strategy RD) (i.e., both direct and retail channel). In line with Cai et al. (2009) and Wang et al. (2016) who propose similar models with two segments of consumers, we divide the consumers into two types according to their channel preference—online channel consumers and store consumers. Meanwhile, the products from two different channels are identical and the two channels are substitutable for consumers.

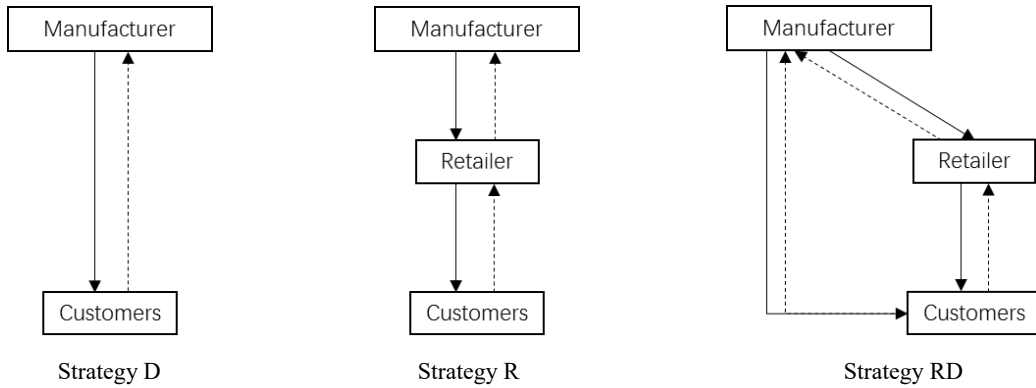


Fig. 2 Channel systems with one manufacturer

We develop linear demand functions in which the consumers' choice is decided by their initial channel preference and the product's selling price. The numbers of the consumers who prefer the direct channel and the retail channel are α^D and α^R , respectively. We highlight the ratio of these two numbers and assume $\alpha = \alpha^D / \alpha^R > 0$. Therefore, α reflects the ratio of consumers' channel preference and describes the difference of the consumers' size. α^D and α^R can be interpreted as the consumers' initial channel preference, and we also introduce parameter η to denote the degree of

consumers' switching to retail (direct) channels due to the lack of direct (retail) channels, thus $\eta \in [0,1]$. In two extreme cases, for example, $\eta=0$ means that none of the consumers would change to retail (direct) channels when selling companies don't run their preferred direct (retail) channels; $\eta=1$ represents that all consumers would change their preference here, thus they can easily accept their the less preferred channels. Therefore, parameter η here also denotes the consumers' acceptance of their less preferred channels.

When the prices in different channels are not identical, consumers' price sensitivity also impacts their channel preference. The price difference would result in significant change in channel selection, then channel members tend to adjust their pricing strategies to balance the consumers preference. Therefore, we assume that in the case where direct and indirect channels exist at the same time, the corresponding selling prices would become identical at equilibrium. Thus, we can focus on the impact of channel substitutability. Based on the parameters discussed above, we list the demand functions for the retail and direct channel in Table 1, where demand functions are varied with the manufacturer's different channel strategies. We denote the choice of strategy with $S \in \{D, R, RD\}$.

Table 1 Demand functions in the supply chain with one manufacturer

Demand	Channel Strategy (S)		
	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	$(\alpha^R + \eta\alpha^D)(1-p)$	$\alpha^R(1-p)$

Let c^R denote the operating cost in the retail channel and c^D denote the operating cost in the direct channel. We normalize maximum possible price to 1, thus, nonnegative demands exist only when $p \leq 1$ as shown in Table 1. Operating costs are less than the selling price for the profitability. Thus, the unit operating costs of the channels are normalized between 0 and 1, i.e., $c^R \in (0,1)$ and $c^D \in (0,1)$ are used to distinguish the costs of selling activities between two channels, include marketing, pre-purchasing and after service, delivering, warehousing and other processes (Wang et al., 2016). In the retail channel, the retailer may provide consumers with free trials as well as purchasing suggestions in store, and the warehousing as well as the inventory costs are an important factor for retailers. Their ordering decisions are based on past experience and demand forecasting, which impacts the manufacturer's production plan in multi-echelon channels. Compared with the retail channel, delivering

is a key process when consumers buy products online. The manufacturer needs to balance the speed and cost of delivering products. Therefore, if the retail channel has larger operating costs, i.e., $c^R > c^D$, the service added in the retail store may be costly and of high quality, e.g., John Lewis and Marks & Spencer top the value-added services league in the UK. The direct channel can also achieve lower warehousing and inventory costs in industries as PC and furniture in which the manufacturers can adopt an “assemble-to-order” strategy that requires a lower inventory level than the “make-to-order” strategy in physical stores (Tsay and Agrawal, 2004a). If $c^R < c^D$, the delivering and customization costs in the direct/online channel may be considerable especially for products with low margins and low volumes. In addition, we ignore the production cost of the product for the purpose of simplification and assume the wholesale price between the manufacturer and the retailer is w . We define

$$\delta = \frac{1-c^D}{1-c^R} = 1 + \frac{c^R - c^D}{1-c^R} \quad (4.1)$$

as the relative cost structure in direct and indirect channels. $\delta > 1$ denotes the retail channel has a higher operating cost than the direct channel; $\delta < 1$ denotes the direct channel has a higher operating cost than the retail channel; $\delta = 1$ denotes operating costs in two channels are identical. Let δ_{S_1, S_2} represent the threshold of cost structure that strategy S_1 and strategy S_2 have same performance, thus, $\delta > \delta_{S_1, S_2}$ denotes the region that strategy S_1 outperforms strategy S_2 and $\delta < \delta_{S_1, S_2}$ denotes the region that strategy S_2 outperforms strategy S_1 .

Parameters α and η represent the consumers' preference attitude towards direct and indirect channels, i.e., difference of two channels in market level, while δ represents the cost structure which shows the difference of direct and indirect channels in operational level. Hence, we subsequently explore the channel members' profits and channel selection under internal and external factors. Let 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 ($S \in \{D, R, RD\}$) are determined respectively with

$$\pi_M(S) = (p - c^D)d^D(S) + wd^R(S), \quad (4.2)$$

$$\pi_R(S) = (p - w - c^R)d^R(S). \quad (4.3)$$

In strategy R, the manufacturer only focuses on production activities, and selling activities are carried out through an independent retailer who decides the retail price. The manufacturer can also

integrate its producing and selling activities without depending on a retailer in strategy D and makes decision on selling price in the direct channel himself. In addition, combining the above two strategies is also an option for the manufacturer in strategy RD. We consider the case where the manufacturer follows the retailer's retail price as the selling price in the direct channel in strategy RD, which is also discussed by Cattani et al. (2006) and Ding et al. (2016), here the manufacturer maximizes its profit through setting the wholesale price. This scenario is common in real-life practice and manufacturers can unify the online and offline selling through an identical price following the retailer's set price. Although the manufacturer is still the Stackelberg leader, it is not powerful enough to dominate the pricing, thus the selling price is based on the retailer's decision-making.

In line with Cattani et al. (2006), we explore a sequential game when the manufacturer is the Stackelberg leader and the retailer is the follower and find the subgame-perfect equilibrium (SPE) under the manufacturer's channel strategy. This equilibrium is determined by backward induction in this sequential game with perfect information, and the game sequence is listed as follows:

- (1) The manufacturer chooses his channel strategy;
- (2) The manufacturer decides the wholesale price if he has a retail channel, otherwise if the manufacturer doesn't offer a retail channel, he can only decides its direct price;
- (3) If the manufacturer chooses the retail channel, the retailer decides the retail price, and if the manufacturer chooses direct channel as well, he follows the retailer's selling price in the direct channel.

4.1. Analysis of SPE

The equilibrium price and profits of three strategies are listed in Table 2. The manufacturer and retailer have different pricing strategies under three channel approaches and thus have different performance, which provides a number of insights. Their profit performance is highly effected by the cost structure (c^R and c^D), the ratio of channels' market size (α) and the acceptance of less preferred channel (η). In strategy D and strategy R, the channel members' profits increase in α and η , and decreases in c^D or c^R . This is intuitive because the consumers' final preference is decided by their initial channel preference and the acceptance of less preferred channel. If one channel attracts more consumers and can be highly accepted as an alternative selection for consumers who prefer another channel, the channel members who choose this channel own more potential to gain profits. Also, in strategy RD, consumers who prefer the direct channel and the retail channel can both purchase through

their preferred channel, thus the channel members' profits are only impacted by the cost structure (c^D and c^R) and the ratio of channels' market size (α).

Table 2 Equilibria in strategies D, R and RD

	D	R	RD
p^S	$\frac{1+c^D}{2}$	$\frac{3+c^R}{4}$	$\frac{\alpha+3+\alpha c^D+c^R}{2(\alpha+2)}$
$\pi_M(S)$	$\frac{\delta^2(1-c^R)^2(\alpha+\eta)\alpha^R}{4}$	$\frac{(1-c^R)^2(1+\alpha\eta)\alpha^R}{8}$	$\frac{(1+\alpha\delta)^2(1-c^R)^2\alpha^R}{4(\alpha+2)}$
$\pi_R(S)$	-	$\frac{(1-c^R)^2(1+\alpha\eta)\alpha^R}{16}$	$\frac{(1+\alpha\delta)^2(1-c^R)^2\alpha^R}{4(\alpha+2)^2}$

Proposition 1. Let p^S denote the equilibrium selling price in strategy S ($S \in \{D, R, RD\}$). The equilibrium selling prices in three systems satisfy: (1) $p^D < p^{RD} < p^R$, if $\delta > 1/2$; (2) $p^D = p^{RD} = p^R$, if $\delta = 1/2$; (3) $p^D > p^{RD} > p^R$, if $\delta < 1/2$.

The selling prices in single-channel strategies are decided by the channel' operating costs, while the difference of channel's market size also has an impact on the selling price in the dual-channel scenario, i.e., the selling price increases in α when the operating cost in the direct channel is relatively higher ($\delta < 1/2$), and decreases in α when the operating cost in the direct channel is relatively lower ($\delta > 1/2$)^①. This reveals that although the consistent selling price is decided by the retailer, the pricing decision also contains the information in both the direct and retail channels. Proposition 1 also illustrates that the difference between operating costs in channels influences the difference in pricing decision in strategy R and strategy D. The selling price in strategy RD is always in the middle between selling prices in single channels when $\delta \neq 1/2$, thus the pricing decision in strategy RD reveals a balance between the operating cost in both the direct and retail channels.

There is not a strategy that is most effective at maximizing profit of the entire supply chain, which is related to the cost structure in the direct and indirect channels^②. This illustrates that cost structure is a

^① In strategy RD, the first-order derivative of the selling price in α is $\partial p / \partial \alpha = -(1-2c^D+c^R)/(\alpha+2)^2$ and has $\partial p / \partial \alpha < 0$ when $\delta > 1/2$ and $\partial p / \partial \alpha > 0$ when $\delta < 1/2$.

^② We compare the total profit of the manufacturer and the retailer in three channel strategies, and none of them is always larger than profits in other two strategies. As the subsequent discussion, this efficiency is highly related to cost structures, which is similar to the relationship in Proposition 2: when the operating cost in the direct channel is relatively higher, the total profits in strategy R is the highest, when the indirect cost is relatively higher, the total profits in strategy D is the highest, otherwise strategy RD is most effective in the total supply chain when the cost structure is neither too large nor too small.

vital factor that influences the performance of the entire supply chain under manufacturer's different channel strategies. Although our demand functions assume that a larger number of consumers is attracted in strategy RD, a dual-channel structure doesn't necessarily mean the maximum profit generation for the entire supply chain due to the horizontal competition.

4.2. Manufacturer's channel selection

As shown in Table 2, the manufacturer has different profits performance in three channel strategies, which causes the change of its channel preference under specified market characters and factors. We characterize the regions associated with different strategies based on the relation between operating costs of direct and indirect channels.

Proposition 2. *The manufacturer's best strategy is: strategy R when $\delta \in (0, \min(\delta_{RD,R}, \delta_{D,R}))$; strategy D when $\delta \in (\max(\delta_{D,RD}, \delta_{D,R}), +\infty)$; strategy RD when $\delta \in (\delta_{RD,R}, \delta_{D,RD})$ and $\delta_{RD,R} < \delta_{D,RD}$, where*

$$\delta_{D,RD} = \frac{\alpha + \sqrt{(\alpha + \eta)(2 + \alpha)}}{2\alpha + 2\eta + \alpha\eta}, \quad \delta_{RD,R} = \frac{\sqrt{2(2 + \alpha)(1 + \alpha\eta)} - 2}{2\alpha} \quad \text{and} \quad \delta_{D,R} = \sqrt{\frac{1 + \alpha\eta}{2(\alpha + \eta)}}.$$

Proposition 2 represents the manufacturer's channel selection under the segmentation of cost structures. The results are rather intuitive: 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), and strategy RD is the best one when $\delta \in (\delta_{RD,R}, \delta_{D,RD})$. The fact that $\delta_{RD,R} < 3/4$ shows the manufacturer will choose a single-retail channel when the direct cost is much higher than the retail cost, otherwise the dual-channel strategy is a better choice. Therefore, the region $\delta \in (\delta_{RD,R}, \delta_{D,RD})$ doesn't necessarily mean that δ is close to 1, which indicates that strategy RD can also be the best strategy when operating costs in two channels differ widely as further shown in Fig. 3.

Proposition 2 clarifies the importance of the operating costs in different channels when the manufacturer swings among channel strategies. Other factors, such as consumers' channel preference and acceptance of less preferred channels, also come into play and influence the thresholds of evaluating operating costs, i.e., $\delta_{RD,R}, \delta_{D,RD}, \delta_{D,R}$. There is not a best strategy for the manufacturer that maintains

its 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 as well instead of its continuous pure direct business model in 2006 when the development of high technological products boosted the demand and raised the requirement for marketing and service. This change requires high operating cost 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.

Our results are inconsistent with Cai (2010) who find the dual-channel strategy outperforms both 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 to corroborate the findings in this paper.

Corollary 1. (1) Threshold $\delta_{D, RD}$ decreases in α and η ; (2) Threshold $\delta_{RD, R}$ decreases in α and increases in η ; (3) Threshold $\delta_{D, R}$ always decreases in α , but decreases in η when $\alpha < 1$ and increases in η when $\alpha > 1$. Specifically, when $\alpha = 1$, η has no impact on threshold $\delta_{D, R}$.

Corollary 1 shows the effect of parameters' change on the thresholds. All thresholds are decreasing in α , which illustrates that the high market size of the direct channel becomes an advantage for the direct-channel strategy. This is intuitive and highlights the importance of market characters in the decision-making of channel strategies. In addition, the increasing value of η also raises the segment's size of the single-channel strategy compared with the dual-channel strategy.

We conduct a numerical analysis to explore deeper insights implied by Proposition 2 and Corollary 1 in Fig. 3, which represents the impact of the consumers' acceptance of their less preferred channels (η) and the ratio of consumers' channel preference (α) on the manufacturer's channel preference. When the operating cost of the direct channel is much higher than that in the retail channel (i.e., δ is in a lower level), strategy R is the best choice and strategy D is the worst. This also applies when the retail channel's operating cost is high (i.e., δ is in a higher level), then strategy D becomes the manufacturer's best choice and Strategy R becomes the worst. Fig. 3 also suggests that strategy RD is selected when the operating costs in two channels are within a certain region, i.e., $\delta \in (\delta_{RD, R}, \delta_{D, RD})$. Examples in Fig. 3 show that when the operating costs are identical, i.e., $\delta = 1$, strategy D instead of strategy RD is the best strategy. This also illustrates that the supply chain system has its own balance point of costs where single strategies lose their cost advantage, and this is not always the point of

identical costs.

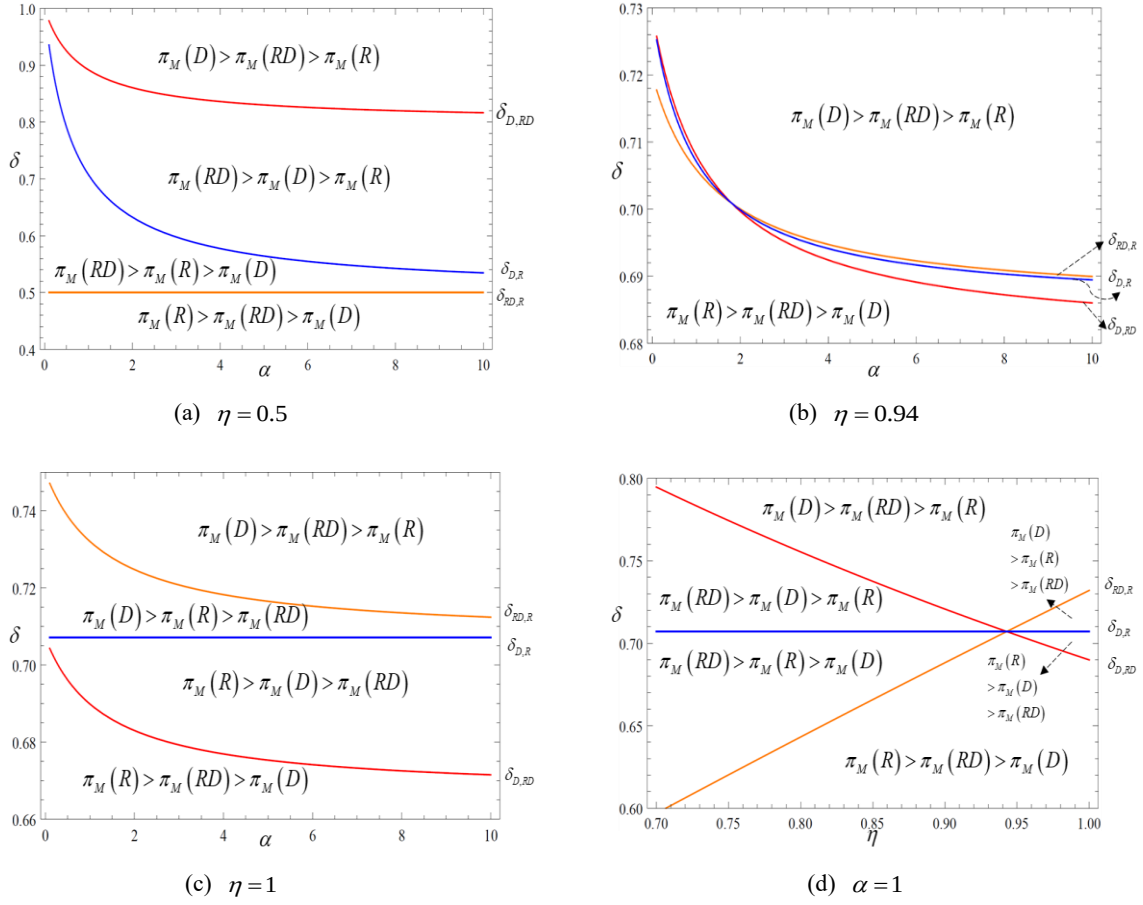


Fig. 3 The sensitivity of parameters on the channel selection (one manufacturer)

Thresholds here are also determined by the market factors. Fig. 3 (a-c) shows the manufacturer's preference regions based on the difference of market sizes and cost structures, and Fig. 3 (d) shows the segmentation based on the acceptance of less preferred channel and cost structures. Corollary 1 illustrates both the value of α and η can influence thresholds and then the channel selection, however, Fig. 3 further explains that the impact of η is more significant than that of α , because a large η can eliminate the selection of strategy RD regardless of the α value. When $\eta=0.5$ as an example, Fig. 3(a) illustrates that the selection channel strategies (i.e., $\delta_{D,RD}$ and $\delta_{RD,R}$) are more dependent on the cost structure as the impact of α is relatively steady. When $\eta=0.94$ and $\eta=1$, Fig. 3(b-c) shows that strategy RD will not be selected with the increase of α . The high acceptance of consumers' less preferred channel mitigates the negative effect of lacking one specific channel as consumers would change easily to a new channel, thus the dual-channel strategy loses its priority. This is also reflected in Fig. 3(d) where strategy RD is losing its size of region when consumers are more

willing to accept their less preferred channel. In an extreme situation when η is close to 1 in Fig. 3(c-d), strategy RD would never be an option regardless of the cost structure and consumers' initial channel preference if all the consumers would easily change their channel preference and buy products when their preferred channel doesn't exist in the market.

5. Symmetric Systems with Two Manufacturers

We have discussed in the previous section that there is not a channel strategy for a single manufacturer that is always preferred, and several parameters have different impacts on the manufacturer's decision-making. Then in this section, the focal manufacturer is competing with a similar manufacturer producing similar products in the market and we aim to compare the focal manufacturer's channel strategies with and without the existence of a competitor.

We consider a market with two manufacturers and one retailer, where the products of two manufacturers are highly substitutable by each other. Less substitutable products can relieve the conflict through different market positionings that narrow the overlap in the same market, the channel strategies in this case reflect the consumer retention in distinct market segmentations. Therefore, we introduce the symmetric assumption to measure the competing positions of products in the same market segmentation, i.e., the manufacturers are symmetric in costs and the level of power in the market. In this case, consumers' price-sensitivity to highly substitutable products can be very high, and the price difference can result in dramatic change of consumers' product preference. As would be expected, the price strategy of two products achieve the equilibrium that manufacturers adopt an equal pricing strategy. In real-life practice, some same products from different brands maintain similar selling price in retail and online stores, e.g., Coca-cola and Pepsi, and non-price factors, such as channel structures, service levels, and inventory levels, determine consumers' channel patronage choices significantly (Tsay and Agrawal, 2004a). Therefore, the price factors may not be the leading factor even though products are selling through different channels, e.g., some in retail channel and others in direct channel. We thereby assume the identical price of two products for simplification purpose. We also follow our previous assumption that manufacturers' direct prices are following the retailer's selling price. Therefore, we assume consumers can buy products in a same price whether in direct or retail channel. In addition, we assume half of consumers prefer one product and half of consumers prefer another in direct or retail channels in the equilibrium, and the consumers will switch their purchasing products if their preferred one is not

selling in the market. Here we highlight the difference of retail and direct channels, i.e., consumers will switch to a new channel only if manufacturers don't operate their preferred channel, otherwise, they will buy products in their preferred channel.

These two manufacturers are the leaders of the supply chain in pricing, and they can determine their channel structures (i.e., which channels to adopt) and the wholesale prices. For each manufacturer, there are three channel strategies, i.e., strategy D, strategy R and strategy RD, thus the market has six channel strategies in total (considering the symmetry) (Fig. 4). We have discussed the manufacturer's channel selection in a single-manufacturer market, then in this section, we switch to the change of the focal manufacturer's channel selection encountering a competing manufacturer. Considering the existence of a competing manufacturer, which is denoted as the competitor, the focal manufacturer selects the channel strategy when the competitor is adopting strategy D, strategy R or strategy RD. We thereby discuss and compare the focal manufacturer's three channel strategies when the competitor is adopting a particular channel strategy, i.e., best response to a particular channel strategy.

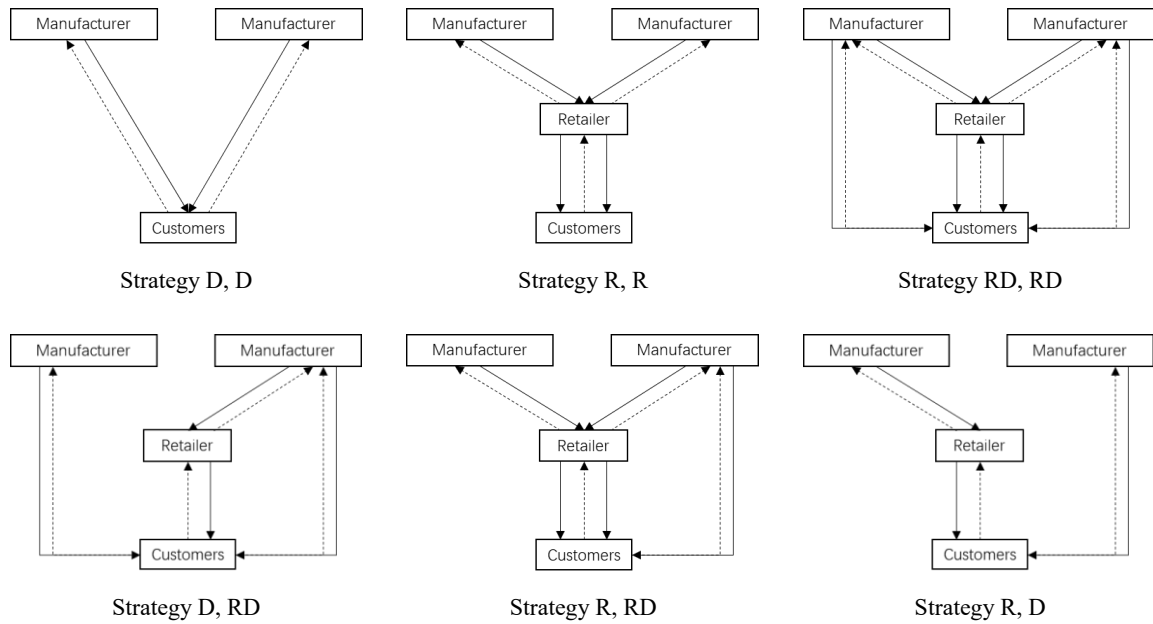


Fig. 4 Channel systems with two manufacturers

Recall that we divide the consumers into two types according to their channel preference—online channel consumers (α^D) and store consumers (α^R), and we also use $\alpha = \alpha^D / \alpha^R = \alpha^D > 0$ which reflects the difference of the consumers' channel preference. The operating cost in channels is discussed in last section, and we use the same assumption that $c^R \in (0,1)$ and $c^D \in (0,1)$ distinguish the costs

of selling activities between retail and direct channels. The symmetric system also means the operating cost in direct channels is identical for different manufacturers. Demand functions are listed in Table 3.

Table 3 Demand functions in the supply chain with two manufacturers

Demand	Channel Strategy Profile (S_1, S_2)					
	D, D	R, R	RD, RD	D, RD	R, RD	R, D
$d_1^D(S_1, S_2)$	$\frac{\alpha^D + \eta\alpha^R}{2}(1-p)$	0	$\frac{\alpha^D}{2}(1-p)$	$\frac{\alpha^D}{2}(1-p)$	0	0
$d_2^D(S_1, S_2)$	$\frac{\alpha^D + \eta\alpha^R}{2}(1-p)$	0	$\frac{\alpha^D}{2}(1-p)$	$\frac{\alpha^D}{2}(1-p)$	$\alpha^D(1-p)$	$\alpha^D(1-p)$
$d_1^R(S_1, S_2)$	0	$\frac{\alpha^R + \eta\alpha^D}{2}(1-p)$	$\frac{\alpha^R}{2}(1-p)$	0	$\frac{\alpha^R}{2}(1-p)$	$\alpha^R(1-p)$
$d_2^R(S_1, S_2)$	0	$\frac{\alpha^R + \eta\alpha^D}{2}(1-p)$	$\frac{\alpha^R}{2}(1-p)$	$\alpha^R(1-p)$	$\frac{\alpha^R}{2}(1-p)$	0

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 , $\pi_R(S_1, S_2)$ denote the profit of the retailer when the two manufacturer's strategy profile is (S_1, S_2) . The profit functions of the focal manufacturer and the retailer are

$$\pi_M(S_1, S_2) = (p - c^D)d_1^D(S_1, S_2) + w_1d_1^R(S_1, S_2), \quad (5.1)$$

$$\pi_R(S_1, S_2) = (p - w_1 - c^R)d_1^R(S_1, S_2) + (p - w_2 - c^R)d_2^R(S_1, S_2). \quad (5.2)$$

In the Stackelberg game, the manufacturers are assumed to be the leaders. We explore a game that combines the sequential game and the simultaneous game, in which the manufacturers are the Stackelberg leaders who move simultaneously, and the retailer is the follower. This power balance scenario is described as vertical Nash in Choi (1991) where a manufacturer cannot observe another manufacturer's wholesale price but the retail price on the conditions of his wholesale price. The model fits the market where neither manufacturers nor retailers control the market and they are equally sized. Backward induction is used for the subgame perfect Nash equilibrium under the manufacturers' channel strategy. The game sequence is listed as follows:

- (1) The manufacturers choose their channel strategies;
- (2) If only one manufacturer has a retail channel, he decides the wholesale price; if both manufacturers have retail channels, they offer separate wholesale prices, and the retailer chooses a lower one and applies to both manufacturers; if manufacturers don't offer a retail channel, they can only decide their direct price.
- (3) If the retailer comes into play, she decides the retail price, and if manufacturers choose direct channel

as well, they follow the retailer's selling price in the direct channel.

The results listed in Table 4 are the equilibrium prices and profits of one manufacturer under three strategies when facing a direct-channel, retail-channel or dual-channel competitor, respectively, which is the basis of our further analytical and numerical analysis.

Table 4 A manufacturer's best response profit when the competitor's choice of strategy is fixed

The competitor's strategy selection	The manufacturer's strategy selection		
	Strategy D	Strategy R	Strategy RD
Strategy D	$\frac{\delta^2(\alpha+\eta)(1-c^R)^2\alpha^R}{8}$	$\frac{(1-c^R)^2\alpha^R}{8}$	$\frac{(2+\delta\alpha)^2(1-c^R)^2\alpha^R}{8(\alpha+4)}$
Strategy R $\delta < \frac{1}{3}$ $\delta > \frac{1}{3}$	$\frac{(4\delta-1)\alpha(1-c^R)^2\alpha^R}{16}$	$\frac{(1+\alpha\eta)(1-c^R)^2\alpha^R}{18}$	$\frac{(2+\alpha+2\delta\alpha+\alpha^2-2\delta\alpha^2)(1-\alpha+4\delta\alpha)(1-c^R)^2\alpha^R}{4(3+\alpha)^2}$
			$\frac{(2+\alpha)(1-\alpha+4\delta\alpha)(1+\alpha-2\delta\alpha)(1-c^R)^2\alpha^R}{4(3+\alpha)^2}$
Strategy RD $\delta < \frac{1}{3}$ $\delta > \frac{1}{3}$	$\frac{(8\delta+\delta\alpha-2)(2+\delta\alpha)(1-c^R)^2\alpha\alpha^R}{8(\alpha+4)^2}$	$\frac{(1-\alpha+4\delta\alpha)(1-c^R)^2(1+\alpha-2\delta\alpha)\alpha^R}{2(3+\alpha)^2}$	$\frac{(\alpha+4)(1+\delta\alpha)^2(1-c^R)^2\alpha^R}{8(\alpha+3)^2}$
		$\frac{(1+\alpha-2\delta\alpha)(1+\delta\alpha)(1-c^R)^2\alpha^R}{2(\alpha+3)^2}$	

5.1. Best Response to Strategy D

When the competing manufacturer adopts strategy D, another manufacturer has three channel strategies to choose from, i.e., strategy D, strategy R and strategy RD.

Proposition 3. *When the competitor adopts strategy D, the manufacturer's best response is: strategy R when $\delta \in (0, \delta_{RD,R}^D)$; strategy D when $\delta \in (\delta_{D,RD}^D, +\infty)$; strategy RD when $\delta \in (\delta_{RD,R}^D, \delta_{D,RD}^D)$, where*

$$\delta_{D,RD}^D = \frac{2[\alpha + \sqrt{(\alpha+\eta)(4+\alpha)}]}{4\alpha + 4\eta + \alpha\eta}, \quad \delta_{RD,R}^D = \frac{\sqrt{4+\alpha}-2}{\alpha}, \quad \delta_{D,R}^D = \frac{1}{\sqrt{\alpha+\eta}} \quad \text{and} \quad \delta_{D,RD}^D > \delta_{D,R}^D > \delta_{RD,R}^D.$$

Corollary 2. $\delta_{D,RD}^D$, $\delta_{RD,R}^D$ and $\delta_{D,R}^D$ are decreasing in α ; $\delta_{D,RD}^D$ and $\delta_{D,R}^D$ are decreasing in η .

Proposition 3 shows the manufacturer's channel preference when the competitor adopts a direct-channel strategy, and Fig. 5 further illustrates the sensitivity of each parameter on the manufacturer's

channel preference. Recap $\pi_M(S_i, S_j)$ denote the profit of the manufacturer with strategy S_i and facing a competitor with strategy S_j , and the segments in these figures represent the manufacturer's best selection among three strategies.

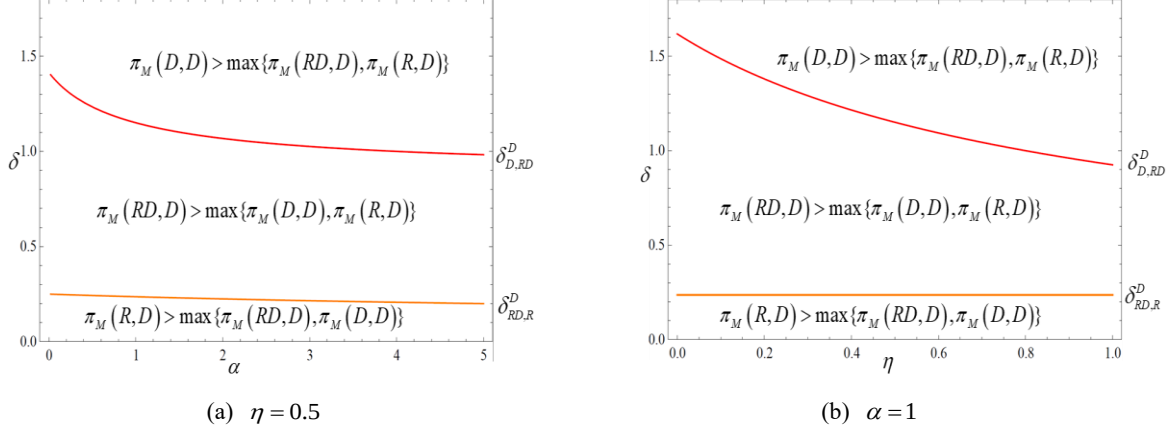


Fig. 5 The sensitivity of parameters on the channel selection (best response to strategy D)

When the competitor is adopting a direct channel strategy, consumers' acceptance of their less preferred channels (η) has no impact on the manufacturer's channel selection between strategy RD and strategy R (i.e., $\delta_{RD,R}^D$) but exerts a monotonic impact on channel selection between strategy RD and strategy D (i.e., $\delta_{D,RD}^D$ is decreasing in η), thus a higher acceptance rate η always extends the acceptable cost structure that makes strategy D outperforms strategy RD. The role of η has changed here compared with the single-manufacturer case where η 's influence is connected with the value of α . In a single-manufacturer case, competition concentrates on the difference between two channels, where the consumers' preference attitude plays an important role and strategy RD can be out of selection under any cost structure when consumers' preference attitude is in a certain range. However, the competing manufacturers distract the channel competition and reduces the impact of α and η . Thus, $\delta_{D,RD}^D > \delta_{D,R}^D > \delta_{RD,R}^D$ denotes that the manufacturer can always choose from three strategies based on cost structure under any consumers' preference attitudes.

5.2. Best Response to Strategy R

According to the optimal results listed in Table 4, when the competitor sells products through a traditional retail channel, the manufacturer's best strategy is shown in Proposition 4.

Proposition 4. *When the competitor adopts strategy R, (1) if $2+9\alpha-16\alpha\eta < 0$, strategy R outperforms strategy RD, thus the manufacturer's best response is: strategy R when $\delta \in (0, \delta_{D,R}^R)$; strategy D when*

$\delta \in (\delta_{D,RD}^R, +\infty)$; (2) if $2+9\alpha-16\alpha\eta \geq 0$, the manufacturer's best response is: strategy R when

$\delta \in (0, \delta_{RD,R}^R) \cup (\delta_{R,RD}^R, \max(\delta_{R,RD}^R, \delta_{D,R}^R))$; strategy D when $\delta \in (\max(\delta_{D,R}^R, \delta_{D,RD}^R), +\infty)$; strategy RD

when $\delta \in (\max(\delta_{RD,R}^R, \delta_{RD,D}^R), \min(\delta_{D,RD}^R, \delta_{R,RD}^R))$, where,

$$\delta_{D,RD}^R = \frac{5\alpha^2 + 8\alpha - 5 + (3+\alpha)\sqrt{\alpha^2 + 10\alpha + 17}}{16\alpha(2+\alpha)},$$

$$\delta_{R,RD}^R = \frac{3(2+\alpha)(1+3\alpha) + (3+\alpha)\sqrt{(2+\alpha)(2+9\alpha-16\alpha\eta)}}{24\alpha(2+\alpha)},$$

$$\delta_{RD,D}^R = \begin{cases} \frac{(\alpha-1)(5\alpha-1) - (3+\alpha)\sqrt{(\alpha-1)(\alpha+7)}}{16\alpha(\alpha-1)} & (\alpha > 1) \\ 0 & (0 < \alpha \leq 1) \end{cases},$$

$$\delta_{RD,R}^R = \begin{cases} \frac{-9\alpha^2 - 15 + (3+\alpha)\sqrt{(16\eta-9)\alpha^2 - 2(1+8\eta)\alpha - 25}}{24\alpha(1-\alpha)} & \left(\eta \leq \frac{1}{2}, \alpha \neq 1\right) \\ \frac{2}{9}(1+\eta) & \left(\eta \leq \frac{1}{2}, \alpha = 1\right) \\ \frac{3(2+\alpha)(1+3\alpha) - (3+\alpha)\sqrt{(2+\alpha)(2+9\alpha-16\alpha\eta)}}{24\alpha(2+\alpha)} & \left(\eta > \frac{1}{2}, 2+9\alpha-16\alpha\eta > 0\right) \end{cases} \quad \text{and}$$

$$\delta_{D,R}^R = \frac{8+9\alpha+8\alpha\eta}{36}.$$

The manufacturer's channel preference changes a lot when competing with a retail-channel manufacturer. Unlike the simple thresholds in Proposition 3, Proposition 4 shows the manufacturer's channel preference is affected by the market factors and cost structure in a more complex way. The segmentation in Fig. 6 further illustrates the influence of different parameters. η has more significant impacts on the channel selection between strategy R and RD, while when α value is fixed, the threshold that distinguish strategy D from other two strategies is relatively steady with the change of η as shown in Fig. 6 (a-b). Fig. 6 also reveals that the increasing α decreases the cost structure (i.e., δ) that segmenting the channel selection between strategy R and other two strategies. Thus, as shown in Fig. 6 (a-b), the cost structure that benefits most to strategy RD will change to be more profitable in strategy D when α is increasing, and strategy RD will lose its advantage and may be out of selection when α is larger than a threshold (in Fig. 6 (d)). Specifically, Fig. 6 also illustrates that when both α and η are high, the manufacturer will not select strategy RD under any cost structure. This is similar to the case with only one manufacturer, where consumers' high acceptance of less preferred channel

reduces the advantage of dual-channel strategies.

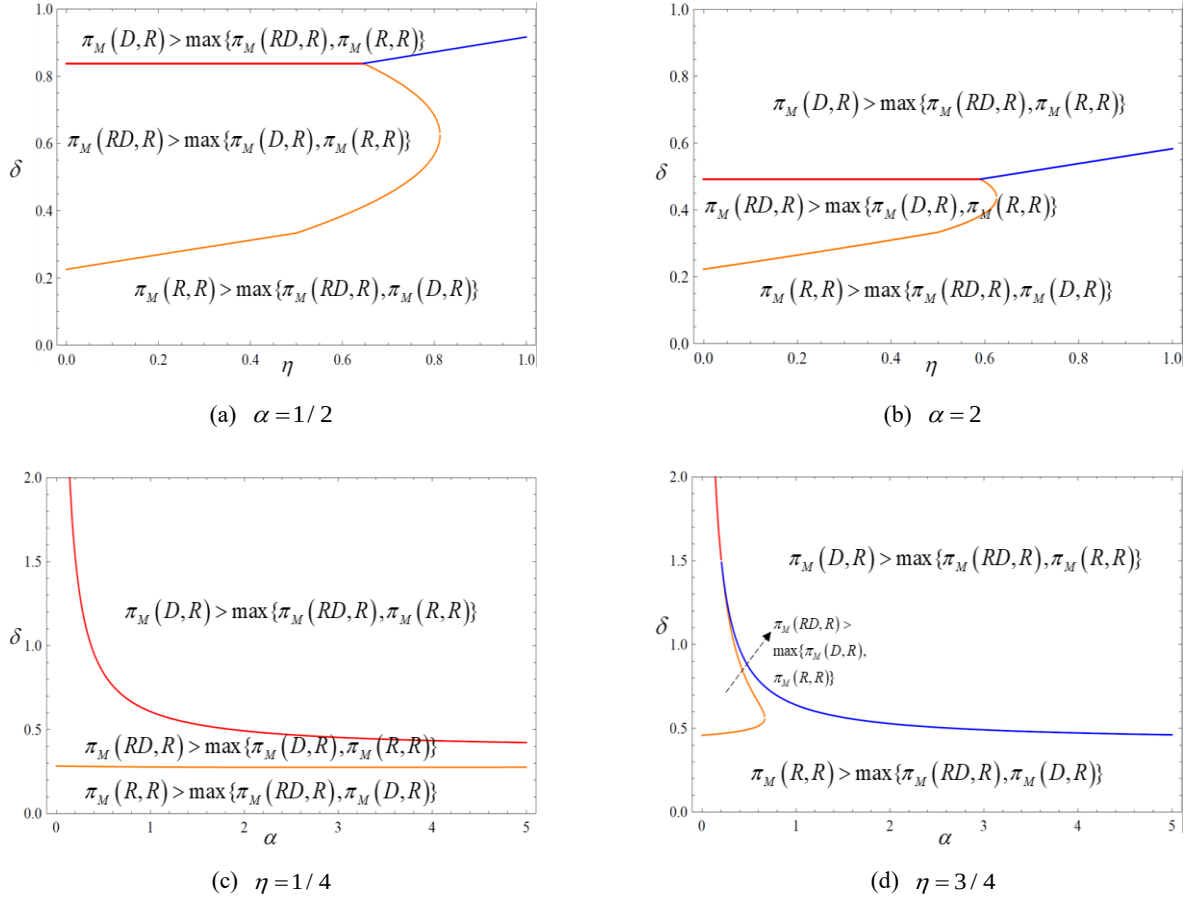


Fig. 6 The sensitivity of parameters on the channel selection (competitor with strategy R)

5.3. Best Response to Strategy RD

Next, we discuss the scenario when the competitor is selling through dual channels. The results in Table 4 show that the consumers' acceptance of less preferred channel has no impact on the channel selection of the manufacturer as consumers can always buy through their preferred channels when the competitor is selling through both direct and retail channels.

Proposition 5. *When the competitor adopts strategy RD, the manufacturer can always benefit more from strategy RD than strategy R, and the manufacturer's best response is: (1) strategy RD when $\delta \in (0, \delta_{D, RD}^{RD})$; (2) strategy D when $\delta \in (\delta_{D, RD}^{RD}, +\infty)$, where $\delta_{D, RD}^{RD} = 1 + \frac{2}{\alpha}$.*

Corollary 3. *When the operating costs in retail and direct channels are identical ($c^R = c^D$), strategy RD is the best for a manufacturer who is facing a competing manufacturer with strategy RD.*

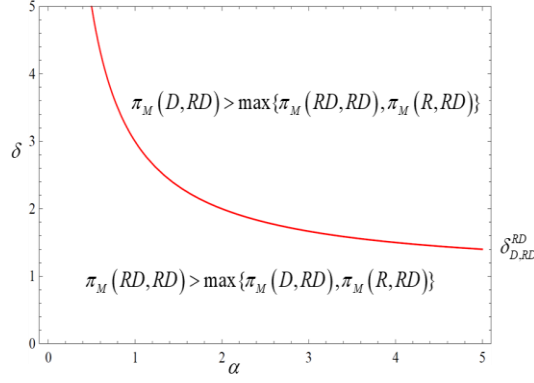


Fig. 7 The sensitivity of parameters on the channel selection (competitor with strategy RD)

The manufacturer is actually choosing from strategy D and strategy RD when competing with a dual-channel manufacturer and the threshold is affected by the value of α . Fig. 7 illustrates that this impact is rather significant especially when $\alpha < 1$. This finding suggests that when the market size of direct channel is smaller than that of the retail channel, cost structure δ doesn't play an important role in channel selection between strategy D and RD. Specially, Corollary 3 reveals that in the case with $c^R = c^D$, strategy RD is always the best strategy for the manufacturer regardless of market factors such as α and η . In addition, a dual-channel competitor intensifies the competition within the same channel type. If the manufacturer adopts a retail channel as a counterplan, this will be detriment to the profits in two ways. First, the fierce competition in the retail level restricts the manufacturer's profitability. Since the competitor is operating a direct channel at the same time, no consumer will switch to retail stores based on our assumption, which contributes to the fierce competition in the retail level. Second, the competition within the direct-channel level will not affect the competition in the retail level if at least one manufacturer is operating a direct channel. Without a rival in the direct channel, the competitor will benefit a lot in this channel. However, if the manufacturer can add a direct channel besides the retail channel, the manufacturer will own extra profits in strategy RD, which explains why strategy RD outperforms strategy D when encountering a dual-channel competitor.

5.4. Equilibria in channel selection

Considering the channel selection of two competing manufacturers as a game, we can explore the existence of Nash equilibrium in this game, which rests on the manufacture's channel selection with a symmetric competitor as discussed in previous sections.

Proposition 6. (1) Strategy profile (R, R) is a Nash equilibrium either if $2+9\alpha-16\alpha\eta < 0$ and

$\delta \in (0, \delta_{D,R}^R)$ or if $2+9\alpha-16\alpha\eta \geq 0$ and $\delta \in (0, \delta_{RD,R}^R) \cup (\delta_{R,RD}^R, \max(\delta_{R,RD}^R, \delta_{D,R}^R))$; (2) strategy profile (D, D) is a Nash equilibrium if $\delta \in (\delta_{D,RD}^D, +\infty)$; (3) strategy profile (RD, RD) is a Nash equilibrium if $\delta \in (0, \delta_{D,RD}^{RD})$; (4) asymmetric strategy profiles, e.g., (D, RD) , (R, D) , (R, RD) , cannot be the Nash equilibrium in this game.

Corollary 4. The manufacturer's profit is highest in: (R, R) when $\delta \in (0, \min(\delta_{RD,R}^N, \delta_{D,R}^N))$; (D, D) when $\delta \in (\max(\delta_{D,RD}^N, \delta_{D,R}^N), +\infty)$; (RD, RD) when $\delta \in (\delta_{RD,R}^N, \delta_{D,RD}^N)$ and $\delta_{RD,R}^N < \delta_{D,RD}^N$, where

$$\delta_{D,RD}^N = \frac{\alpha(4+\alpha) + (3+\alpha)\sqrt{(\alpha+\eta)(4+\alpha)}}{9\alpha + 9\eta + 6\alpha\eta + 2\alpha^2 + \alpha^2\eta}, \quad \delta_{RD,R}^N = \frac{2(3+\alpha)\sqrt{(4+\alpha)(1+\alpha\eta)} - 3(4+\alpha)}{3\alpha(4+\alpha)} \quad \text{and}$$

$$\delta_{D,R}^N = \frac{2}{3}\sqrt{\frac{1+\alpha\eta}{\alpha+\eta}}.$$

As shown in Proposition 6, there is not a constant Nash equilibrium in the two-manufacturer competition. Since the symmetric nature of two manufacturers, if one manufacturer chooses the same strategy as the competitor's, this can also be the case that the competitor will choose also the same as the manufacturer's. Therefore, symmetric strategy profiles can become Nash equilibria under certain conditions. However, Proposition 6 also reveals that asymmetric strategy profiles cannot become Nash equilibria in this case. Although three symmetric strategy profiles may become Nash equilibria in this game, the results in Corollary 4 shows that there is not a specific equilibrium that superior to others.

Table 5 Equilibria matrix

	$\delta = 0.2$			$\delta = 0.7$			$\delta = 1$			$\delta = 5$		
$\eta \backslash \alpha$	0.2	0.5	0.8	0.2	0.5	0.8	0.2	0.5	0.8	0.2	0.5	0.8
0.5	(R, R) (RD, RD)	(R, R) (RD, RD)	(R, R) (RD, RD)	(RD, RD)	(RD, RD)	(R, R) (RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(D, D) (RD, RD)	(D, D) (RD, RD)	(D, D) (RD, RD)
1	(R, R) (RD, RD)	(R, R) (RD, RD)	(R, R) (RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(D, D) (RD, RD)	(D, D)	(D, D)	(D, D)
2	(R, R) (RD, RD)	(R, R) (RD, RD)	(R, R) (RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(RD, RD)	(D, D) (RD, RD)	(D, D)	(D, D)	(D, D)

Note: The color of shading denotes the manufacturer's best channel strategy when considered as the only manufacturer in the market under the condition of known α , η and δ , i.e., blue denotes strategy R, yellow denotes strategy D, green denotes strategy RD.

As it becomes complex when the cost structures vary in the proper range, we use a numerical example in Table 5 to further illustrate the Nash equilibria in this game. We explore the scenarios when

each of three parameters, i.e., δ , α and η , is in a low, medium and high value. The results in Table 5 provide a number of insights. Strategy profile (D, D) becomes the only equilibrium when the ratio of market size is large (i.e., the market size of retail channels only accounts for a small portion) and the operating cost of direct channels is much smaller than that of retail channels. Otherwise, strategy profile (RD, RD) is always a Nash equilibrium in this case. Strategy profile (R, R) also becomes a Nash equilibrium if the operating cost of direct channels is much larger than that of retail channels. Cost structure is an important factor that impacts the Nash equilibria in the game as shown in Table 5. However, there are some “exceptions” that reveals the impact of market factors. For example, strategy profile (R, R) become a Nash equilibrium when $\alpha = 0.5$, $\eta = 0.8$ and $\delta = 0.7$; strategy profile (D, D) become a Nash equilibrium when $\alpha = 1.2$, $\eta = 0.8$ and $\delta = 1$.

Three colours in Table 5 shows the inconsistency in the two equilibria under SPE (a single manufacturer) and Nash equilibrium (two symmetric manufacturers), which implies the uncertainties created by the competition from structural equivalence. When the operating cost in the retail channel is low, e.g., $\delta = 0.2$, a single manufacturer prefers strategy R as the best channel strategy; in a competing scenario, however, the game reaches the equilibria at either the symmetric retail-channel strategies or the symmetric dual-channel strategies, in which the manufacturers' payoff in the dual-channel strategies is less than that in the retail-channel strategies. The decision of strategy R under the consideration of a single manufacturer in the market may be unstable and switch to strategy RD in the real competition with others. When the operating costs in different channels remain the same, i.e., $\delta = 1$, the reaction of channel selection differs significantly. For example, a single manufacturer prefers strategy D if consumers are more likely to accept their less preferred channel because the identical cost indicates that the elimination of intermediaries promotes to the profit redistribution which benefits the manufacturer. This is not the case anymore when the competitor is positioned as strategy profile (RD, RD) becomes the Nash equilibrium under the same condition of consumers' preference. One reason is that the best response to strategy D might be strategy RD that attracts the consumers who insist on their initial channel preference, thus strategy D lags because of the consumer loss.

6. Conclusions

New selling platforms have brought about opportunities as well as challenges for upstream manufacturers. Although dual-channel strategy that integrating both traditional physical stores and

emerging online selling seems to be more profitable for manufacturers, different channel strategies have been adopted by manufacturers from various industries selling different products. In order to find out the feasibility of different channel strategies and explore their range of application, we develop a linear demand model to analyse the manufacturer's channel selection between single-channel strategies and a dual-channel strategy. Apart from a single manufacturer's decision, we also add the action of a symmetric 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. The symmetric nature of manufacturers refers to the product similarity that consumers don't prefer a particular product. We then focus on the channel selection based on different levels to distinguish direct and retail channels, i.e., market level and cost level.

We don't consider the case when the manufacturer is extremely powerful to dominate the supply chain because the manufacturer tends to adopt a unified direct channel instead of the dual-channel strategy^③. The case that the retailer acts as a Stackelberg leader is not considered either because it provides less insights for management. If a retailer is more powerful, the manufacturer tends to be less dominant. Consumers herein are focusing more on products sold through the dominant retailer than products with an "unknown" brand, thus adopting a single direct-channel strategy is less likely to be a selection for the manufacturer, and the competitiveness of the direct channel in a dual-channel strategy is obviously lowered. Therefore, we particularly explore the case when manufacturers lead the game but cannot determine the retail price. The retail price is determined by the retailer and the manufacturer follows it as the direct price.

Manufacturers' decision on whether adopting a single-channel or multi-channel strategy is the main focus in this paper. There is not a best channel strategy in different scenarios. Our findings show that market factors and cost structure play important roles in manufacturer's channel preference. Although multi-channel strategies may increase the market potential and approaches to the market demand, there exists advanced requirement and trade-off behind the option. In fact, a dual-channel strategy is a buffer when there are not obvious advantages in both direct and retail channels as well as a reflection between the operation resources and market requirement. In addition, competitors' channel options would change

^③ Based on backward induction, when the manufacturer can decide both the selling price and the wholesale price in a dual-channel supply chain, the optimal wholesale price would be negative and the manufacturer cannot gain profits from the retail channel. In this case, the manufacturer would stop selling through an intermediate retailer and integrate the selling activities through its direct channel selling.

the capability in channels, thus swapping their relative advantages and disadvantages. Therefore, the channel preference is a dynamic decision that changes over time and varies from industry to industry. Actually, the dual-channel strategy will lose its advantage when more consumers would like to accept their less preferred channels, then a dual-channel strategy becomes out of the manufacturer's selection when consumers can easily switch to other channels, e.g., from the retail (direct) to direct (retail) channels.

According to the comparison between a single manufacturer and two competing manufacturers, we find that the impact of market factors and cost structure can be overestimated or underestimated when only considering a single manufacturer's channel strategy, actually they play different roles when the manufacturer is facing a competitor with distinct strategies. The two market factors exert more significant impacts on channel selection when the competitor is adopting a retail-channel strategy. This is also the case in a single manufacturer consideration. However, when encountering a direct-channel competitor, these impacts become slighter; the consumers' acceptance of less preferred channels doesn't come into play when the competitor is adopting dual channels. This implies that there may exist bias when the manufacturer only considers the interaction with the retailer, actually things have changed dramatically when the competitor exists and operates distinct channel strategies. Therefore, apart from the interaction with downstream retailers, it is necessary for manufacturers to take horizontal competitors' actions into account when making decisions.

Although a manufacturer may not mimic the competitor's channel strategy as the best strategy, the Nash equilibria between two manufacturers remain as a symmetric channel structure, i.e., identical channel strategies for two manufacturers producing and selling products that cannot be easily differentiated by consumers. Under the similar or identical operating costs in the direct and retail channels, the manufacturer might believe that eliminating intermediaries is appropriate when consumers can accept both channels easily, however, the peer competition amplifies the consumers' slight difference of preference towards multiple channels that both manufacturer tend to retain possible consumers through offering multiple selections to fulfil their preference. When the operating cost of a particular channel is much lower, the manufacturer tends to focus on this single channel at the first glance, whereas the market might reach the equilibrium of symmetric dual-channel strategies because of the unbalanced market sizes and the dynamic market and cost levels. As an example, the process of cost adjustment from previous cost structures, e.g., the slumping cost due to technology development,

may remain the equilibrium of symmetric dual-channel strategies in the new cost structures.

The limitation of this research concerns the assumption of consistent pricing and the bargaining power of channel members. Although consistent pricing is a popular strategy in practice, there are still some companies that distinguish the pricing decision between channels as swim lanes instead of integration. In addition, the wholesale price and retail price may also be determined by the negotiation between the manufacturer and the retailer. Future work could explore the impacts if different pricing schemes in reality. Furthermore, the channel members may have different bargaining power that affects one channel member's channel strategy. Our research is focusing on the market with a relatively less powerful retailer, however, considering the leading retailer as Wal-Mart, some relatively small or medium manufacturers are also facing the problems of operating mix channels effectively. Future work could discuss the impacts of different bargaining structures on channel members' strategies and fulfil the gaps under different market structures.

7. Appendix A -Obtaining the values in Tables

7.1. Table 2

In strategy RD, the retailer and manufacturer's profit functions are

$$\pi_M = (p - c^D)\alpha^D(1-p) + w\alpha^R(1-p), \quad \pi_R = (p - w - c^R)\alpha^R(1-p).$$

Then we have $d\pi_R/dp = (1 - 2p + w + c^R)\alpha^R$, $d^2\pi_R/dp^2 = -2\alpha^R < 0$. The retailer's profit function is concave, and the best response of the selling price is $p = (1 + w + c^R)/2$. Substitute the above equation into the manufacturer's profit function, we have $d\pi_M/dw = [1 + \alpha c^D - (2 + \alpha)w - (1 + \alpha)c^R]\alpha^R/2$, $d^2\pi_M/dw^2 = -\alpha^R(2 + \alpha)/2 < 0$. Thus, the manufacturer's profit is concave in w . Solving the first-order condition gives the optimal values. The optimal values in strategy R and strategy D are calculated in a similar way.

7.2. Table 4

We begin with the case when the competitor is adopting strategy R since the calculation in other two cases are similar. When the manufacturer adopts strategy D, the competitor, the manufacturer and the retailer's profit functions are

$$\pi_C = w_C\alpha^R(1-p), \quad \pi_M = (p - c^D)\alpha^D(1-p), \quad \pi_R = (p - w_C - c^R)\alpha^R(1-p).$$

Then we have $d\pi_R/dp = \alpha^R(1 - 2p + w_C + c^R)$, $d^2\pi_R/dp^2 = -2\alpha^R < 0$. Thus, the retailer's

profit function is concave, and the best response of the selling price is $p = (1 + w_C + c^R)/2$. Substitute the above equation into the competitor's profit function, we have $d\pi_C/dw_C = (1 - 2w - c^R)\alpha^R/2$, $d^2\pi_C/dw_C^2 = -\alpha^R < 0$. Thus, the competitor's profit is concave in w_C . Solving the first-order condition gives the manufacturer's optimal profit shown in Table 4.

When the manufacturer adopts strategy R, the competitor, the manufacturer and the retailer's profit functions are

$$\pi_C = \frac{w_C}{2}(\alpha^R + \eta\alpha^D)(1-p), \quad \pi_M = \frac{w}{2}(\alpha^R + \eta\alpha^D)(1-p),$$

$$\pi_R = \left(p - \frac{w + w_C}{2} - c^R\right)(\alpha^R + \eta\alpha^D)(1-p).$$

Then we have $d\pi_R/dp = (\alpha^R + \eta\alpha^D)[1 - 2p + (w + w_C)/2 + c^R]$, $d^2\pi_R/dp^2 = -2(\alpha^R + \eta\alpha^D) < 0$. Thus, the retailer's profit function is concave, and the best response of the selling price is $p = [1 + (w + w_C)/2 + c^R]/2$. Substitute the above equation into the competitor and the manufacturer's profit function, we have $d^2\pi_C/dw_C^2 = -3(\alpha^R + \eta\alpha^D)/8 < 0$ and $d^2\pi_M/dw^2 = -3(\alpha^R + \eta\alpha^D)/8 < 0$. Thus, the manufacturer's profit function is concave in w and the competitor's profit function is concave in w_C , where $w = w_C = 2(1 - c^R)/3$. Solving the first-order condition gives the manufacturer's optimal profit shown in Table 4.

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

$$\pi_{MC} = w_C \frac{\alpha^R}{2}(1-p), \quad \pi_M = (p - c^D)\alpha^D(1-p) + w \frac{\alpha^R}{2}(1-p),$$

$$\pi_R = \alpha^R \left(p - \frac{w + w_C}{2} - c^R\right)(1-p).$$

Then we have $d\pi_R/dp = \alpha^R[1 - 2p + (w + w_C)/2 + c^R]$, $d^2\pi_R/dp^2 = -2\alpha^R < 0$. Thus, the retailer's profit function is concave, and the best response of the selling price is $p = [1 + (w + w_C)/2 + c^R]/2$. Substitute the above equations into the manufacturer's profit function, we have $\partial^2\pi_C/\partial w_C^2 = -\alpha^R/4 < 0$ and $\partial^2\pi_M/\partial w^2 = -\alpha^D/2 < 0$. Thus, the manufacturer's profit function is concave in w and the competitor's profit function is concave in w_C , where $w = 2(1 - c^R - \alpha + 2\alpha c^D - \alpha c^R)/(3 + \alpha)$ and $w_C = 2(1 - c^R + \alpha - \alpha c^D)/(3 + \alpha)$. The retailer will choose a lower wholesale price as a unified wholesale price to both manufacturers. Therefore, if

$\delta \leq 1/3$, $w = w_C = 2(1 - c^R + \alpha - \alpha c^D)/(3 + \alpha)$; if $\delta > 1/3$,
 $w = w_C = 2(1 - c^R - \alpha + 2\alpha c^D - \alpha c^R)/(3 + \alpha)$. Substituting the above equations into the manufacturer's profit function, the manufacturer's optimal profits are shown in Table 4.

7.3. Table 5

Table 6 Profits

Competitor Manufacturer	D	R	RD
D	8.75%	9.38%	5.02%
R	12.50%	6.11%	3.06%
RD	17.36%	6.38%	10.33%

Under the example with $\eta = 0.2$, $\alpha = 0.5$ and $\delta = 1$, the profits of the manufacturer under different channel strategies are listed in Table 6. When the competitor is adopting strategy D, R and RD, the manufacturer's best responses are strategy RD, D and RD, respectively. As the symmetric nature of two manufacturers, when the manufacturer is adopting strategy D, R and RD, the competitor's best responses are strategy RD, D and RD, respectively. Therefore, the only Nash equilibrium in this example is (RD, RD). We also obtain Nash equilibria in other cases in this way.

8. Appendix B – Proof of Propositions and Lemmas

8.1. Proposition 1

These results follow directly from pair-wise comparison of the selling prices in different channel strategies listed in Table 2.

8.2. Proposition 2

First, we prove there are only three relationships among $\delta_{D,RD}$, $\delta_{RD,R}$ and $\delta_{D,R}$:
 $\delta_{RD,R} < \delta_{D,R} < \delta_{D,RD}$, $\delta_{RD,R} = \delta_{D,R} = \delta_{D,RD}$ and $\delta_{RD,R} > \delta_{D,R} > \delta_{D,RD}$. If $\delta_{RD,R} < \delta_{D,RD}$, then strategy D, R or RD is the best strategy when $\delta > \delta_{D,RD}$, $\delta < \delta_{RD,R}$ or $\delta_{RD,R} < \delta < \delta_{D,RD}$, respectively. Thus, the threshold between strategy D and strategy R has $\delta_{D,R} \in (\delta_{RD,R}, \delta_{D,RD})$, i.e., $\delta_{RD,R} < \delta_{D,R} < \delta_{D,RD}$. If $\delta_{RD,R} = \delta_{D,RD}$, strategy D or R is the best strategy when $\delta > \delta_{RD,R} = \delta_{D,RD}$ or $\delta < \delta_{RD,R} = \delta_{D,RD}$. Thus, the threshold between strategy D and strategy R is $\delta_{D,R} = \delta_{RD,R} = \delta_{D,RD}$. If $\delta_{RD,R} > \delta_{D,RD}$, then strategy D or R is the best strategy when $\delta > \delta_{RD,R}$ or $\delta < \delta_{D,RD}$, respectively. Thus, the threshold between strategy D and strategy R has $\delta_{D,R} \in (\delta_{D,RD}, \delta_{RD,R})$, and strategy D or R is the best strategy when

$\delta > \delta_{D,R}$ or $\delta < \delta_{D,R}$. Therefore, strategy RD would not be the best strategy when $\delta_{RD,R} \geq \delta_{D,R} \geq \delta_{D,RD}$

Results in Proposition 2 follow directly from 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 $\Delta\pi_M(R-D) = \pi_M(R) - \pi_M(D) = \alpha_R(1-c_R)^2[-2(\alpha+\eta)\delta^2 + \alpha\eta + 1]/8$. Thus, we have

$\pi_M(R) > \pi_M(D)$ when $0 < \delta < \sqrt{\frac{1+\alpha\eta}{2(\alpha+\eta)}} = \delta_{D,R}$, and $\pi_M(R) < \pi_M(D)$ when $\delta > \delta_{D,R}$. Similarly,

we have $\delta_{RD,R}$ and $\delta_{D,RD}$. 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 $\delta_{RD,R} < \delta_{D,RD}$.

8.3. Corollary 1

(1) We have

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

Then we prove $4\eta\sqrt{(\alpha+\eta)(2+\alpha)} - (\alpha\eta^2 + 2\eta^2 + 4\eta + 4\alpha)$ is negative:

$$\frac{\partial \left\{ \left[4\eta\sqrt{(\alpha+\eta)(2+\alpha)} \right]^2 - (\alpha\eta^2 + 2\eta^2 + 4\eta + 4\alpha)^2 \right\}}{\partial \alpha} = -2(2-\eta)^2(2+\eta)(2\alpha + 2\eta + \alpha\eta) < 0.$$

Then we have $\left[4\eta\sqrt{(\alpha+\eta)(2+\alpha)} \right]^2 - (\alpha\eta^2 + 2\eta^2 + 4\eta + 4\alpha)^2$ is decreasing in α . Given $\alpha = 0$, we have $\left[4\eta\sqrt{(\alpha+\eta)(2+\alpha)} \right]^2 - (\alpha\eta^2 + 2\eta^2 + 4\eta + 4\alpha)^2 = -4(2-\eta)^2\eta^2 < 0$. As $\alpha > 0$, then we have $\left[4\eta\sqrt{(\alpha+\eta)(2+\alpha)} \right]^2 - (\alpha\eta^2 + 2\eta^2 + 4\eta + 4\alpha)^2 < 0 \Leftrightarrow \frac{\partial \delta_{D,RD}}{\partial \alpha} < 0$

Meanwhile,

$$\frac{\partial \delta_{D,RD}}{\partial \eta} = \frac{(2+\alpha)(2\alpha^2 + 2\eta + 2\alpha + \alpha\eta + 2\alpha\sqrt{(\alpha+\eta)(2+\alpha)})}{2(2\alpha + 2\eta + \alpha\eta)^2 \sqrt{(\alpha+\eta)(2+\alpha)}} < 0.$$

Therefore, we have $\delta_{D,RD}$ is decreasing in α and η .

(2) We have

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

Then we prove $4\sqrt{(2+\alpha)(1+\alpha\eta)} - 2(4+\alpha+2\alpha\eta)$ is negative:

$$\frac{\partial \left\{ \left[4\sqrt{(2+\alpha)(1+\alpha\eta)} \right]^2 - 4(4+\alpha+2\alpha\eta)^2 \right\}}{\partial \alpha} = -4\alpha(1-2\eta)^2 < 0.$$

Then we have $\left[4\sqrt{(2+\alpha)(1+\alpha\eta)} \right]^2 - 4(4+\alpha+2\alpha\eta)^2$ is decreasing in α . Given $\alpha = 0$, we have $\left[4\sqrt{(2+\alpha)(1+\alpha\eta)} \right]^2 - 4(4+\alpha+2\alpha\eta)^2 = 0$. As $\alpha > 0$, then we have

$$\left[4\sqrt{(2+\alpha)(1+\alpha\eta)} \right]^2 - 4(4+\alpha+2\alpha\eta)^2 < 0 \Leftrightarrow \frac{\partial \delta_{RD,R}}{\partial \alpha} < 0.$$

Meanwhile,

$$\frac{\partial \delta_{RD,R}}{\partial \eta} = \frac{2+\alpha}{2\sqrt{2(2+\alpha)(1+\alpha\eta)}} > 0.$$

Therefore, we have $\delta_{RD,R}$ is decreasing in α and increasing in η .

(3) We have

$$\frac{\partial \delta_{D,R}}{\partial \alpha} = -\frac{1-\eta^2}{2(\alpha+\eta)\sqrt{2(\alpha+\eta)(1+\alpha\eta)}} < 0; \quad \frac{\partial \delta_{D,R}}{\partial \eta} = -\frac{1-\alpha^2}{2(\alpha+\eta)\sqrt{2(\alpha+\eta)(1+\alpha\eta)}}.$$

Therefore, $\delta_{D,R}$ always decreases in α , but decreases in η when $\alpha < 1$ and increases in η when $\alpha > 1$. Specifically, when $\alpha = 1$, η has no impact on $\delta_{D,R}$.

8.4. Proposition 3

Results in Proposition 3 follow directly from pair-wise comparison of the profits in different channel strategies listed in Table 4.

$$\Delta\delta = \delta_{D,RD}^D - \delta_{RD,R}^D = \frac{2\left[\alpha + \sqrt{(\alpha+\eta)(4+\alpha)}\right]}{4\alpha + 4\eta + \alpha\eta} - \frac{\sqrt{4+\alpha} - 2}{\alpha}, \text{ thus}$$

$$\frac{\partial \Delta\delta}{\partial \eta} = -\frac{(4+\alpha)2\alpha^2 + 4\eta + \alpha\left[4 + \eta + 2\sqrt{(\alpha+\eta)(4+\alpha)}\right]}{(4\alpha + 4\eta + \alpha\eta)^2 \sqrt{(\alpha+\eta)(4+\alpha)}} < 0.$$

We have $\Delta\delta$ is decreasing in η . When $\eta = 1$, the minimum value of $\Delta\delta$ is

$$\Delta\delta = \frac{8+10\alpha+2\alpha^2 - (4+5\alpha)\sqrt{4+\alpha} + 2\alpha\sqrt{(1+\alpha)(4+\alpha)}}{\alpha(4+5\alpha)}.$$

Since $8+10\alpha+2\alpha^2 - (4+5\alpha)\sqrt{4+\alpha} + 2\alpha\sqrt{(1+\alpha)(4+\alpha)}$ is a continuous function when $\alpha > 0$ and there exist three solutions for $8+10\alpha+2\alpha^2 - (4+5\alpha)\sqrt{4+\alpha} + 2\alpha\sqrt{(1+\alpha)(4+\alpha)} = 0$: $\alpha = -4, -4/5, 0$, $8+10\alpha+2\alpha^2 - (4+5\alpha)\sqrt{4+\alpha} + 2\alpha\sqrt{(1+\alpha)(4+\alpha)}$ is always negative or positive when $\alpha > 0$. Also, we have $8+10\alpha+2\alpha^2 - (4+5\alpha)\sqrt{4+\alpha} + 2\alpha\sqrt{(1+\alpha)(4+\alpha)} = 6.2 > 0$, thus $\Delta\delta \geq \Delta\delta|_{\eta=1} > 0$ and $\delta_{D,RD}^D > \delta_{RD,R}^D$. Recap the proof in Proposition 2, we have $\delta_{D,RD}^D > \delta_{D,R}^D > \delta_{RD,R}^D$.

8.5. Corollary 2

Similar to the proof of Corollary 1, these results follow directly from first-order derivatives of $\delta_{D,RD}^D$, $\delta_{RD,R}^D$ and $\delta_{D,R}^D$.

8.6. Proposition 4

These results follow directly from pair-wise comparison of the profits in different channel strategies listed in Table 4.

8.7. Proposition 5

These results follow directly from pair-wise comparison of the profits in different channel strategies listed in Table 4.

8.8. Corollary 3

Since $\delta_{D,RD}^{RD} = 1 + \frac{2}{\alpha} > 1$, when $c^R = c^D$, $\delta = 1 < \delta_{D,RD}^{RD}$, thus strategy RD is the best strategy.

8.9. Proposition 6

If strategy R is the best response to a competitor with strategy R, according to the symmetric nature of two manufacturers, when anyone chooses strategy R, it is appropriate to response with the same strategy. Therefore, strategy profile (R, R) is a Nash equilibrium. Similarly, symmetric strategy profile (RD, RD) and (D, D) can also be Nash equilibria in an appropriate situation.

For asymmetric strategy profile (R, RD) and (RD, R), strategy R cannot be the best response to a competitor with strategy RD, thus, (R, RD) and (RD, R) cannot be Nash equilibria.

If asymmetric strategy profile (RD, D) or (D, RD) is the Nash equilibrium, strategy D is the best response to a competitor with strategy RD, meanwhile, strategy RD is the best response to a competitor with strategy D. Here δ satisfies $\delta \in [\delta_{D,RD}^{RD}, \delta_{D,RD}^D]$.

$$\Delta\delta = \delta_{D,RD}^D - \delta_{D,RD}^{RD} = \frac{2[\alpha + \sqrt{(\alpha + \eta)(4 + \alpha)}]}{4\alpha + 4\eta + \alpha\eta} - 1 - \frac{2}{\alpha}, \text{ thus, } \frac{\partial \Delta\delta}{\partial \eta} < 0, \Delta\delta \text{ is decreasing in } \eta.$$

Since $\Delta\delta|_{\eta=0} = -\frac{\sqrt{4+\alpha}(\sqrt{4+\alpha} - \sqrt{\alpha})}{2\alpha} < 0$, $\Delta\delta < 0$ and $\delta_{D,RD}^D < \delta_{D,RD}^{RD}$. Therefore, $[\delta_{D,RD}^{RD}, \delta_{D,RD}^D]$

is empty, asymmetric strategy profile (RD, D) or (D, RD) cannot be the Nash equilibrium in this game.

Similarly, the range of δ , satisfying strategy R is the best response to a competitor with strategy D and strategy D is the best response to a competitor with strategy R, is also empty. Therefore, asymmetric strategy profile (R, D) or (R, D) is not the Nash equilibrium in this game.

8.10. Corollary 4

These results follow directly from pair-wise comparison of the profits in different channel strategies listed in Table 4.

References

- Achrol, R.S., 1997. Changes in the theory of interorganizational relations in marketing: Toward a network paradigm. *Journal of the Academy of Marketing Science* 25, 56-71.
- Anderson, E.J., Bao, Y., 2010. Price competition with integrated and decentralized supply chains. *European Journal of Operational Research* 200, 227-234.
- Bernstein, F., Federgruen, A., 2004. Dynamic inventory and pricing models for competing retailers. *Naval Research Logistics (NRL)* 51, 258-274.
- Bernstein, F., Federgruen, A., 2005. Decentralized Supply Chains with Competing Retailers Under Demand Uncertainty. *Management Science* 51, 18-29.
- Boyaci, T., 2005. Competitive stocking and coordination in a multiple-channel distribution system. *IIE Transactions* 37, 407-427.
- Cachon, G.P., 2003. Supply chain coordination with contracts. *Handbooks in Operations Research and Management Science* 11, 227-339.
- Cai, G., 2010. Channel selection and coordination in dual-channel supply chains. *Journal of Retailing* 86, 22-36.
- Cai, G., Zhang, Z.G., Zhang, M., 2009. Game theoretical perspectives on dual-channel supply chain competition with price discounts and pricing schemes. *International Journal of Production Economics* 117, 80-96.
- Cao, E., Ma, Y., Wan, C., Lai, M., 2013. Contracting with asymmetric cost information in a dual-channel supply chain. *Operations Research Letters* 41, 410-414.
- Cattani, K., Gilland, W., Heese, H.S., Swaminathan, J., 2006. Boiling frogs: Pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Production and Operations Management* 15, 40.
- Chen, J., Bell, P.C., 2012. Implementing market segmentation using full-refund and no-refund customer returns policies in a dual-channel supply chain structure. *International Journal of Production Economics* 136, 56-66.
- Chen, J., Zhang, H., Sun, Y., 2012. Implementing coordination contracts in a manufacturer Stackelberg dual-channel supply chain. *Omega* 40, 571-583.
- Chen, K.-Y., Kaya, M., Özer, Ö., 2008. Dual Sales Channel Management with Service Competition. *Manufacturing & Service Operations Management* 10, 654-675.
- Chiang, W.-y.K., Chhajed, D., Hess, J.D., 2003. Direct Marketing, Indirect Profits: A Strategic Analysis of Dual-Channel Supply-Chain Design. *Management Science* 49, 1-20.
- Choi, S.C., 1991. Price competition in a channel structure with a common retailer. *Marketing Science* 10, 271-296.
- Choi, S.C., 1996. Price competition in a duopoly common retailer channel. *Journal of retailing* 72, 117-134.
- Choi, S.C., 2003. Expanding to direct channel: Market coverages as entry barrier. *Journal of Interactive Marketing* 17, 25-40.
- Coughlan, A.T., 1985. Competition and cooperation in marketing channel choice: Theory and application. *Marketing science* 4, 110-129.
- Dan, B., Xu, G., Liu, C., 2012. Pricing policies in a dual-channel supply chain with retail services. *International Journal of Production Economics* 139, 312-320.
- David, A., Adida, E., 2015. Competition and Coordination in a Two-Channel Supply Chain. *Production and Operations Management* 24, 1358-1370.
- Ding, Q., Dong, C., Pan, Z., 2016. A hierarchical pricing decision process on a dual-channel problem with one manufacturer and one retailer. *International Journal of Production Economics* 175, 197-212.
- Dumrongsiri, A., Fan, M., Jain, A., Moinzadeh, K., 2008. A supply chain model with direct and retail channels. *European Journal of Operational Research* 187, 691-718.
- Frambach, R.T., Roest, H.C., Krishnan, T.V., 2007. The impact of consumer internet experience on channel preference and usage intentions across the different stages of the buying process. *Journal of Interactive Marketing* 21, 26-41.
- Gibbons, R., 1992. A primer in game theory. Harvester Wheatsheaf.
- Håkansson, H., Havila, V., Pedersen, A.-C., 1999. Learning in networks. *Industrial Marketing Management* 28, 443-452.
- Havila, V., Johanson, J., Thilenius, P., 2004. International business-relationship triads. *International Marketing Review* 21, 172-186.

- Hua, G., Wang, S., Cheng, T.C.E., 2010. Price and lead time decisions in dual-channel supply chains. *European Journal of Operational Research* 205, 113-126.
- Huang, H., Ke, H., Wang, L., 2016. Equilibrium analysis of pricing competition and cooperation in supply chain with one common manufacturer and duopoly retailers. *International Journal of Production Economics* 178, 12-21.
- Huang, W., Swaminathan, J.M., 2009. Introduction of a second channel: Implications for pricing and profits. *European Journal of Operational Research* 194, 258-279.
- Ingene, C.A., Parry, M.E., 1995a. Channel coordination when retailers compete. *Marketing Science* 14, 360-377.
- Ingene, C.A., Parry, M.E., 1995b. Coordination and manufacturer profit maximization: The multiple retailer channel. *Journal of Retailing* 71, 129-151.
- Ingene, C.A., Parry, M.E., 2004. *Mathematical models of distribution channels*. Springer Science & Business Media.
- Kumar, N., Ruan, R., 2006. On manufacturers complementing the traditional retail channel with a direct online channel. *Quantitative Marketing and Economics* 4, 289-323.
- Li, B., Chen, P., Li, Q., Wang, W., 2014. Dual-channel supply chain pricing decisions with a risk-averse retailer. *International Journal of Production Research* 52, 7132-7147.
- Li, B., Hou, P.-W., Chen, P., Li, Q.-H., 2016. Pricing strategy and coordination in a dual channel supply chain with a risk-averse retailer. *International Journal of Production Economics* 178, 154-168.
- Liang, T.-P., Huang, J.-S., 1998. An empirical study on consumer acceptance of products in electronic markets: a transaction cost model. *Decision Support Systems* 24, 29-43.
- Liu, B., Cai, G.G., Tsay, A.A., 2014. Advertising in asymmetric competing supply chains. *Production and Operations Management* 23, 1845-1858.
- Liu, M., Cao, E., Salifou, C.K., 2016. Pricing strategies of a dual-channel supply chain with risk aversion. *Transportation Research Part E: Logistics and Transportation Review* 90, 108-120.
- Lu, Q., Liu, N., 2015. Effects of e-commerce channel entry in a two-echelon supply chain: A comparative analysis of single- and dual-channel distribution systems. *International Journal of Production Economics* 165, 100-111.
- Lus, B., Muriel, A., 2009. Measuring the impact of increased product substitution on pricing and capacity decisions under linear demand models. *Production and Operations Management* 18, 95-113.
- Möller, K.K., Halinen, A., 1999. Business relationships and networks: Managerial challenge of network era. *Industrial Marketing Management* 28, 413-427.
- Matsui, K., 2016. Asymmetric product distribution between symmetric manufacturers using dual-channel supply chains. *European Journal of Operational Research* 248, 646-657.
- McGuire, T.W., Staelin, R., 1983. An industry equilibrium analysis of downstream vertical integration. *Marketing Science* 2, 161-191.
- Moon, Y., Yao, T., Friesz, T.L., 2010. Dynamic Pricing and Inventory Policies: A Strategic Analysis of Dual Channel Supply Chain Design. *Service Science* 2, 196-215.
- Moorthy, K.S., 1988. Strategic decentralization in channels. *Marketing Science* 7, 335-355.
- Mukhopadhyay, S.K., Yao, D.-Q., Yue, X., 2008. Information sharing of value-adding retailer in a mixed channel hi-tech supply chain. *Journal of Business Research* 61, 950-958.
- Office-of-National-Statistics, 2017. Retail Sales Index internet sales, in: Murphy, R. (Ed.).
- Röller, L.-H., Tombak, M.M., 1990. Strategic choice of flexible production technologies and welfare implications. *The Journal of Industrial Economics*, 417-431.
- Röller, L.-H., Tombak, M.M., 1993. Competition and investment in flexible technologies. *Management Science* 39, 107-114.
- Savaskan, R.C., Van Wassenhove, L.N., 2006. Reverse channel design: the case of competing retailers. *Management Science* 52, 1-14.
- Shipley, D., Egan, C., Edgett, S., 1991. Meeting source selection criteria: direct versus distributor channels. *Industrial Marketing Management* 20, 297-303.
- Singh, N., Vives, X., 1984. Price and quantity competition in a differentiated duopoly. *The RAND Journal of Economics*, 546-554.
- Sinha, S., Sarmah, S., 2010. Coordination and price competition in a duopoly common retailer supply chain. *Computers & Industrial Engineering* 59, 280-295.
- Sorescu, A., Frambach, R.T., Singh, J., Rangaswamy, A., Bridges, C., 2011. Innovations in retail business models. *Journal of Retailing* 87, S3-S16.
- Statista, 2017. E-commerce share of total global retail sales from 2015 to 2021.
- Trivedi, M., 1998. Distribution channels: An extension of exclusive retailership. *Management Science* 44, 896-909.
- Tsay, A.A., Agrawal, N., 2000. Channel dynamics under price and service competition. *Manufacturing &*

Service Operations Management 2, 372-391.

Tsay, A.A., Agrawal, N., 2004a. Channel conflict and coordination in the e-commerce age. *Production and Operations Management* 13, 93-110.

Tsay, A.A., Agrawal, N., 2004b. Modeling conflict and coordination in multi-channel distribution systems: A review, *Handbook of quantitative supply chain analysis*. Springer, pp. 557-606.

Verhoef, P.C., Kannan, P., Inman, J.J., 2015. From Multi-Channel Retailing to Omni-Channel Retailing: Introduction to the Special Issue on Multi-Channel Retailing. *Journal of Retailing* 91, 174-181.

Wang, J.-C., Wang, A.-M., Wang, Y.-Y., 2013. Markup pricing strategies between a dominant retailer and competitive manufacturers. *Computers & Industrial Engineering* 64, 235-246.

Wang, S.-D., Zhou, Y.-W., Min, J., Zhong, Y.-G., 2011. Coordination of cooperative advertising models in a one-manufacturer two-retailer supply chain system. *Computers & Industrial Engineering* 61, 1053-1071.

Wang, W., Li, G., Cheng, T.C.E., 2016. Channel selection in a supply chain with a multi-channel retailer: The role of channel operating costs. *International Journal of Production Economics* 173, 54-65.

Watson, G.F., Worm, S., Palmatier, R.W., Ganesan, S., 2015. The Evolution of Marketing Channels: Trends and Research Directions. *Journal of Retailing* 91, 546-568.

Wei, J., Zhao, J., 2016. Pricing decisions for substitutable products with horizontal and vertical competition in fuzzy environments. *Annals of Operations Research* 242, 505-528.

Wu, C.-H., Chen, C.-W., Hsieh, C.-C., 2012. Competitive pricing decisions in a two-echelon supply chain with horizontal and vertical competition. *International Journal of Production Economics* 135, 265-274.

Wu, D., Baron, O., Berman, O., 2009. Bargaining in competing supply chains with uncertainty. *European Journal of Operational Research* 197, 548-556.

Xia, Y., 2011. Competitive strategies and market segmentation for suppliers with substitutable products. *European Journal of Operational Research* 210, 194-203.

Xiao, T., Qi, X., 2008. Price competition, cost and demand disruptions and coordination of a supply chain with one manufacturer and two competing retailers. *Omega* 36, 741-753.

Xu, G., Dan, B., Zhang, X., Liu, C., 2014. Coordinating a dual-channel supply chain with risk-averse under a two-way revenue sharing contract. *International Journal of Production Economics* 147, 171-179.

Xu, H., Liu, Z.Z., Zhang, S.H., 2012. A strategic analysis of dual-channel supply chain design with price and delivery lead time considerations. *International Journal of Production Economics* 139, 654-663.

Yan, R., 2008. Profit sharing and firm performance in the manufacturer-retailer dual-channel supply chain. *Electronic Commerce Research* 8, 155-172.

Yan, R., Ghose, S., 2010. Forecast information and traditional retailer performance in a dual-channel competitive market. *Journal of Business Research* 63, 77-83.

Yan, R., Pei, Z., 2009. Retail services and firm profit in a dual-channel market. *Journal of Retailing and Consumer Services* 16, 306-314.

Yang, S.-L., Zhou, Y.-W., 2006. Two-echelon supply chain models: Considering duopolistic retailers' different competitive behaviors. *International Journal of Production Economics* 103, 104-116.

Yang, S., Shi, V., Jackson, J.E., 2015. Manufacturers' channel structures when selling asymmetric competing products. *International Journal of Production Economics* 170, 641-651.

Yao, D., Liu, J., 2005. Competitive pricing of mixed retail and e-tail distribution channels. *Omega* 33, 235-247.

Yao, D., Yue, X., Mukhopadhyay, S., Wang, Z., 2009. Strategic inventory deployment for retail and e-tail stores. *Omega* 37, 646-658.

Yue, X., Liu, J., 2006. Demand forecast sharing in a dual-channel supply chain. *European Journal of Operational Research* 174, 646-667.

Zaheer, A., Gulati, R., Nohria, N., 2000. Strategic networks. *Strategic Management Journal* 21, 203.

Zhang, R., Liu, B., Wang, W., 2012. Pricing decisions in a dual channels system with different power structures. *Economic Modelling* 29, 523-533.

Zhao, J., Wei, J., Li, Y., 2014. Pricing decisions for substitutable products in a two-echelon supply chain with firms' different channel powers. *International Journal of Production Economics* 153, 243-252.

Zhao, X., Shi, C., 2011. Structuring and contracting in competing supply chains. *International Journal of Production Economics* 134, 434-446.