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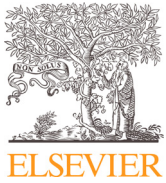
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When should a manufacturer set its direct price and wholesale price in dual-channel supply chains?

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ABSTRACT

Applying an observable delay game framework developed in noncooperative game theory, we investigate the timing problem concerning when a manufacturer managing dual-channel supply chains, consisting of a retail channel and a direct channel, should post its wholesale price and direct price. Conventionally, operational research models describing dual-channel supply chains examine price competition, where the retailer and the manufacturer simultaneously determine the retail and direct prices, respectively. In contrast to this conventional setting, our model demonstrates that such simultaneous price competition never arises if the manufacturer and retailer can choose not only the level of the price but also the timing of pricing. If the manufacturer sets the direct price after setting the wholesale price to the retailer, the retailer accelerates the timing of retail pricing prior to the direct price setting by the manufacturer. Our findings suggest that the manufacturer should post the direct price before or upon, but not after, setting the wholesale price for the retailer. This upfront posting of the direct price not only constitutes the subgame perfect Nash equilibrium of the noncooperative game between channel members but also maximizes the profits for a manufacturer employing multichannel sales strategies.

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1. Introduction

Multichannel sales strategies are now very popular owing to the prevalence of the Internet, which makes it much easier for manufacturers to engage in direct sales. Because direct channels, including catalogs and the Internet, compete against, substitute for, or complement conventional retail channels, finding the best way to utilize them in conjunction with retail channels continues to be a challenge for many firms. Specifically, multiple channels give rise to channel conflict when different channels compete for almost the same market with substitutable products.

Particularly after the rise in Internet use among general households, many manufacturers that previously only distributed products via a retail channel have added a direct channel. To manage these dual distribution channels successfully, different manufacturers have adopted a variety of channel strategies. For instance, when manufacturers, such as Daimler, Nikon, and Rubbermaid, first commenced use of the direct channel, they used the Internet merely as a medium to provide information about their products and/or to

direct users to the nearest retailer carrying the product but without offering the product for sale directly, in order to avoid potential channel conflict. Consider the market for computer products. As an example, IBM redirected orders taken at ibm.com to its distributors in an attempt to mitigate any conflict, while Hewlett-Packard provided their intermediaries with a commission fee for online orders (Tsay & Agrawal, 2004a). Compaq undertook a profit-sharing strategy whereby the company paid intermediaries an agent's fee when their current clients purchased products on Compaq's website (Lee, Lee, & Larsen, 2003). Finally, in contrast to these manufacturers, Dell, a successful Internet marketer in the personal computer (PC) market, added its retail channel only after selling its products and establishing its brand through its direct channel. Dell opened kiosk locations in shopping malls across the US from 2002 and has operated full-scale manufacturer-owned stores since late 2006 (Zehr, 2008). In 2008, Dell expanded into retail stores, such as Wal-Mart and Best Buy, and shut down all of its US kiosks.

In the context of multichannel management, the extent to which a manufacturer should set a direct price to maximize total profits across all channels has commanded significant attention from both the academic and practical viewpoint. However, the existing operational research literature has neglected the question of the timing at which the manufacturer should determine the di-

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rect price, even though it is a critical practical issue for manufacturers adopting a multichannel sales strategy. Consequently, this paper investigates the timing problem when a manufacturer managing dual-channel supply chains, comprising a retail channel and a direct channel, should post its wholesale and direct prices using an observable-delay game framework recently developed in the noncooperative game theory literature (e.g., [Hamilton & Slutsky, 1990](#); [van Damme & Hurkens, 1996, 1999, 2004](#)). Put differently, our main research questions are:

- "When" does a manufacturer managing a dual-channel supply chain set the wholesale and direct prices to maximize profit, and
- "What" prices should the manufacturer set?

Conventionally, operational research and management science (OR/MS) models describing dual-channel supply chains examine price competition where the retailer and the manufacturer simultaneously determine the retail and direct prices, respectively. In contrast, our model demonstrates that such simultaneous price competition never arises if the manufacturer and retailer can choose not only the price level but also the timing of pricing. If the manufacturer sets the direct price after setting the wholesale price for the retailer, the retailer accelerates the timing of retail pricing prior to the direct price setting by the manufacturer. Our findings suggest that the manufacturer should post the direct price before or upon, but not after, setting the wholesale price for the retailer. Such upfront posting of the direct price not only constitutes the subgame perfect Nash equilibrium (SPNE) of the noncooperative game between channel members but also maximizes profits for the manufacturer.

The logic behind this outcome is as follows. If the manufacturer determines the direct price after setting the wholesale price for the retailer, the direct price cannot fully reflect any future reaction by the retailer, leading to a lower level of channel profits. Conversely, if the manufacturer determines the direct price before setting the wholesale price, then the manufacturer can adjust the direct price to its optimal level for both channels by predicting the future reactions of the retailer, thus mitigating double marginalization in the retail channel. This adjustment is the source of the advantages accruing to the manufacturer by posting the direct price before setting the wholesale price.

Nowadays, many manufacturers across a wide range of industries utilize both direct and indirect channels to distribute products. In the IT industry, IBM is often cited as a company that has successfully managed the two types of channels over about three decades.¹ The indirect channels of IBM, which include distributors, value-added resellers, and partners, can be regarded as the retail channel in the model in this paper. Moreover, IBM is known as a company that undertakes a channel strategy to launch several new products only in the direct channel at first, and subsequently through the indirect channel. The following are three examples of products distributed in this way. First, the RS/6000, a reduced instruction set computer technology open system equipped with a UNIX operating system, was a product initially sold through the direct channel and subsequently through the indirect chan-

nel.² Second, the enterprise servers designated S/390s were also sold through the IBM internal channel until 1997, and subsequently were distributed by qualified resellers, as discussed in [Gandolfo and Padelletti \(1999, p. 110\)](#). Third, the sale of System x iDataPlex, a relatively recent IBM product, was initially sold only directly and subsequently through partners.³ Because selling and pricing timing of these products is different between the two channels, they represent appropriate real-world examples of our model.

As discussed, the results of our model suggest that setting the direct price before the wholesale price in the retail channel is the best timing for the manufacturer. Therefore, if we interpret the IBM's channel strategy using our model, IBM initially sells a new product in its direct channel, thereby improving profitability by making the direct price observable to its resellers, including its partners. As such, our model provides a rationale for why a company with dual channels, like IBM, makes the decision to sell a new product first directly to buyers and subsequently through its indirect channel. Our model then effectively explains real-world cases, including that of IBM, thereby providing useful managerial insights for manufacturers managing both retail and direct channels.

The remainder of the paper is structured as follows. [Section 2](#) provides a review of the literature relating to supply chain management from a game-theoretic perspective. In [Section 3](#), we delineate the basic settings of our noncooperative game model. We then investigate when the manufacturer should choose the timing of setting the direct price and the wholesale price applicable to the retailer, identifying the relevant SPNE that specifies the choice of both the timing and level of prices. In [Section 4](#), we extend our model to consider consumer behavior in relation to services, especially because these and not goods receive increasing attention in the supply chain management literature. The final section concludes the paper.

2. Literature review

To date, many OR/MS studies have investigated supply chain management problems from a noncooperative game theoretic perspective (e.g., [Anderson & Bao, 2010](#); [Atkins & Liang, 2010](#); [Grozniak & Heese, 2010](#); [Jeuland & Shugan, 1983](#); [Kumoi & Matsubayashi, 2014](#); [Matsui, 2012](#); [Matsushima & Mizuno, 2013](#); [McGuire & Staelin, 1983](#); [Parlar & Weng, 2006](#); [Xia & Gilbert, 2007](#); [Xie & Wei, 2009](#); [SeyedEsfahani, Biazaran, & Gharakhani, 2011](#); [Wang et al., 2013](#); [Zhou & Cao, 2013](#); [Xiao et al., 2014](#)). In particular, several studies have focused on the management of dual-channel supply chains including direct marketers and conventional intermediaries, such as retailers, typically analyzing the economic impacts of the introduction of a direct Internet channel (e.g., [Balasubramanian, 1998](#); [Chiang, Chhajed, & Hess, 2003](#); [Yao & Liu, 2003](#); [Tsai & Agrawal, 2004a, 2004b](#); [Chiang & Monahan, 2005](#); [Yao, Yue, Wang, & Liu, 2005](#); [Cattani, Gilland, Heese, & Swaminathan, 2006](#); [Liu et al., 2006](#); [Kurata, Yao, & Liu, 2007](#); [Bernstein, Song, & Zheng, 2008](#); [Chen, Kaya, & Özer, 2008](#); [Dumrongsiri, Fan, Jain, & Moinezhadeh, 2008](#); [Mukhopadhyay, Zhu, & Yue, 2008](#); [Cai, Zhang, & Zhang, 2009](#); [Huang & Swaminathan, 2009](#); [Cai, 2010](#); [Chiang, 2010](#); [Hua, Wang, & Cheng, 2010](#); [Khouja & Wang, 2010](#); [Ryan,](#)

¹ [Hardy and Magrath \(1988, pp. 65–66\)](#) state, "most makers of personal computers desire the stability and strength of IBM's Value Added Reseller (VAR) network. ... In 1983, IBM executives decided they would have to use indirect channels rather than their own sales force to establish their personal computers in multiple markets." Moreover, [Cespedes and Corey \(1990, p. 71\)](#) write: "IBM, which had virtually no indirect channels as recently as 1981, was using more than 16 third-party channels by the mid-1980s, including distributors, VARs, retail computer dealers, and a variety of 'complementary marketing organizations' (firms with which IBM conducted marketing activities including joint sales presentations and product installations)."

² [Gandolfo and Padelletti \(1999, p. 110\)](#) conclude "Dealers are the main distribution channel for RS/6000s and PCs. Large quantities of these computers are directly bought from IBM, and since 1996 they have been bought from qualified first-layer resellers."

³ [IBM \(2008\)](#) notes "System x iDataPlex is announced as available through IBM direct sales channel only. It is currently not available through IBM Business Partners." Subsequently, [Watts and Bachmaier \(2012\)](#) state "iDataPlex solutions are acquired either directly through IBM direct sales channels or through IBM business partners." These two documents prove that iDataPlex was initially sold only through the direct channel and then through the indirect channel.

Sun, & Zhao, 2012; Xiong, Yan, Fernandes, Xiong, & Guo, 2012; Chen, Fang, & Wen, 2013; Hsiao & Chen, 2013; Moon & Yao, 2013; Balakrishnan, Sundaresan, & Zhang, 2014; Dan et al., 2014; Feng & Geunes, 2014; Sun & Debo, 2014; Li, Lin, Xu, & Swain, 2015; Rodríguez & Aydın, 2015; Cao, So, & Yin, 2016; Chen et al., 2016; Matsui, 2016). Balasubramanian (1998) investigates the competition between direct marketers and conventional retailers by considering the adaptability of products to direct sales and the product information revealed to customers. He shows that when adaptability is low, direct marketers are better off lowering the level of market information disseminated. Chiang et al. (2003) analyze a manufacturer's decision to sell directly over the Internet, exclusively through a retailer, or through a mix of both approaches. They demonstrate that a direct channel helps the manufacturer to improve overall profitability by mitigating inefficient price double marginalization. Liu, Gupta, and Zhang (2006) show that in the markets where retail price consistency across channels is mandatory, an incumbent traditional brick-and-mortar retailer can deter the entry of a pure-play online retailer by strategically refraining from entering online. Alternatively, in the markets where price consistency is not a constraint, the incumbent can deter the entry of a pure-play online retailer only if it enters online. In the case of the latter, the incumbent is willing to cannibalize its own brick-and-mortar business by charging a low online price. Dumrongsiri et al. (2008) investigate a dual-channel supply chain in which a manufacturer sells to a retailer as well as to consumers directly. They show that the difference in marginal costs of the two channels and demand variability play a major role in motivating the manufacturer to open a direct channel. Huang and Swaminathan (2009) study optimal pricing strategies when sale of a product is through two channels, such as the Internet and a traditional channel. They construct a deterministic demand model where the demand for a given channel depends on prices, the degree of substitution across channels, and the overall market potential, and they identify several prevalent pricing strategies that differ in the degree of autonomy of the Internet channel. Wang, Niu, and Guo (2013) investigate a supply chain comprising an original equipment manufacturer and a contract manufacturer by applying the observable delay game framework. They show that both parties can prefer either Stackelberg leadership or followership depending on multiple factors, including market size, the wholesale price, the percentage of outsourcing, and the degree to which products are substitutable. The present paper is positioned as a contribution to this line of research.

There is another line of research closely related to the current study: that is, the theoretical game literature that investigates the emergence of the endogenous timing of strategies adopted by players. In a noncooperative game framework, whether players move simultaneously or sequentially is important because an alternate order of moves often gives rise to significantly different results. For example, Gal-Or (1985) demonstrated that when two identical players move sequentially in a noncooperative game, the player who moves first (second) earns a higher payoff than the player who moves second (first) if the reaction functions of the players are downward (upward) sloping. In other words, there are inherent first- (second-) mover advantages when the strategy choice of players is negatively (positively) related. Because such an advantage stems from decision timing, it is now recognized that the simultaneity versus the sequentiality of moves should be endogenously determined by the players' decisions (Dowrick, 1986; Hamilton & Slutsky, 1990).

Even though the timing for posting the direct price is a crucial problem for manufacturers, as far as we are aware, no existing research examines the endogenous decision timing in a dual-channel supply chain comprising not only the retail channel but also the direct channel. From a multichannel management perspective, this

paper addresses the issue of the endogenous order of moves by adopting the observable delay game framework (e.g., Hamilton & Slutsky, 1990; van Damme & Hurkens, 1996, 1999, 2004; Amir & Grilo, 1999; Amir & Stepanova, 2006). Therefore, it is worth noting that the present paper is the first to introduce the idea of an observable delay game into the research on dual-channel supply chain management.

3. Model

3.1. Assumptions

Initially, we present the settings underpinning our model. Table 1 lists the variables used in the model. Suppose that a manufacturer produces a good at a variable cost of c per unit and sells the product to consumers directly or through an independent retailer. As illustrated in Fig. 1, we define direct selling by the manufacturer as the direct channel and selling through the retailer as the retail channel. In the retail channel, the manufacturer sets the wholesale price per unit, r , and sells products to the retailer at this price. The retailer then resells the product, with the manufacturer delegating the retail pricing decision to the retailer.

As shown in Fig. 1, we assume that the processing of a customer's order is in a supply chain in which both the direct and retail channels use a make-to-order (MTO) system because no inventory-holding or shortage cost is included in our model. Moreover, we assume that a customer sends his/her order directly to either the retailer in the retail channel or the manufacturer in the direct channel. In the direct channel, the manufacturer commences production after receiving an order from a customer and then delivers a product to that customer. Meanwhile, after receiving an order from a customer, the retailer resends the order to the manufacturer, receives the product from the manufacturer, and finally sends it to the customer. Hence, the retailer plays the role of an agent or mediator. In addition, the retailer plays an economic role in expanding the market through product differentiation as we assume the following demand functions for the two channels.⁴

$$\begin{aligned} q_D &= a_D - b_D p_D + \theta p_R \\ q_R &= a_R - b_R p_R + \theta p_D \end{aligned} \quad (1)$$

p and q are price and quantity, respectively, and subscripts D and R attached to p and q signify the direct and retail channels, respectively. For example, q_R represents the quantity sold by the retail channel. Hereafter, we refer to p_D as the "direct channel price" and p_R as the "retail channel price". The parameters a_D and a_R represent the demand base, as measured by the market size potential of the direct and retail channels, respectively. b_D and b_R are the respective demand sensitivities to the prices of the two channels, and θ is the cross-price sensitivity of demand in one channel to the price of the other channel. We assume that the parameters satisfy the following inequalities:

$$b_D > \theta, b_R > \theta, \quad (2)$$

⁴ Singh and Vives (1984) demonstrate that the linear demand function can be derived based on the following utility function, U , of a representative consumer: $U = \alpha_D q_D + \alpha_R q_R - (\beta_D q_D^2 + \beta_R q_R^2 + 2\rho q_D q_R)/2$. Given this utility, the consumer's surplus denoted S is stated as: $S = U - (p_D q_D + p_R q_R) = \alpha_D q_D + \alpha_R q_R - (\beta_D q_D^2 + \beta_R q_R^2 + 2\rho q_D q_R)/2 - p_D q_D - p_R q_R$. The consumer maximizes S by solving $\partial S / \partial q_D = \partial S / \partial q_R = 0$. Then, we derive $p_D = \alpha_D - \beta_D q_D - \rho q_R$ and $p_R = \alpha_R - \beta_R q_R - \rho q_D$. We may easily transform the inverse demand functions to demand functions, as represented by Eq. (1). The corresponding parameters for the demand and inverse demand functions are as follows: $\alpha_D = (a_D b_R + \theta a_R) / (b_D b_R - \theta^2)$, $\beta_D = b_R / (b_D b_R - \theta^2)$, $\alpha_R = (a_R b_D + \theta a_D) / (b_D b_R - \theta^2)$, $\beta_R = b_D / (b_D b_R - \theta^2)$, and $\rho = \theta / (b_D b_R - \theta^2)$. Ingene and Parry (2004) also explain the derivation of the linear demand function and its application to distribution channels or supply chain management.

Table 1
Notations.

p	Price
q	Quantity
r	Wholesale price
c	Marginal cost
a_D	Intercept of the demand function for the direct channel
a_R	Intercept of the demand function for the retail channel
b_D	Sensitivity of demand in the direct channel to the direct channel price
b_R	Sensitivity of demand in the retail channel to the retail channel price
θ	Cross-price sensitivity between the channels
γ_D	Decrease in demand in the direct channel in response to a unit service increase
γ_R	Increase in demand in the retail channel in response to a unit service increase
s	Retailer's service level
$C(s)$	Service cost function
D	Subscript that represents the direct channel
R	Subscript that represents the retail channel
Π	Profit for the manufacturer
π	Profit for the retailer
t_r	Period when the manufacturer chooses the wholesale price
t_{pD}	Period when the manufacturer chooses the direct channel price
t_{pR}	Period when the retailer chooses the retail channel price
E	Sequence where the manufacturer sets the direct channel price earlier than the price setting by the retailer
S	Sequence where the manufacturer sets the direct channel price simultaneously with the price setting by the retailer
L	Sequence where the manufacturer sets the direct channel price later than the price setting by the retailer

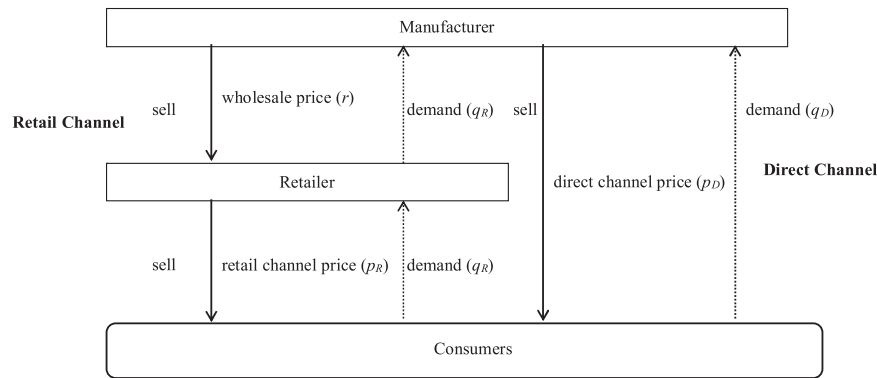


Fig. 1. Channel description.

$$a_D/c > b_D - \theta, a_R/c > b_R - \theta. \quad (3)$$

Inequality (2) indicates that the demand for a channel is more sensitive to a change in the price of its channel than the price of the other channel, which is a natural assumption. Inequality (3) ensures that in equilibrium the manufacturer distributes products through both channels.⁵

The reason why we use simple linear demand functions derived from consumer behavior demanding substitutable products represented by Eq. (1) is to make our analysis consistent with recent OR/MS studies. This facilitates easy comparison of the results with previous work. Even recently, many studies that construct dual-channel supply chain models under competitive environments adopt linear demand functions derived from consumer behavior demanding substitutable products without consideration of other practical factors such as services (e.g., Cai, 2010; David & Adida,

2015; Li et al., 2015). Accordingly, we also employ a linear demand schedule as represented by Eq. (1).⁶

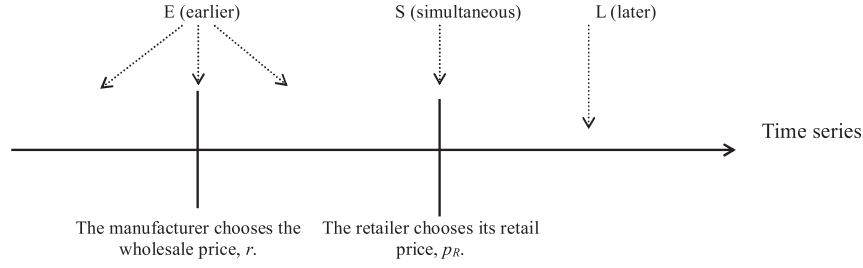
Based on the above settings, we consider the observable delay game proposed by Hamilton and Slutsky (1990), comprising two stages. In stage one, the manufacturer and the retailer simultaneously announce the period in which they will choose their prices and are committed to this choice before they actually do so. In stage two, following the announcement, the manufacturer and the retailer choose their prices knowing when the rival will make their price choices. Because there are three control variables, r , p_D , and p_R , we assume that the second stage is composed of three periods.⁷ The manufacturer determines the wholesale price and the direct channel price, and the retailer determines the retail channel price in one of these three periods.

To identify the timing of pricing, let t_r , t_{pD} , and t_{pR} denote the timing of setting the wholesale price, the direct channel price, and the retail channel price, respectively. Because there are three periods in which the manufacturer and the retailer choose to determine each price, the three variables can take timings of 1, 2, or 3. Namely, in the first stage of the game, the manufacturer chooses

⁵ If Inequality (3) were not satisfied, the manufacturer would have an incentive to distribute products via either only the direct channel or the retail channel in equilibrium to avoid too serious cannibalization across the two competing channels. Indeed, if $a_D/c > b_D - \theta$ is satisfied, $q_D > 0$ holds in equilibrium in all cases shown in Proposition 1. Likewise, if $a_R/c > b_R - \theta$ is met, $q_R > 0$ holds in all cases in the proposition.

⁶ In Section 4, we extend the model by introducing a retail service factor differentiating products between the channels to consider a more practical environment.

⁷ Lu (2006) constructs an observable-delay game model where three control variables are determined in three periods. We employ the same setting of three-period discrete timing to ensure consistency with preceding research, such as Lu (2006).



Note: Timings E, S, and L shown by arrows represent when the manufacturer determines the direct price, p_D .

Fig. 2. Timeline.

t_r and t_{pD} from $\{1, 2, 3\}$ and the retailer chooses t_{pR} from $\{1, 2, 3\}$. As usually assumed in other supply chain studies (e.g., McGuire & Staelin, 1983; Atkins & Liang, 2010), we assume that these timing variables satisfy $t_r < t_{pR}$, such that the retailer sets the retail channel price after observing the wholesale price set by the manufacturer.

3.2. Results

Using Eq. (1), we state the profits for the manufacturer, Π , and retailer, π , as:

$$\begin{aligned}\Pi &= (r - c)q_R + (p_D - c)q_D \\ &= (r - c)(a_R - b_R p_R + \theta p_D) + (p_D - c)(a_D - b_D p_D + \theta p_R)\end{aligned}\quad (4)$$

$$\begin{aligned}\pi &= (p_R - r)q_R \\ &= (p_R - r)(a_R - b_R p_R + \theta p_D).\end{aligned}\quad (5)$$

Using Eqs. (4) and (5), we derive the payoffs for the manufacturer and the retailer by the timing strategy at stage one in this game. Because stage two is composed of three periods when each of three control variables, r , p_D , and p_R , is set, we need to consider $3^3 = 27$ combinations of the sequence of timings for the calculation of all possible payoffs.⁸ However, the constraint $t_r < t_{pR}$ indicates that it is sufficient to investigate only nine combinations of the sequence of timings. Moreover, through calculating the equilibrium, we find that while there are nine possible combinations of timing sequences, there are only three instances of equilibrium payoffs and variables. Accordingly, we distinguish the equilibrium payoffs and variables using the "sequence" of the three prices being set. Let Sequences E, S, and L, respectively, denote that the manufacturer sets the direct channel price earlier than, simultaneously with, and later than, the retail channel price setting by the retailer, as Fig. 2 illustrates. We define Sequence E as the sequence where the timing variables are $(t_r, t_{pD}, t_{pR}) = (1, 1, 2), (1, 1, 3), (1, 2, 3), (2, 1, 3),$ or $(2, 2, 3)$, because $t_{pD} < t_{pR}$ holds in all these combinations. We define Sequence S as the sequence where the timing variables are $(t_r, t_{pD}, t_{pR}) = (1, 2, 2), (1, 3, 3),$ or $(2, 3, 3)$ because $t_{pD} = t_{pR}$ holds. Finally, we define Sequence L as the sequence where the timing variables are $(t_r, t_{pD}, t_{pR}) = (1, 3, 2)$ because $t_{pD} > t_{pR}$ holds. Hereafter, we attach superscripts E, S, or L on equilibrium payoffs and variables to identify the sequence of timings. The following proposition shows the equilibrium outcomes by the sequence. (The Appendix provides all proofs.)

Proposition 1. *The equilibrium values of the payoffs and endogenous variables are as follows by sequence.*

Case. (I): Sequence E

$$\begin{aligned}r^E &= (Y_R/B_0 + c)/2 \\ p_D^E &= (Y_D/B_0 + c)/2 \\ p_R^E &= (Y_R/B_0 + c)/2 + X_R/(4b_R) \\ q_D^E &= X_D/2 + \theta X_R/(4b_R) \\ q_R^E &= X_R/4 \\ \pi^E &= X_R^2/(16b_R) \\ \Pi^E &= (Y_D - B_0c)^2/(4b_R B_0) + X_R^2/(8b_R)\end{aligned}$$

Case. (II): Sequence S

$$\begin{aligned}r^S &= (Y_R/B_0 + c)/2 - \theta^2 X_R/(2b_R B_1) \\ p_D^S &= (Y_D/B_0 + c)/2 + \theta X_R/B_1 \\ p_R^S &= (Y_R/B_0 + c)/2 + (4b_D b_R + \theta^2)X_R/(2b_R B_1) \\ q_D^S &= X_D/2 + \theta(2b_D b_R + \theta^2)X_R/(2b_R B_1) \\ q_R^S &= (2b_D b_R + \theta^2)X_R/B_1 \\ \pi^S &= (2b_D b_R + \theta^2)^2 X_R^2/(b_R B_1^2) \\ \Pi^S &= (Y_D - B_0c)^2/(4b_R B_0) + b_D X_R^2/B_1\end{aligned}$$

Case. (III): Sequence L

$$\begin{aligned}r^L &= (Y_R/B_0 + c)/2 - b_D \theta^2 X_R/(2B_2) \\ p_D^L &= (Y_D/B_0 + c)/2 + \theta(2b_D b_R - \theta^2)X_R/(2B_2) \\ p_R^L &= (Y_R/B_0 + c)/2 + b_D(4b_D b_R - \theta^2)X_R/(2B_2) \\ q_D^L &= X_D/2 + b_D^2 b_R \theta X_R/B_2 \\ q_R^L &= b_D b_R(2b_D b_R - \theta^2)X_R/B_2 \\ \pi^L &= 2b_D^3 b_R^2(2b_D b_R - \theta^2)X_R^2/B_2^2 \\ \Pi^L &= (Y_D - B_0c)^2/(4b_R B_0) + (2b_D b_R - \theta^2)^2 X_R^2/(4b_R B_2)\end{aligned}$$

The symbols included in the values respectively represent the following: $Y_D \equiv b_R a_D + \theta a_R$, $Y_R \equiv b_D a_R + \theta a_D$, $X_D \equiv a_D - (b_D - \theta)c$, $X_R \equiv a_R - (b_R - \theta)c$, $B_0 \equiv b_D b_R - \theta^2$, $B_1 \equiv 8b_D b_R + \theta^2$, and $B_2 \equiv 8b_D^2 b_R^2 - 5b_D b_R \theta^2 + \theta^4$.

By comparing the equilibrium variables in Proposition 1, we derive the following proposition.

Proposition 2. *The following relationships concerning the equilibrium payoffs and variables hold.*

$$\begin{aligned}\Pi^E &> \Pi^S > \Pi^L \\ \pi^E &< \pi^S < \pi^L \\ r^E &> r^S > r^L \\ p_D^E &< p_D^S < p_D^L \\ p_R^E &< p_R^S < p_R^L\end{aligned}$$

The following corollary follows from Proposition 2.

⁸ For a more detailed explanation of this formulation, see Table 1 in Lu (2006, pp. 58–59).

Table 2
Payoff matrix.

		Timing strategy by retailer on t_{pR}		
		1	2	3
Timing strategy by manufacturer on (t_r, t_{pD})	(1, 1)		(Π^E , π^E)	(Π^E , π^E)
	(1, 2)		(Π^S , π^S)	(Π^E , π^E)
	(1, 3)		(Π^L , π^L)	(Π^S , π^S)
	(2, 1)			(Π^E , π^E)
	(2, 2)			(Π^E , π^E)
	(2, 3)			(Π^S , π^S)
	(3, 1)			
	(3, 2)			
	(3, 3)			

Notes: The left variable in parenthesis represents the manufacturer's payoff, and the right variable in parenthesis represents the retailer's payoff from each combination of timing strategies. The payoff enclosed by a circle represents the best response for the manufacturer or the retailer. Hence, the cell where both of the two payoffs in parenthesis are circled constitutes the Nash equilibrium. The cells with diagonal lines are the combinations of strategies that are never realized because $t_r < t_{pR}$ must hold in this timing game. See Proposition 1 for the values of payoffs, Π^E , Π^S , Π^L , π^E , π^S , and π^L .

Corollary 1. *The equilibrium margin for the retailer is higher when the manufacturer sets the direct channel price later; that is:*

$$p_R^E - r^E < p_R^S - r^S < p_R^L - r^L.$$

We may identify the optimal timing strategy for the manufacturer and that for the retailer at stage one using the results of Proposition 2. For tractability of the results, we construct the payoff matrix of the timing game at stage one and present the Nash equilibrium in the following observation.

Observation. *Table 2 illustrates the payoff matrix at stage one. The cell where both of the payoffs in parenthesis are circled constitutes the Nash equilibrium in the timing game.*

Note that we use diagonal lines in the cells in Table 2 to indicate where the combinations of timing strategies do not satisfy $t_r < t_{pR}$. For ease of identifying the optimal timing strategy, we circle the payoff in Table 2 resulting from the optimal strategy. Because the left variable in parenthesis represents the manufacturer's payoff and the right variable the retailer's payoff, the cell where we circle both of the payoffs in parenthesis constitutes the Nash equilibrium in the timing game, as stated in the observation. We draw the following proposition by referring to the table.

Proposition 3. *The combinations of timings that constitute the SPNE are: $(t_r, t_{pD}, t_{pR}) = (1, 1, 2), (1, 1, 3), (2, 1, 3),$ or $(2, 2, 3)$, all of which correspond to Sequence E. This suggests that the manufacturer sets the direct channel price (i) before or upon setting the wholesale price, and (ii) before the retailer sets the retail channel price in equilibrium.*

Proposition 3 is the central finding in this paper and provides the managerial implication that the manufacturer should post the direct channel price as early as possible. Observe that $t_{pD} < t_{pR}$ holds in every combination of timings in Proposition 3, indicating that only Sequence E constitutes the SPNE. Moreover, Proposition 3 and Table 2 suggest that if the manufacturer sets the direct channel price after setting the wholesale price (i.e., $t_r < t_{pD}$), no Nash equilibrium arises because the retailer has an incentive to accelerate the timing of retail pricing so that $t_{pR} \leq t_{pD}$ holds. For example, Table 2 suggests that if the manufacturer sets $(t_r, t_{pD}) = (1, 2)$ or $(1, 3)$, the retailer sets $t_{pR} = 2$, meaning that the

retailer prefers the earlier period to the later period for setting the retail channel price.

3.3. Rationale

Next, we reveal the mechanism that underlies our model to provide a rationale for our result and implication. To understand the logic of the mechanism, we first need to understand the concepts of "strategic complements" and "strategic substitutes" proposed by Bulow, Geanakoplos, and Klemperer (1985), as commonly used in noncooperative game theory. "Strategic complements" means that if a player increases its strategic variable in a noncooperative game, another player also increases its strategic variable in response. Stated differently, if a player undertakes a more (less) aggressive strategy, the other player also undertakes a more (less) aggressive strategy, implying a positive correlation between the strategic variables determined by players. "Strategic substitutes" is the direct opposite of "strategic complements", such that if one player increases its strategic variable, another player decreases its strategic variable. Therefore, the variables characterized by strategic substitutes have a negative correlation. The existing literature shows that prices determined by multiple firms in price competition are strategic complements, whereas quantities determined in quantity competition are strategic substitutes (e.g., Bulow et al., 1985).⁹ Because we consider price competition in this analysis, strategic variables (prices) are strategic complements. Using the concept of strategic complements in price competition, we explore the intuition behind our outcomes by pricing sequence.

First, let us consider Sequence E, which brings the manufacturer the highest profit, as suggested by Proposition 2. Note that p_R has no strategic influence on p_D in Sequence E. This is because p_R is derived as the best-response function including p_D and r (i.e., Eq. (A1) in the Appendix) in a later period, and the manufacturer substitutes this function into its profit function in an earlier period and maximizes the function (i.e., Eq. (A2) in the Appendix), in which p_R no longer appears. That is, the manufacturer perfectly anticipates the retailer's subsequent pricing strategy and thus can ad-

⁹ Price competition and quantity competition are respectively called Bertrand competition and Cournot competition in the economic literature.

just the direct channel price as its optimal level in an earlier stage through backward induction. Indeed, [Proposition 1](#) suggests that the direct channel price in Sequence E (p_D^E) is $((b_R a_D + \theta a_R)/(b_D b_R - \theta^2) + c)/2$, which is the monopoly price level for the manufacturer in the direct channel under the absence of influence from the retail channel. Such upfront optimization enables the manufacturer to glean the highest profit from the direct channel, which is a more important profit source than the retail channel because double marginalization does not arise in the direct channel.

Second, we consider Sequence S. Because p_D and p_R are set simultaneously in this sequence, unlike Sequence E, a strategic effect arises between the two prices. In a competition with two firms, each firm hopes that the other firm behaves less aggressively. Because strategic variables (i.e., p_D and p_R) work as strategic complements in price competition as discussed, each firm must undertake a less aggressive strategy because the other firm then will also undertake a less aggressive strategy. Therefore, the manufacturer (retailer) has the incentive to drive up the direct (retail) channel price in equilibrium, which is less aggressive behavior than a price reduction, to induce the rival to be less aggressive and to raise its price. This behavior induces the equilibrium price to approach the level that maximizes the total profit for the two firms as if they were colluding, because in price competition, the less aggressive strategy by one player increases not only its own profit but also the rival's profit ([Bulow et al., 1985](#)). As a result, p_D and p_R in equilibrium take higher values in Sequence S than in Sequence E; that is, $p_D^E < p_D^S$ and $p_R^E < p_R^S$ hold as shown by [Proposition 2](#).

Next, because the direct channel price and the retail channel price in Sequence S (p_D^S and p_R^S) are higher than their respective optimal levels (p_D^E and p_R^E), the sales quantities in the direct channel and the retail channel are lower in Sequence S than in Sequence E. If the manufacturer did not change the level of the wholesale price from r^E in this situation, the sales quantity in each channel would decrease from the first-best level realized in Sequence E, and profit would fall. To recover this suboptimal status as much as possible, the manufacturer then needs to increase the quantity dealt by the retailer. To induce the retailer to deal a greater quantity, the manufacturer then has to cut down the wholesale price (r) in sequence S below the price in sequence E (r^E). As a result, $r^E > r^S$ holds.

Third, we consider sequence L. At the last move in Sequence L, the manufacturer sets the direct channel price by referring to the retail channel price set earlier. Because prices are strategic complements, the manufacturer tends to drive up the direct channel price in Sequence L, in a way similar to Sequence S. Moreover, when the retailer sets the retail channel price (p_R) in an earlier period, the retailer calculates that the manufacturer will slightly undercut p_R in order to obtain a larger market share than the retailer. This calculation puts pressure on the retailer to maintain a high price to avoid having the manufacturer set a very low price. As a result, the retailer undertakes an even less aggressive strategy in the sequential-move game (Sequence L) than in the simultaneous-move game (Sequence S).¹⁰ Hence, both the manufacturer and the retailer set prices above the levels in the simultaneous-move game, such that $p_R^S < p_R^L$ and $p_D^S < p_D^L$ hold. These two inequalities mean that the higher prices further reduce sales quantities in both of the channels in Sequence L compared with Sequence S, which in turn reduces the manufacturer's profit. To mitigate this sales quantity decline as much as possible, the manufacturer has to reduce

the wholesale price, r , below r^S to induce the retailer to deal in greater quantity. As a result, $r^S > r^L$ holds. Combining $r^S > r^L$ and $p_R^S < p_R^L$ leads to $p_R^S - r^S < p_R^L - r^L$. Eventually, $p_R^E - r^E < p_R^S - r^S < p_R^L - r^L$ suggests that the retailer gains a higher margin as the manufacturer sets the direct channel price in a later period. That is, double marginalization is more noticeable in the sequence ordering of L, S, and E, as shown in [Corollary 1](#).¹¹

4. Extension: introduction of service factor

Recently, [Wang, Wallace, Shen, and Choi \(2015\)](#) give an extensive overview of research in the supply chain management of services, suggesting that services provided by retailers can have a substantial impact on consumer behavior. Given this research stream, in this section we extend the model in the previous section to consider consumer behavior demanding products with differentiated services between channels. Following recent OR studies that construct dual-channel models involving a service factor, we modify the demand functions for [Eq. \(1\)](#) in the basic model to the following.

$$\begin{aligned} q_D &= a_D - b_D p_D + \theta p_R - \gamma_D s \\ q_R &= a_R - b_R p_R + \theta p_D + \gamma_R s \end{aligned} \quad (6)$$

where s is the level of service provided by the retailer. The positive parameters γ_R and γ_D respectively measure the increase in demand in the retail channel and the decrease of demand in the direct channel, in response to a unit increase in service. Hence, [Eq. \(6\)](#) indicates that as the retailer enhances the service level, demand for the retail channel increases while demand for the direct channel decreases.¹² We also assume a strictly convex service cost function, $C(s)$, for the retailer incurring the cost of services, so that $C(0)=0$, $dC(s)/ds > 0$, and $d^2C(s)/ds^2 > 0$ hold following the extant literature (e.g., [Tsay & Agrawal, 2004a](#); [Yan & Pei, 2009](#); [Dan, Xu, & Liu, 2012](#)).¹³ Accordingly, the respective profits for the manufacturer and the retailer are:

$$\begin{aligned} \Pi &= (r - c)q_R + (p_D - c)q_D \\ &= (r - c)(a_R - b_R p_R + \theta p_D + \gamma_R s) \\ &\quad + (p_D - c)(a_D - b_D p_D + \theta p_R - \gamma_D s) \end{aligned} \quad (7)$$

$$\begin{aligned} \pi &= (p_R - r)q_R - C(s) \\ &= (p_R - r)(a_R - b_R p_R + \theta p_D + \gamma_R s) - C(s). \end{aligned} \quad (8)$$

The next proposition holds in the extended model.

¹¹ The following insight from [Moorthy and Fader \(1989\)](#) reinforces our result; they show that the margin decisions of the manufacturer and the retailer are strategic substitutes in a competitive environment in a two-echelon supply chain. In our model, the manufacturer's margin in the retail channel is $r - c$ and the retailer's margin is $p_R - r$. Because the marginal cost of the product for the manufacturer in our model is fixed as c , $r^E - c > r^S - c > r^L - c$ suggested by [Proposition 2](#) and $p_R^E - r^E < p_R^S - r^S < p_R^L - r^L$ in [Corollary 1](#) indicate a negative correlation between the two margins, which is consistent with the finding in [Moorthy and Fader \(1989\)](#).

¹² While a number of previous studies of dual-channel supply chain management apply this type of demand function (e.g., [Hua et al., 2010](#); [Hu & Li, 2012](#); [Chen et al., 2013](#)), the demand functions in [Dan et al. \(2012\)](#) are most similar to [Eq. \(6\)](#). [Yan and Pei \(2009\)](#) detail the consumer behavior underpinning this type of demand function where they assume that heterogeneous consumers are along a line and that consumers have different product values according to their position on the line. Moreover, [Yan and Pei \(2009\)](#) assume that each consumer obtains additional utility by receiving services from the retailer. [Yan and Pei \(2009\)](#) demonstrate that this consumer behavior setting leads to this type of demand function form, in which retailer service level linearly increases the demand for the retail channel while decreasing the demand for the direct channel. Because consumers have different values of willingness to purchase, such demand function forms draw on heterogeneous but not representative consumers.

¹³ While previous studies often assume a quadratic service cost function such as $C(s) = \eta s^2/2$ where $\eta > 0$, we need not restrict the cost function to such a specific form because our central result holds even for a general cost function.

¹⁰ The explanation of the logic here is based on [Shy \(1996, p. 142\)](#). Texts on industrial organization generally provide more detailed explanation and illustration of the mechanism that each equilibrium price of two competitors in a sequential-move game is higher than that in a simultaneous-move game (i.e., $p_R^S < p_R^L$ and $p_D^S < p_D^L$). See, for example, [Shy \(1996, pp. 141–142\)](#) or [Belleflamme and Peitz \(2010, pp. 78–79\)](#).

Proposition 4. The equilibrium payoffs by sequence are as follows.

Case. (I): Sequence E

$$\Pi^E = (Y_D - s(b_R\gamma_D - \theta\gamma_R) - B_0c)^2 / (4b_RB_0) + (X_R + s\gamma_R)^2 / (8b_R)$$

$$\pi^E = (X_R + s\gamma_R)^2 / (16b_R) - C(s)$$

Case. (II): Sequence S

$$\Pi^S = (Y_D - s(b_R\gamma_D - \theta\gamma_R) - B_0c)^2 / (4b_RB_0) + b_D(X_R + s\gamma_R)^2 / B_1$$

$$\pi^S = (2b_Db_R + \theta^2)(X_R + s\gamma_R)^2 / (b_RB_1^2) - C(s)$$

Case. (III): Sequence L

$$\Pi^L = (Y_D - s(b_R\gamma_D - \theta\gamma_R) - B_0c)^2 / (4b_RB_0) + (X_R + s\gamma_R)^2 (2b_Db_R - \theta^2)^2 / (4b_RB_2)$$

$$\pi^L = 2b_D^3b_R^2(X_R + s\gamma_R)^2 (2b_Db_R - \theta^2) / B_2^2 - C(s)$$

The symbols included in the payoffs respectively represent the following: $Y_D \equiv b_Ra_D + \theta a_R$, $X_R \equiv a_R - (b_R - \theta)c$, $B_0 \equiv b_Db_R - \theta^2$, $B_1 \equiv 8b_Db_R + \theta^2$, and $B_2 \equiv 8b_D^2b_R^2 - 5b_Db_R\theta^2 + \theta^4$.

Note that in Proposition 4, we can interpret s as either an exogenously fixed parameter or a control variable endogenously determined by the retailer. If we adopt the latter interpretation, the retailer maximizes π by solving $\partial\pi/\partial s = 0$ and derives the optimal service level, s^* , as the function of exogenous parameters: $s^* = s(a_R, b_D, b_R, \gamma_R, c, \theta)$. We then substitute this optimal service level, s^* , into each payoff function in Proposition 4, deriving the equilibrium payoffs after controlling for the service level of the retailer. The next proposition follows from Proposition 4.

Proposition 5. The following relationships concerning the equilibrium payoffs hold in the extended model.

$$\Pi^E > \Pi^S > \Pi^L$$

$$\pi^E < \pi^S < \pi^L$$

Using Proposition 5, we can construct a payoff matrix like Table 2. Because the order of payoffs classified by the sequence in Proposition 5 is identical to that in Proposition 2, we identify Sequence E as the SPNE based on the payoff matrix that suggests the equilibria are the same as those in Table 2.

Recall in Proposition 4 that s can be either an exogenously fixed parameter or an endogenous control variable in equilibrium that the retailer determines. For example, suppose that s^* is the optimal service level for the retailer that maximizes its profit in Sequence S, π^S . Even when s is fixed as s^* , Proposition 5 suggests that $\pi^S < \pi^L$ holds, meaning that the retailer obtains at least the maximum profit of Sequence S when choosing Sequence L. Hence, $\Pi^E > \Pi^S > \Pi^L$ and $\pi^E < \pi^S < \pi^L$ hold regardless of whether the retailer's profit has been maximized with respect to the service or not. In either case, Sequence E constitutes the equilibrium.

Proposition 6. Only Sequence E arises in the SPNE when consumer behavior depends on the retailer's service, suggesting that the manufacturer sets the direct channel price (i) before or upon setting the wholesale price, and (ii) before the retailer sets the retail channel price in equilibrium.

Proposition 6 proves that even when retailer service is considered as an additional practical factor affecting consumer behavior, the central result of the basic model in the previous section remains to hold. Namely, the result that the manufacturer has an advantage in posting the direct price before the wholesale price is robust under circumstances that are more general.

5. Conclusion and discussion

This paper investigates the problem of when a manufacturer managing dual-channel supply chains should set its selling prices. The most notable conclusion from our analysis is that a manufacturer that seeks to maximize its profit should determine the direct price before or upon setting the wholesale price to a retailer. Conversely, if the manufacturer sets the direct price in a period after setting the wholesale price, there is no stable equilibrium regarding the timing of price determination by the manufacturer and retailer. Therefore, price competition where the retail and direct channel prices are set simultaneously never occurs, but only a sequential price-setting game arises, in which the manufacturer initially sets the direct and wholesale prices, and the retailer then determines the retail price.

Our result is also noteworthy from the viewpoint of noncooperative game theory. It has been widely acknowledged that price competition is characterized by a second-mover advantage under quite general conditions; that is, the later a player makes its decision, the greater the payoff it receives (Gal-or, 1985; Shy, 1996, pp. 141–142; Belleflamme & Peitz, 2010, pp. 78–79). Contrary to this conventional insight, our model indicates that both the manufacturer and the retailer have an incentive to expedite the timing of the pricing decision to improve their own profits in a game within a multichannel structure, which appears to constitute a first-mover advantage. However, note that the "first mover" discussed here represents the first mover not in the "whole game", but in the "subgame" where the manufacturer and the retailer respectively set the direct channel price and the retail channel price. Accordingly, the "first-mover advantage" suggested does not result from the whole game but rather from the subgame where p_D and p_R are set. In the whole game of this dual-channel problem, the manufacturer is fixed as the first mover, whereas the retailer is the second mover, because the retailer can set the retail channel price, p_R , after observing the manufacturer's setting the wholesale price, r . This means that the manufacturer can always adjust the wholesale price r , in an earlier stage based on the anticipation of retailer's subsequent pricing behavior. This upfront adjustment of r by the manufacturer is the fundamental reason for the disappearance of the second-mover advantage in the subsequent subgame. Therefore, if the manufacturer postpones setting the direct channel price by espousing the conventional insight, the manufacturer will collect lower profits. Our study suggests that a manufacturer must be aware of this opposing insight; i.e., a later-mover disadvantage stemming from posting the direct channel price after the retailer sets the retail channel price in the subgame.

Our research from the game-theoretic point of view proposes that the timing of pricing in each channel is an essential problem for a manufacturer that employs dual channels. As briefly discussed in the introduction, our model describes past pricing decisions in dual channels made by PC manufacturers such as Dell and IBM. While most PC manufacturers that initially distributed their products through a traditional retail channel subsequently constructed a direct channel, Dell originally used only a direct channel and subsequently added a retail channel, which means that Dell established the direct price before determining the wholesale price in the retail channel. To be exact, upfront setting of the direct price by the manufacturer (Dell) worked as a commitment, which changed the subsequent behavior of retail pricing by retailers. Moreover, IBM undertook the channel strategy to distribute several products initially only through the direct channel, and then through the indirect channel, including its partners, as discussed in the introduction. Evaluating IBM's dual-channel strategy, Hardy and Magrath (1988, p. 66) declare "The company has been quite successful; large customers can buy direct, while smaller, more dispersed customers buy from distribution channels." This means

that IBM is a manufacturer that has successfully used dual channels. Our model suggests that the policy of differentiating the timing of pricing and distribution between the two channels is one of the factors that enhanced its profitability. Hence, these cases are consistent with our result that a manufacturer can pursue greater profit by setting the direct channel price before setting the wholesale price, as shown in Propositions 3 and 6.

As coordination between a multi-channel manufacturer and a traditional retailer commands the interest of researchers and practitioners, we can develop our model to incorporate other factors associated with actual business environments. For example, we may extend the observable delay game model in this paper by introducing competition between multiple manufacturers managing dual-channel supply chains. Moreover, while considering the MTO system in our model, we can introduce contracts between supply chain members including two-part tariffs or a buyback/return policy employed by the manufacturer to coordinate the traditional retailer.¹⁴ We reserve these topics for future study.

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Appendix

Proof of Proposition 1. We solve the game in a backward manner by the sequence of pricing timing.

Case (I): when $(t_r, t_{pD}, t_{pR}) = (1, 1, 2), (1, 1, 3), (1, 2, 3), (2, 1, 3),$ or $(2, 2, 3)$

At first glance, the order in which prices are set varies among these five sequences of timings and thus leads to different payoffs. However, we later prove that every combination of these timing strategies leads to the same payoffs because of the envelope theorem by further dividing this case into three cases; i.e., Case (I)-(i), (ii), and (iii), below.

The retailer sets the retail channel price at the last move because $t_{pR} > t_r$ and $t_{pR} > t_{pD}$ hold in this case. Using the backward induction technique, we first maximize Eq. (5) with respect to p_R by solving $\partial \pi / \partial p_R = 0$, yielding:

$$p_R = (a_R + b_R r + \theta p_D) / (2b_R). \quad (A1)$$

Note that the second-order conditions for all maximization problems in this appendix are satisfied because all profit functions are concave and quadratic with respect to the strategic variable (price). Therefore, we henceforth omit writing the second-order conditions.

Next, we analyze the manufacturer's decision on the direct channel price. We put Eq. (A1) into Eq. (4), yielding:

$$\Pi = (r - c)(a_R - b_R r + \theta p_D) / 2 + (p_D - c)(a_D - b_D p_D + \theta(a_R + b_R r + \theta p_D) / (2b_R)). \quad (A2)$$

We derive the equilibrium by each of the three cases, such that the manufacturer sets the direct channel price (i) before, (ii) upon, and (iii) after setting the wholesale price.

Case (I)-(i): when $(t_r, t_{pD}, t_{pR}) = (2, 1, 3)$

The manufacturer sets the direct channel price before setting the wholesale price in this case. We maximize Eq. (A2) with respect to r by solving $\partial \Pi / \partial r = 0$, yielding:

$$r = (a_R + 2\theta p_D + (b_R - \theta)c) / (2b_R). \quad (A3)$$

Subsequently, we put Eq. (A3) into Eq. (A2) and maximize it on p_D by solving $\partial \Pi / \partial p_D = 0$, obtaining:

$$p_D = ((b_R a_D + \theta a_R) / (b_D b_R - \theta^2) + c) / 2. \quad (A4)$$

Replacing p_D in Eq. (A3) with Eq. (A4), we have:

$$r = ((b_D a_R + \theta a_D) / (b_D b_R - \theta^2) + c) / 2. \quad (A5)$$

Plugging Eqs. (A4) and (A5) into Eq. (A1) yields:

$$p_R = (a_R + (b_R + \theta)c) / (4b_R) + (b_D a_R + \theta a_D) / (2(b_D b_R - \theta^2)). \quad (A6)$$

Case (I)-(ii): when $(t_r, t_{pD}, t_{pR}) = (1, 1, 2), (1, 1, 3),$ or $(2, 2, 3)$

In these three combinations, the manufacturer sets the direct channel price simultaneously with setting the wholesale price. Hence, we maximize Eq. (A2) with respect to both r and p_D by solving $\partial \Pi / \partial r = \partial \Pi / \partial p_D = 0$, obtaining:

$$r = ((b_D a_R + \theta a_D) / (b_D b_R - \theta^2) + c) / 2, \\ p_D = ((b_R a_D + \theta a_R) / (b_D b_R - \theta^2) + c) / 2. \quad (A7)$$

Putting Eq. (A7) into (A1) yields:

$$p_R = (a_R + (b_R + \theta)c) / (4b_R) + (b_D a_R + \theta a_D) / (2(b_D b_R - \theta^2)). \quad (A8)$$

Case (I)-(iii): when $(t_r, t_{pD}, t_{pR}) = (1, 2, 3)$

In this case, the manufacturer sets the direct channel price after setting the wholesale price but before the retail channel price is set. We maximize Eq. (A2) on p_D by solving $\partial \Pi / \partial p_D = 0$, which yields:

$$p_D = (2b_R a_D + \theta(a_R + b_R(2r - c))) / (2(b_D b_R - \theta^2)) + c / 2. \quad (A9)$$

Inserting Eq. (A9) into Eq. (A2) and maximizing it with respect to r by solving $\partial \Pi / \partial r = 0$ gives:

$$r = ((b_D a_R + \theta a_D) / (b_D b_R - \theta^2) + c) / 2. \quad (A10)$$

Replacing r in Eq. (A9) with Eq. (A10), we have:

$$p_D = ((b_R a_D + \theta a_R) / (b_D b_R - \theta^2) + c) / 2. \quad (A11)$$

Plugging Equations (A10) and (A11) into Eq. (A1) yields:

$$p_R = (a_R + (b_R + \theta)c) / (4b_R) + (b_D a_R + \theta a_D) / (2(b_D b_R - \theta^2)). \quad (A12)$$

Finally, we insert either Eqs. (A4)–(A6) of Case (I)-(i), Eqs. (A7)–(A8) of Case (I)-(ii), or Equations (A10)–(A12) of Case (I)-(iii) into Eqs. (4) and (5), yielding the equilibrium profits for the manufacturer and the retailer as: $\Pi = (b_R a_D + \theta a_R - (b_D b_R - \theta^2)c^2) / (4b_R(b_D b_R - \theta^2)) + (a_R - (b_R - \theta)c)^2 / (8b_R)$ and $\pi = (a_R - (b_R - \theta)c)^2 / (16b_R)$, which correspond to Π^E and π^E in Table 2. Notice that the envelope theorem leads to the same equilibrium values in Cases (I)-(i), (ii), and (iii).

¹⁴ OR models that focus on the economic roles of return policies used between manufacturers and distributors appear in the supply chain management literature (e.g., Matsui, 2010; Ohmura & Matsuo, 2016).

Case (II): when $(t_r, t_{pD}, t_{pR}) = (1, 2, 2), (1, 3, 3),$ or $(2, 3, 3)$

Maximization of Eq. (4) on p_D and Eq. (5) on p_R , i.e., $\partial \Pi / \partial p_D = \partial \Pi / \partial p_R = 0$, gives:

$$\begin{aligned} p_D &= (2b_R(a_D + b_D c) + \theta(a_R + b_R(3r - 2c))) / (4b_D b_R - \theta^2) \\ p_R &= (2b_D(a_R + b_R r) + \theta(a_D + \theta r + (b_D - \theta)c)) / (4b_D b_R - \theta^2). \end{aligned} \quad (A13)$$

Inserting Eq. (A13) into Eq. (4) and maximizing it with respect to r by solving $\partial \Pi / \partial r = 0$ gives:

$$\begin{aligned} r &= ((b_D a_R + \theta a_D) / (b_D b_R - \theta^2) + c) / 2 \\ &\quad - \theta^2(a_R - (b_R - \theta)c) / (2b_R(8b_D b_R + \theta^2)). \end{aligned} \quad (A14)$$

Finally, inserting Equations (A13) and (A14) into Eqs. (4) and (5) yields the equilibrium profits for the manufacturer and the retailer as: $\Pi = (b_R a_D + \theta a_R - (b_D b_R - \theta^2)c)^2 / (4b_R(b_D b_R - \theta^2)) + b_D(a_R - (b_R - \theta)c)^2 / (8b_D b_R + \theta^2)$ and $\pi = (2b_D b_R + \theta^2)^2(a_R - (b_R - \theta)c)^2 / (b_R(8b_D b_R + \theta^2)^2)$, which correspond to Π^S and π^S in Table 2.

Case (III): when $(t_r, t_{pD}, t_{pR}) = (1, 3, 2)$

Maximization of Eq. (4) with respect to p_D by solving $\partial \Pi / \partial p_D = 0$ gives:

$$p_D = (a_D + b_D c + \theta(p_R + r - c)) / (2b_D). \quad (A15)$$

Replacing p_D in Eq. (5) with Eq. (A15) and maximizing it on p_R by solving $\partial \Pi / \partial p_R = 0$ yields:

$$p_R = (2b_D(a_R + b_R r) + \theta(a_D + (b_D - \theta)c)) / (2(2b_D b_R - \theta^2)). \quad (A16)$$

Inserting Equations (A15) and (A16) into Eq. (4) and maximizing it with respect to r by solving $\partial \Pi / \partial r = 0$ gives:

$$\begin{aligned} r &= ((b_D a_R + \theta a_D) / (b_D b_R - \theta^2) + c) / 2 \\ &\quad - b_D \theta^2(a_R - (b_R - \theta)c) / (2(8b_D^2 b_R^2 - 5b_D b_R \theta^2 + \theta^4)). \end{aligned} \quad (A17)$$

Finally, inserting Equations (A15), (A16), and (A17) into Eqs. (4) and (5) yields the equilibrium profits for the manufacturer and the retailer as:

$$\begin{aligned} \Pi &= (b_R(a_D - b_D c) + \theta(a_R + \theta c))^2 / (4b_R(b_D b_R - \theta^2)) \\ &\quad + (a_R - (b_R - \theta)c)^2 (2b_D b_R - \theta^2)^2 / (4b_R(8b_D^2 b_R^2 - 5b_D b_R \theta^2 + \theta^4)) \end{aligned}$$

and $\pi = 2b_D^3 b_R^2(a_R - (b_R - \theta)c)^2 (2b_D b_R - \theta^2) / (8b_D^2 b_R^2 - 5b_D b_R \theta^2 + \theta^4)^2$, which correspond to Π^L and π^L in Table 2. \square

Proof of Proposition 2. Using the values in Proposition 1, we derive the following series of inequalities. The definitions of X_R , B_1 , and B_2 in the inequalities are in Proposition 1. Note that the signs of the inequalities are determined using the assumptions represented by Inequalities (2)–(3).

$$\Pi^E - \Pi^S = \theta^2 X_R^2 / (8b_R B_1) > 0$$

$$\Pi^S - \Pi^L = \theta^2 (8b_D^2 b_R^2 - \theta^4) X_R^2 / (4b_R B_1 B_2) > 0$$

$$\pi^E - \pi^S = -3\theta^2 (16b_D b_R + 5\theta^2) X_R^2 / (16b_R B_1^2) < 0$$

$$\begin{aligned} \pi^S - \pi^L &= -\theta^4 (64b_D^4 b_R^4 - 46b_D^3 b_R^3 \theta^2 \\ &\quad - 5b_D^2 b_R^2 \theta^4 + 6b_D b_R \theta^6 - \theta^8) X_R^2 / (b_R B_1^2 B_2^2) < 0 \end{aligned}$$

$$r^E - r^S = \theta^2 X_R / (2b_R B_1) > 0$$

$$r^S - r^L = \theta^4 (6b_D b_R - \theta^2) X_R / (2b_R B_1 B_2) > 0$$

$$p_D^E - p_D^S = -\theta X_R / B_1 < 0$$

$$p_D^S - p_D^L = -\theta^3 (4b_D b_R - 3\theta^2) X_R / (2B_1 B_2) < 0$$

$$p_R^E - p_R^S = -\theta^2 X_R / (4b_R B_1) < 0$$

$$p_R^S - p_R^L = -\theta^2 (8b_D^2 b_R^2 - \theta^4) X_R / (2b_R B_1 B_2) < 0$$

\square

Proof of Corollary 1. Because Proposition 2 suggests that $r^E > r^S > r^L$ and $p_R^E < p_R^S < p_R^L$ hold, it follows that $p_R^E - r^E < p_R^S - r^S < p_R^L - r^L$ is satisfied. \square

Proof of Proposition 3. Table 2 suggests that the combinations of timing strategies that constitute the SPNE are $(t_r, t_{pD}, t_{pR}) = (1, 1, 2), (1, 1, 3), (2, 1, 3),$ or $(2, 2, 3)$. The relationship of $t_{pD} \leq t_r$ in the four combinations proves (i) in this proposition, whereas the relationship of $t_{pD} < t_{pR}$ proves (ii). \square

Proof of Proposition 4. By tracking identical solving processes by the sequence shown in the proof for Proposition 1 with Eq. (6) as the demand function instead of Eq. (1), we derive the payoff functions in the extended model as shown in this proposition. \square

Proof of Proposition 5. Based on the payoffs in Proposition 4, the following inequalities that prove this proposition hold. The definitions of X_R , B_1 , and B_2 in the inequalities are in Proposition 4.

$$\Pi^E - \Pi^S = \theta^2 (X_R + s\gamma_R)^2 / (8b_R B_1) > 0$$

$$\Pi^S - \Pi^L = \theta^2 (8b_D^2 b_R^2 - \theta^4) (X_R + s\gamma_R)^2 / (4b_R B_1 B_2) > 0$$

$$\pi^E - \pi^S = -3\theta^2 (16b_D b_R + 5\theta^2) (X_R + s\gamma_R)^2 / (16b_R B_1^2) < 0$$

$$\begin{aligned} \pi^S - \pi^L &= -\theta^4 (64b_D^4 b_R^4 - 46b_D^3 b_R^3 \theta^2 - 5b_D^2 b_R^2 \theta^4 + 6b_D b_R \theta^6 - \theta^8) \\ &\quad \times (X_R + s\gamma_R)^2 / (b_R B_1^2 B_2^2) < 0 \end{aligned}$$

\square

Proof of Proposition 6. Only Sequence E constitutes the SPNE in the extended model due to given the same logic behind the basic model shown in Proposition 3. \square

References

- Amir, R., & Grilo, I. (1999). Stackelberg versus Cournot equilibrium. *Games and Economic Behavior*, 26(1), 1–21.
- Amir, R., & Stepanova, A. (2006). Second-mover advantage and price leadership in Bertrand duopoly. *Games and Economic Behavior*, 55(1), 1–20.
- Anderson, E. J., & Bao, Y. (2010). Price competition with integrated and decentralized supply chains. *European Journal of Operational Research*, 200(1), 227–234.
- Atkins, D., & Liang, L. (2010). A note on competitive supply chains with generalised supply costs. *European Journal of Operational Research*, 207(3), 1316–1320.
- Balakrishnan, A., Sundaresan, S., & Zhang, B. (2014). Browse-and-switch: retail-online competition under value uncertainty. *Production and Operations Management*, 23(7), 1129–1145.
- Balasubramanian, S. (1998). Mail versus mall: a strategic analysis of competition between direct marketers and conventional retailers. *Marketing Science*, 17(3), 181–195.
- Belleflamme, P., Peitz, M., (2010). *Industrial organization: Markets and strategies*. Cambridge University Press, Cambridge, UK.
- Bernstein, F., Song, J.-S., & Zheng, X. (2008). Bricks-and-mortar vs. Clicks-and-mortar: an equilibrium analysis. *European Journal of Operational Research*, 187(3), 671–690.
- Bulow, J., Geanakoplos, J., & Klemperer, P. (1985). Multimarket oligopoly: strategic substitutes and complements. *Journal of Political Economy*, 93(3), 488–511.
- Cai, G. (2010). Channel selection and coordination in dual-channel supply chains. *Journal of Retailing*, 86(1), 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(1), 80–96.
- Cao, J., So, K. C., & Yin, S. (2016). Impact of an "online-to-store" channel on demand allocation, pricing and profitability. *European Journal of Operational Research*, 248(1), 234–245.
- 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(1), 40–56.
- Cespedes, F. V., & Corey, E. R. (1990). Managing multiple channels. *Business Horizons*, 33(4), 67–77.
- Chen, Y. C., Fang, S.-C., & Wen, U.-P. (2013). Pricing policies for substitutable products in a supply chain with Internet and traditional channels. *European Journal of Operational Research*, 224(3), 542–551.
- Chen, K.-Y., Kaya, M., & Özer, Ö. (2008). Dual sales channel management with service competition. *Manufacturing and Service Operations Management*, 10(4), 654–675.
- Chen, X., Wang, X., & Jiang, X. (2016). The impact of power structure on the retail service supply chain with an O2O mixed channel. *Journal of the Operational Research Society*, 67(2), 294–301.
- Chiang, W.-Y. K. (2010). Product availability in competitive and cooperative dual-channel distribution with stock-out based substitution. *European Journal of Operational Research*, 200(1), 111–126.
- 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), 1–20.
- Chiang, W.-Y. K., & Monahan, G. E. (2005). Managing inventories in a two-echelon dual-channel supply chain. *European Journal of Operational Research*, 162(2), 325–341.
- van Damme, E., & Hurkens, S. (1996). Commitment-robust equilibria and endogenous timing. *Games and Economic Behavior*, 15(2), 290–311.
- van Damme, E., & Hurkens, S. (1999). Endogenous Stackelberg leadership. *Games and Economic Behavior*, 28(1), 105–129.
- van Damme, E., & Hurkens, S. (2004). Endogenous price leadership. *Games and Economic Behavior*, 47(2), 404–420.
- Dan, B., Liu, C., Xu, G., & Zhang, X. (2014). Pareto improvement strategy for service-based free-riding in a dual-channel supply chain. *Asia-Pacific Journal of Operational Research*, 31(6), 1–27.
- Dan, B., Xu, G., & Liu, C. (2012). Pricing policies in a dual-channel supply chain with retail services. *International Journal of Production Economics*, 139(1), 312–320.
- David, A., & Adida, E. (2015). Competition and coordination in a two-channel supply chain. *Production and Operations Management*, 24(8), 1358–1370.
- Dowrick, S. (1986). von Stackelberg and Cournot duopoly: choosing roles. *RAND Journal of Economics*, 17(2), 251–260.
- Dumrongirai, A., Fan, M., Jain, A., & Moinezhadeh, K. (2008). A supply chain model with direct and retail channels. *European Journal of Operational Research*, 187(3), 691–718.
- Feng, T., & Geunes, J. (2014). Speculation in a two-stage retail supply chain. *IIIE Transactions*, 46(12), 1315–1328.
- Gal-Or, E. (1985). First mover and second mover advantages. *International Economic Review*, 26(3), 649–653.
- Gandolfo, A., & Padellietti, F. (1999). From direct to hybrid marketing: a new IBM go-to-market model. *European Journal of Innovation Management*, 2(3), 109–117.
- Groznik, A., & Heese, H. S. (2010). Supply chain interactions due to store-brand introductions: the impact of retail competition. *European Journal of Operational Research*, 203(3), 575–582.
- Hamilton, J. H., & Slutsky, S. M. (1990). Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. *Games and Economic Behavior*, 2(1), 29–46.
- Hardy, K. G., & Magrath, A. J. (1988). Ten ways for manufacturers to improve distribution management. *Business Horizons*, 31(6), 65–69.
- Hsiao, L., & Chen, Y. J. (2013). The perils of selling online: manufacturer competition, channel conflict, and consumer preferences. *Marketing Letters*, 24(3), 277–292.
- Hu, W., & Li, Y. (2012). Retail service for mixed retail and E-tail channels. *Annals of Operations Research*, 192(1), 151–171.
- Hua, G., Wang, S., & Cheng, T. E. (2010). Price and lead time decisions in dual-channel supply chains. *European Journal of Operational Research*, 205(1), 113–126.
- Huang, W., & Swaminathan, J. M. (2009). Introduction of a second channel: implications for pricing and profits. *European Journal of Operational Research*, 194(1), 258–279.
- IBM. (2008). IBM posts SPEC CPU2006 scores for System x iDataPlex. http://public.dhe.ibm.com/eserver/benchmarks/news/newsblurb_iDataPlex_speccpu_042308.pdf, accessed on March 9, 2016.
- Ingenie, C. A., & Parry, M. E. (2004). *Mathematical models of distribution channels*. Springer.
- Jeuand, A. P., & Shugan, S. M. (1983). Managing channel profits. *Marketing Science*, 2(3), 239–272.
- Khouja, M., & Wang, Y. (2010). The impact of digital channel distribution on the experience goods industry. *European Journal of Operational Research*, 207(1), 481–491.
- Kumoi, Y., & Matsubayashi, N. (2014). Vertical integration with endogenous contract leadership: stability and fair profit allocation. *European Journal of Operational Research*, 238(1), 221–232.
- Kurata, H., Yao, D., & Liu, J. J. (2007). Pricing policies under direct vs. indirect channel competition and national vs. store brand competition. *European Journal of Operational Research*, 180(1), 262–281.
- Lee, Y., Lee, Z., & Larsen, K. R. (2003). Coping with Internet channel conflict. *Communications of the ACM*, 46(7), 137–142.
- Li, Y., Lin, Z., Xu, L., & Swain, A. (2015). Do the electronic books reinforce the dynamics of book supply chain market?—A theoretical analysis. *European Journal of Operational Research*, 245(2), 591–601.
- Liu, Y., Gupta, S., & Zhang, Z. J. (2006). Note on self-restraint as an online entry-deterrence strategy. *Management Science*, 52(11), 1799–1809.
- Lu, Y. (2006). Endogenous timing in a mixed oligopoly with foreign competitors: the linear demand case. *Journal of Economics*, 88(1), 49–68.
- Matsui, K. (2010). Returns policy, new model introduction, and consumer welfare. *International Journal of Production Economics*, 124(2), 299–309.
- Matsui, K. (2012). Strategic upfront marketing channel integration as an entry barrier. *European Journal of Operational Research*, 220(3), 865–875.
- Matsui, K. (2016). Asymmetric product distribution between symmetric manufacturers using dual-channel supply chains. *European Journal of Operational Research*, 248(2), 646–657.
- Matsushima, N., & Mizuno, T. (2013). Vertical separation as a defense against strong suppliers. *European Journal of Operational Research*, 228(1), 208–216.
- McGuire, T., & Staelin, R. (1983). An industry equilibrium analysis of downstream vertical integration. *Marketing Science*, 2(2), 161–191.
- Moon, Y., & Yao, T. (2013). Investment timing for a dual channel supply chain. *European Journal of Industrial Engineering*, 7(2), 148–174.
- Moorthy, K. S., & Fader, P. (1989). Strategic interaction within a channel. In L. Pellegrini, & S. Reddy (Eds.), *Retail and marketing channels* (pp. 84–99). London, UK: Routledge.
- Mukhopadhyay, S. K., Zhu, X., & Yue, X. (2008). Optimal contract design for mixed channels under information asymmetry. *Production and Operations Management*, 17(6), 641–650.
- Ohmura, S., & Matsuo, H. (2016). The effect of risk aversion on distribution channel contracts: implications for return policies. *International Journal of Production Economics*, 176(1), 29–40.
- Parlar, M., & Weng, Z. K. (2006). Coordinating pricing and production decisions in the presence of price competition. *European Journal of Operational Research*, 170(1), 211–227.
- Rodríguez, B., & Aydin, G. (2015). Pricing and assortment decisions for a manufacturer selling through dual channels. *European Journal of Operational Research*, 242(3), 901–909.
- Ryan, J. K., Sun, D., & Zhao, X. (2012). Competition and coordination in online marketplaces. *Production and Operations Management*, 21(6), 997–1014.
- SeyedEsfahani, M. M., Biazaran, M., & Gharakhani, M. (2011). A game theoretic approach to coordinate pricing and vertical co-op advertising in manufacturer–retailer supply chains. *European Journal of Operational Research*, 211(2), 263–273.
- Shy, O. (1996). *Industrial organization: Theory and applications*. Cambridge, MA: MIT Press.
- Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *RAND Journal of Economics*, 15(4), 546–554.
- Sun, J., & Debo, L. (2014). Sustaining long-term supply chain partnerships using price-only contracts. *European Journal of Operational Research*, 233(3), 557–565.
- Tsay, A., & Agrawal, N. (2004a). Channel conflict and coordination in the e-commerce age. *Production and Operations Management*, 13(1), 93–110.
- Tsay, A., & Agrawal, N. (2004b). Modeling conflict and coordination in multi-channel distribution systems: a review. In D. Simchi-Levi, S. D. Wu, & Z. M. Shen (Eds.), *Handbook of quantitative supply chain analysis: Modeling in the e-business era*. international series in operations research and management science (pp. 557–606). Norwell, MA: Kluwer Academic Publishers.
- Wang, Y., Niu, B., & Guo, P. (2013). On the advantage of quantity leadership when outsourcing production to a competitive contract manufacturer. *Production and Operations Management*, 22(1), 104–119.
- Wang, Y., Wallace, S. W., Shen, B., & Choi, T. M. (2015). Service supply chain management: a review of operational models. *European Journal of Operational Research*, 247(3), 685–698.
- Watts, D., & Bachmaier, M. (2012). Implementing an IBM System x iDataPlex Solution. *IBM Redbooks*. Springville, UT: Vervante.
- Xia, Y., & Gilbert, S. M. (2007). Strategic interactions between channel structure and demand enhancing services. *European Journal of Operational Research*, 181(1), 252–265.
- Xiao, T., Choi, T. M., & Cheng, T. C. E. (2014). Product variety and channel structure strategy for a retailer-Stackelberg supply chain. *European Journal of Operational Research*, 233(1), 114–124.
- Xie, J., & Wei, J. (2009). Coordinating advertising and pricing in a manufacturer–retailer channel. *European Journal of Operational Research*, 197(2), 785–791.
- Xiong, Y., Yan, W., Fernandes, K., Xiong, Z.-K., & Guo, N. (2012). Bricks vs. Clicks: the impact of manufacturer encroachment with a dealer leasing and selling of durable goods. *European Journal of Operational Research*, 217(1), 75–83.
- Yan, R., & Pei, Z. (2009). Retail services and firm profit in a dual-channel market. *Journal of Retailing and Consumer Services*, 16(4), 306–314.
- Yao, D., & Liu, J. (2003). Channel redistribution with direct selling. *European Journal of Operational Research*, 144(3), 646–658.
- Yao, D., Yue, X., Wang, X., & Liu, J. (2005). The impact of information sharing on a returns policy with the addition of a direct channel. *International Journal of Production Economics*, 97(2), 196–209.
- Zehr, D. (2008). Dell to close all U.S. kiosks as it moves PCs into stores. *Austin American Statesman*, (January 31) D1.
- Zhou, Y. W., & Cao, Z. H. (2013). Equilibrium structures of two supply chains with price and displayed-quantity competition. *Journal of the Operational Research Society*, 65(10), 1544–1554.