Optimal bargaining timing of a wholesale price for a manufacturer with a retailer in a dual-channel supply chain

Matsui, Kenji

(Citation)
European Journal of Operational Research,287(1):225-236

(Issue Date)
2020-11-16

(Resource Type)
journal article

(Version)
Version of Record

European Journal of Operational Research 287 (2020) 225–236

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Decision Support

Optimal bargaining timing of a wholesale price for a manufacturer with a retailer in a dual-channel supply chain

Kenji Matsui

Graduate School of Business Administration, Kobe University, 2-1, Rokkodaicho, Nada-ku, Kobe, Japan

ARTICLE INFO

Article history:
Received 14 September 2019
Accepted 5 May 2020
Available online 18 May 2020

Keywords:
Pricing
Dual-channel supply chain
Bargaining
Decision timing
Game theory

ABSTRACT

This paper explores the optimal timing of when a manufacturer should bargain a wholesale price with a retailer in a dual-channel supply chain that consists of the manufacturer and the retailer. To address the problem, we construct a game-theoretic model in which the manufacturer can sell products directly to consumers (direct channel) and through the retailer (retail channel). We also assume that the manufacturer determines the direct price in the direct channel and the retailer determines the retail price in the retail channel, while the manufacturer and the retailer bargain the wholesale price. The analytical solution of our model yields the following clear-cut result: the manufacturer achieves its highest profit by bargaining the wholesale price earlier than determining the direct price. Moreover, we show that this result holds even if the control variables determined by the two supply chain members at the retail market level are not prices but quantities, proving the robustness of the result. Consequently, the result provides the managerial implication usable for practical decision-making that if a manufacturer using a dual-channel supply chain can choose the timing to negotiate the wholesale price with a retailer, the manufacturer should have the opportunity before determining the direct price or the quantity of products sold directly to consumers.

1. Introduction

The rapid advancement of information and communication technology in recent decades has induced manufacturers to redesign their sales and supply chain distribution strategies. Specifically, a significant growth in online sales based on e-commerce has encouraged manufacturers to introduce their own online channels to sell products directly to end-consumers. To cover a wider range of customers, several leading manufacturers have adopted dual-channel supply chain systems that combine a traditional retail store channel and a direct channel. Such manufacturers operate in a range of industries including consumer electronics (e.g., Apple, Dell, and Sony), fashion and apparel (e.g., Adidas, Coach, and Nike), and food and beverages (e.g., Budweiser Beer and Coca-Cola) (Yang, Luo & Zhang, 2018).

Particularly in a dual-channel environment, an upstream manufacturer must carefully maintain its relationship with a downstream retailer because channel conflicts that hinder total supply chain optimization can arise between the manufacturer and the retailer who compete in the end-consumer market. As a more specific problem, a manufacturer needs to pay attention to its negotiation opportunities with a downstream retailer when adopting a dual-channel supply chain system. Indeed, many cases of wholesale price bargaining can be found in various industries including raw materials, manufacturing, services, electricity, and health care (Nagarajan & Sošić, 2008). In addition, the current power shift from upstream to downstream along supply channels allows downstream retailers to influence their purchase prices (Tagashira & Minami, 2019). Several huge retailers such as Carrefour, Tesco, and Wal-Mart often have a stronger competitive position than upstream suppliers (Ertek & Griffin, 2002). There are also cases in which such mega-retailers demand a margin on a product from a supplier before the supplier determines the wholesale price (Krishnan & Soni, 1997). Such a change in the price leadership indicates a power shift from suppliers to retailers.

Given the growing importance of negotiations between upstream and downstream channel members for successful supply chain management, this paper focuses on the bargaining on the wholesale price in a dual-channel environment. Whereas the ideal level of the wholesale price bargained by a supplier and a buyer has been explored in the academic literature, the ideal timing for supply chain members to bargain the price has rarely been examined even though this issue is of practical importance. Given this research stream, this paper specifically explores the problem concerning when a manufacturer should bargain a wholesale price

E-mail address: kmatsui@b.kobe-u.ac.jp

https://doi.org/10.1016/j.ejor.2020.05.004
0377-2217/

with a retailer in a dual-channel supply chain that consists of the manufacturer and the retailer. To address this problem, we construct a game-theoretic model in which the manufacturer can sell products directly to consumers (direct channel) and through the retailer (retail channel). We also assume that the manufacturer determines the direct price in the direct channel and the retailer determines the retail price in the retail channel, while the manufacturer and the retailer bargain the wholesale price. The analytical solution of our model yields the following clear-cut result: i.e., the manufacturer achieves its highest profit by bargaining the wholesale price earlier than determining the direct price. Moreover, we show that this result holds even if the control variables determined by the two supply chain members at the retail market level are not prices but quantities, proving the robustness of the result. Consequently, the result provides the managerial implication usable for practical decision-making that if a manufacturer using a dual-channel supply chain can choose the timing to negotiate the wholesale price with a retailer, the manufacturer should have the opportunity before determining the direct price or the quantity of products sold directly to consumers.

The logic behind the above outcome is laid out below. Suppose that the manufacturer bargains the wholesale price in the retail channel before determining its direct price in the direct channel. Then, even if the bargaining breaks down between the manufacturer and the retailer, the manufacturer will be able to flexibly control the direct price after the breakdown of the bargaining because the manufacturer has not committed to a particular direct price before the bargaining in this case. This flexible control of the direct price enhances the point of disagreement of the manufacturer in the bargaining and hence enables the manufacturer to gain a larger allocation of the surplus from the bargaining. Suppose, in contrast, that the manufacturer bargains the wholesale price after or simultaneously with determining the direct price. If the negotiation breaks down in this case, the manufacturer will become unable to flexibly control the direct price because the manufacturer has committed to a particular direct price and thus cannot help selling at the precommitted direct price. This precommitment deteriorates the manufacturer's disagreement point in the bargaining, reducing the surplus allocated to the manufacturer. As a result, we derive the result that the manufacturer earns a higher profit by bargaining the wholesale price before determining its direct price, which is the central message of this paper.

This logic also applies to the case in which the control variable is not the price but the quantity. Suppose that the manufacturer determines the quantity in the direct channel under competition with the retailer, which determines the quantity in the retail channel. Then, if bargaining the wholesale price before determining its quantity supplied from the direct channel, the manufacturer can flexibly control the quantity in the direct channel even if the negotiation breaks down. Consequently, the same managerial implication is derived in the quantity-setting scenario. It should be noted whereas the logic behind our results is clearly laid out, there has been no previous research that properly formulates a rigorous analytical model that describes this timing problem and derives a robust answer to it.

We overview several business cases in which the bargaining of wholesale conditions has significantly influenced the bargaining parties' profitability. First, we consider the case of Dell, a manufacturer currently using dual-channel supply chains. Dell began using a direct sales channel early on, before Internet usage became common among households. As Dell originally used only a direct channel, with retail channel sales launched much later, the company established the direct price of its personal computers (PCs) in the direct channel before bargaining on the wholesale price in the retail channel. Indeed, Dell focused solely on direct sales for a long period: i.e., after setting up its business in 1984, it did not fully launch retail channel sales until towards the end of the 2000s. However, it should be noted that from 1990 to 1994, Dell temporarily sold its products through a limited number of retailers, including CompUSA, Circuit City, Price Club, and Sam's Club, an experience that Michael Dell evaluates as being unsuccessful. Dell and Fredman (1999) state that even though PCs sold quite well through the retail channel, these retail sales barely contributed to overall profitability. The low profit margins on the business led Dell to completely pull PCs out from the retail channel in 1994. This low margin in the retail channel meant that Dell was unable to sell products at advantageous wholesale terms through the selected large retailers. These retailers could demand substantial margins from Dell because sales of PCs from existing manufacturers through retail channels dominated sales from direct channels in the early in the 1990s. In contrast, in the late 2000s, when sales of PCs through direct channels became more prevalent, it became easier for Dell to obtain advantageous wholesale terms from retailers and to launch retail channel sales because the retailers were threatened by the increasing share of manufacturers' direct sales. This case indicates that determining the timing for negotiating wholesale terms and conditions with a retailer is a crucial problem for a manufacturer using a dual-channel supply chain.

Negotiations of wholesale terms are also conducted between book publishers and resellers, as a number of publishers currently sell books in both printed and electronic forms via online and offline channels. A well-known case is the intense negotiation on transactional terms for books between Hachette Book Group and Amazon, which took place over seven months in 2014.[1] Hachette is the fourth-largest publisher selling books through a dual-channel supply chain in the United States. In April 2014, Amazon demanded control over prices of Hachette titles as a condition for a new revised contract with the publisher. The condition would allow Amazon to lower the prices of most e-books significantly to a standard price of $9.99; thus, Hachette refused to comply with this demand. In response to Hachette's refusal, Amazon engaged in bullying tactics, as shown by prolonged delivery times, several titles missing from search results, and the inability to preorder upcoming titles, which had a significantly negative impact on the publisher's sales. Then, in July 2014, Amazon proposed a compromise plan under which 100% of e-book profits would be paid to authors. However, Hachette rejected this proposal. Finally, in November 2014, Hachette and Amazon reached an agreement that the publisher would retain control over price setting for its e-books, but that it would be offered financial incentives from Amazon to reduce prices. Again, this case suggests that the bargaining process and timing of wholesale terms with a large-scale reseller is an important practical problem for book publishers with dual channels.[2]

Another prominent manufacturer is Nike, which uses the direct channel of Nike.com to sell sports products. The company began to sell its products through Amazon in the summer of 2017 and bargained its wholesale terms with Amazon, which functioned as a reseller. However, Amazon put little effort into reselling the products purchased directly from Nike as the first-party supplier because the Nike-branded products purchased from third-party resellers were more profitable and appealing to the platform provider (Safdar & Mattioli, 2019). As a result, after two years of selling through Amazon, Nike announced that the company would

[1] Media sources, including the *Wall Street Journal*, reported extensively on this bargaining process during 2014, and a detailed summary is provided by Sternad (2019).

[2] Focusing on the timing of publication, Li et al. (2015b) investigate the problem facing a publisher in choosing the launch times of printed and electronic books. Specifically, Amazon provides two options to publishers, a "simultaneous launch" of printed and electronic books, or a "lag launch," in which the electronic version is launched only after the launch of the printed version. The choice of the launch timing is a practical problem for a publisher under dual-channel environments.

pull out from Amazon in November 2019. This case indicates that even a prominent manufacturer in a dual-channel environment faces difficulties in obtaining advantageous transactional terms and adequate sales efforts for products from a dominant retailer.

Finally, suppliers encroaching on retailing operations with a direct channel naturally trigger defensive reactions from retailers. In this regard, Fortune reports on letters sent by Home Depot, a retail chain dealing in DIY products, to more than 1000 of its suppliers in May 1999 (Brooker, 1999).[3] In effect, Home Depot implied that it might stop selling products of the suppliers if they sold products through their own e commerce direct channels.

All of the real-life cases above indicate that when and how a manufacturer selling products through dual-channel supply chains should bargain its wholesale price with a retailer has become a crucial practical problem. The motivation for this paper is the bargaining difficulties confronting manufacturers given the change in the current dual-channel environments, as not only traditional retail companies but also platform businesses are rapidly growing in power as retail intermediaries. Given that the bargaining of the wholesale prices as well as the dual-channel supply chain management have become important issues, this paper not only contributes to the academic literature, but also provides useful insights into business practices by addressing both of these issues.

The rest of the paper is organized as follows. Section 2 provides an overview of the literature relating to game-theoretic research on dual-channel supply chain management and bargaining. In Section 3, we describe the assumptions and settings of our model. Section 4 derives the results concerning when the manufacturer should bargain the wholesale price with the retailer. Section 5 considers another alternative scenario in which the control variable is not sales prices but quantities. In Section 6, we extend the model by applying the framework of an observable delay game. The last section concludes the paper.

2. Literature review

Currently, a large number of OR/MS (operational research/management science) studies have investigated dual-channel supply chain management issues under various business environments using game theory (e.g., Alawneh & Zhang, 2018; Arya, Mittendorf & Sappington, 2007; Batarfi, Jaber & Zanoni, 2016; Cai, 2010; Cai, Zhang & Zhang, 2009; Cattani, Gilland, Heese & Swaminathan, 2006; Chai, Yan, Li, Palmer & Huang, 2020; Chen, Zhang & Sun, 2012; Chen, Fang & Wen, 2013; Chen, Liang, Yao & Sun, 2017; Chen Pun & Li, 2018b; Chiang, 2010; Chiang & Monahan, 2005; Chiang, Chhajed & Hess, 2003; Cui, 2019; Dumrongsiri, Fan, Jain & Moinzadeh, 2008; Esenduran, Lu & Swaminathan, 2020; Groznik & Heese, 2010; Guan, Gurnani, Geng & Luo, 2019; Guan, Liu, Chen & Wang, 2020; Ha, Long & Nasiry, 2016; Hao & Jiang, 2019; He, Gan & Yuan, 2019; He, Huang & Li, 2019; Hua, Wang & Cheng, 2010; Huang & Swaminathan, 2009; Huang, Guan & Xiao, 2018; Kurata, Yao & Liu, 2007; Lan, Li & Papier, 2018; Li & Jiang, 2019; Li, Gilbert & Lai, 2014, 2015a; Li, Xie, Zhao & Tang, 2016; Lin, Zhou & Hou, 2020; Matsui, 2016, 2017; Modak & Kelle, 2019; Perlman, Ozinci & Westrich, 2019; Pu, Sun & Han, 2019; Qing, Deng & Wang, 2017; Rodríguez & Aydın, 2015; Song, Tang & Zhao, 2019; Tsay & Agrawal, 2004; Wang, Yan, Du & Zhao, 2020; Wei, Asian, Ertek & Hu, 2019; Xia & Niu, 2019; Xiao & Shi, 2016; Xiong, Yan, Fernandes, Xiong & Guo, 2012; Xu, Qi & Bai, 2018; Yan, Zhao & Lan, 2017; Yan, Xiong, Chu, Li & Xiong, 2018; Yan, Zhao & Chen, 2018; Yan, Zhao & Liu, 2018; Yang et al., 2018; Yao & Liu, 2003; Yu, Cheong & Sun, 2017; Yu, Sun & Guo, 2019; Yue & Liu, 2006; Zennyo, 2020; Zhang & Zhang, 2020; Zhang, Li, Zhang & Dai, 2019a; Zhang, Tang, Zaccour & Zhang, 2019b; Zhang, Zhang & Zhu, 2019c; Zheng, Yu, Jin & Xia, 2019; Zhou, Zhao & Wang, 2019). Chiang et al. (2003) investigate the optimal channel strategy for a manufacturer on whether the manufacturer sells its products directly using the Internet, only via a retailer, or by using a mix of both channels. They show that even if no sales occur in the direct Internet channel, the direct channel improves the profitability of the manufacturer because it mitigates the inefficient double marginalization that potentially arises in the retail channel. This result indicates that the introduction of an Internet channel is worthwhile for both manufacturer and retailer to improve channel efficiency. Arya et al. (2007) demonstrate that supplier encroachment on retail operations with direct sales can benefit a retailer even when the encroachment engenders no synergies, product differentiation, or price discrimination. The encroachment induces the supplier to undercut the wholesale price to prevent an excessive fall in the retailer's demand for the product. The lower wholesale price and increased downstream competition mitigate double marginalization, thereby promoting efficiency gains that can attain Pareto improvements. Li et al. (2014) investigate the influence of supplier encroachment under an uncertain environment where a reseller is better informed than the supplier. They find that the supplier's launch of a direct channel can lead to costly signaling behavior on the part of the reseller, as the reseller diminishes the order quantity when the market size is small. Such a downward order distortion can amplify double marginalization. As a result, supplier encroachment can result in deterioration of its own profitability, particularly when the reseller has a significant efficiency advantage in the selling process and there is a high probability that market size is small. Ha et al. (2016) study a supply chain with manufacturer encroachment in which product quality is endogenously determined and customers' preferences for quality are heterogeneous. They find that when the manufacturer can flexibly adjust quality, encroachment makes the retailer worse off in a wide range of circumstances. In addition, they show that a manufacturer offering differentiated products through two channels prefers to sell its high-quality product through the direct channel. They conclude that quality differentiation does not always benefit either manufacturer or retailer, contrary to conventional wisdom. Alawneh and Zhang (2018) investigate the inventory policy in a dual-channel warehouse, which is divided into the area for fulfilling online orders and the area for fulfilling offline orders and storing products. They develop a model for inventory of multiple items that considers the constraints of warehouse capacity, lead time uncertainty, and demand to provide a solution method. They show that their proposing inventory policy adds flexibility to the dual-channel warehouse and supply chain. Li, Zhang, Chiu, Liu and Sethi (2019b) investigate the issue of channel sharing between a manufacturer and a retailer that compose a dual-channel supply chain. They show that the retailer cannot preclude the manufacturer from entering an online market by refusing channel sharing when the diseconomy of direct selling is relatively low. They also show that when the diseconomy is high, the retailer's refusal is effective if the product quality of the store brand is sufficiently low. Assuming both an endogenous product quality decision and asymmetric demand information, Zhang et al. (2019a) examine the effects of manufacturer encroachment on quality and profits for supply chain members. Manufacturer encroachment results in a signaling game, whereby the retailer distorts the order quantity downward when market size is small. They show that whereas

[3] Brooker (1999) reports on the letter as follows. "It is important for you to be aware of Home Depot's current position on its' [sic] vendors competing with the company via e-commerce direct to consumer distribution. We think it is short-sighted for vendors to ignore the added value that our retail stores contribute to the sales of their products. ... We recognize that a vendor has the right to sell through whatever distribution channels it desires. However, we too have the right to be selective in regard to the vendors we select and we trust that you can understand that a company may be hesitant to do business with its competitors."

Table 1
Summary of papers examining pricing timing decisions in dual-channel supply chains.

Paper	Key aspects	Major findings
Matsui (2017)	An observable delay game, which is called a timing game, is adopted to derive a subgame perfect equilibrium identifying the optimal timing of decisions made by a manufacturer and a retailer.	A manufacturer can maximize its profit by setting the direct retail price before setting the wholesale price in an indirect channel.
Matsui (2018)	An observable delay game is adopted to derive a subgame perfect equilibrium identifying the optimal timing of decisions made by a manufacturer and two retailers.	The two retailers constituting a multi-channel supply chain maximize their respective profits by sequentially setting their prices, but not simultaneously.
Chen et al. (2019)	A dual-channel supply chain that consists of an original equipment manufacturer (OEM) and an original design manufacturer (ODM) is considered. How the desirable pricing timing depends on the competition decision is examined.	If the OEM is a risk lover, the OEM is less willing to move later as the wholesale price increases, which is a result that differs from classical Bertrand competition.
Li et al. (2019a)	The optimal timings of service provision as well as pricing in a dual-channel with the presence of showrooming effect are investigated.	The showrooming effect allows the supply chain to benefit the most when a retailer determines its service level at last. The late service provision enables the supply chain to generate a higher profit as the showrooming effect becomes greater.
Liu and Ke (2020)	A manufacturer and an e-commerce platform as a retail intermediary are considered. How the optimal decision timing for supply chain members to set decision variables differs between an agency contract and a wholesale contract is examined.	The e-commerce platform achieves maximum profit when its rival is the leader, so does the manufacturer. The e-commerce platform should not set its retail price early in any case.
Yan et al. (2020)	An e-commerce platform that not only works as a retail intermediary but also provides credit to their upstream suppliers is considered.	The e-retailer achieves the first-mover advantage by announcing pricing decisions earlier than the supplier.

the manufacturer always benefits from encroachment, the retailer benefits only when the manufacturer has an intermediate direct selling cost because, in this situation, the retailer can prevent the manufacturer from selling directly. The present paper first aims to contribute to this stream of research on dual-channel supply chain management.

Moreover, there is a recent research stream that applies the bargaining framework developed in game theory to supply chain management issues (e.g., Feng & Lu, 2012; Feng, Lai & Lu, 2015; Guo & Iyer, 2013; Lovejoy, 2010; Modak & Kelle, 2019; Nagarajan & Bassok, 2008; Qing et al., 2017; Wang, Niu, Guo & Song, 2020; Yang et al., 2018). Lovejoy (2010) suggests that because a Stackelberg model framework, in which either a supplier or a buyer exerts full bargaining power to determine the parameters involved in a take-it-or-leave-it contract, is inconsistent with various empirical evidence, a bargaining framework is often more realistic, in which each firm can mutually exert influence in determining a contract. Given this argument, we consider a bargaining model of the wholesale price instead of a simple Stackelberg model. Qing et al. (2017) address the problem of capacity allocation by a monopolistic supplier under bargaining with a manufacturer. The supplier is assumed to allocate the capacity of a key element to its external channel via a manufacturer, its internal channel, or a mix of both channels. They find that the supplier shares more capacity as its own bargaining power increases, whereas the manufacturer shares less capacity as its own bargaining power increases, indicating that the change in bargaining power engenders opposite effects on their capacities shared in the dual channel. While Qing et al. (2017) investigate the bargaining of capacity allocation between a supplier and a buyer, the present paper focuses on the bargaining of the wholesale price. Yang et al. (2018) examine the effect of nonlinear pricing on the phenomenon of supplier encroachment in a dual-channel supply chain that consists of a retailer and a supplier. They consider the situation in which the firms bilaterally negotiate the wholesale price and the quantity, showing that nonlinear pricing with the use of revenue-sharing coordinates the supply chain under the presence of encroachment. In addition, their result indicates that the retailer always suffers from the possibility of encroachment even when the supplier introduces an inactive direct channel. Modak and Kelle (2019) apply the framework of Nash bargaining to the problem of dual-channel supply chain management under stochastic demand that depends on price and delivery time. Considering both centralized and decentralized decision systems under unknown distribution functions of random variables, they investigate the influence of the delivery time and channel preference of customers on the optimal operation. Among the previous papers in this research strand, Qing et al. (2017), Yang et al. (2018), and Modak and Kelle (2019) are especially closely related to this paper, because they consider a dual-channel supply chain environment to investigate the bargaining problem.

Finally, the number of OR papers that investigate the desirable timing of decisions made by supply chain members is increasing gradually (e.g., Chen, Chen & Li, 2018a; Chen, Yan, Ma & Yang, 2019; Li & Chen, 2018; Li, Li & Sun, 2019a; Li, Zhang & Liu,2019c; Liu & Ke, 2020; Matsui, 2017, 2018; Yan, Liu, Xu & He, 2020). Considering a Stackelberg game in which the manufacturer is the leader that unilaterally dictates the wholesale price, Matsui (2017) explores the timing problem concerning when the manufacturer using a dual-channel supply chain should determine the wholesale price and direct price, demonstrating that the manufacturer should set the direct price before the wholesale price. Differing from Matsui (2017), the assumption in this paper is that the wholesale price is not dictated by the manufacturer but determined through bargaining between the manufacturer and the retailer. This setting leads to different conclusions between this paper and the previous work. Namely, we derive the result that a manufacturer should set its direct price *after* a wholesale price is determined through bargaining, which is the opposite to Matsui's (2017) result that a manufacturer should set its direct price *before* a wholesale price is set. In other words, if the process of the formation of the wholesale price is changed from the Stackelberg game to the Nash bargaining game, Matsui's (2017) result is reversed completely. Chen et al. (2019) consider a dual-channel supply chain that consists of an original equipment manufacturer (OEM) and an original design manufacturer (ODM). They explore whether the OEM and the ODM who compete in a downstream product market should cooperate and how the competition decision affects the desirable pricing timing. They establish a multi-stage model describing competition between the OEM and the ODM, drawing managerial implications. Li et al. (2019a) explore how the timing of service provision by a retailer affects the equilibrium profits of the retailer and the manufacturer in a dual-channel supply chain. They show

Table 2
Notation.

w	wholesale price
p_R	retail price
p_D	direct price
q_R	quantity in the retail channel
q_D	quantity in the direct channel
c_R	marginal cost of supplying a product from the retail channel
c_D	marginal cost of supplying a product from the direct channel
a	intercept of the inverse demand function
b	slope of the inverse demand function
θ	substitutability of products from the two channels ($0 < \theta < 1$)
γ	bargaining power of the manufacturer ($0 < \gamma < 1$)
R	subscript denoting the retail channel
D	subscript denoting the direct channel
Π	profit of the manufacturer
π	profit of the retailer
$\bar{\Pi}$	disagreement point of the manufacturer in the bargaining
$\bar{\pi}$	disagreement point of the retailer in the bargaining

that the showrooming effect allows the supply chain to benefit the most when a retailer determines its service level as late as possible in the process. Furthermore, they show that the ex-post service effort strategy enables the supply chain to generate a higher profit as the showrooming effect becomes greater. Overall, the results of the above studies indicate that the order of moves of channel members significantly affects the economic outcomes achieved in supply chains. The current paper also contributes to this stream of research by investigating the optimal timing of a manufacturer's decision.

Table 1 summarizes the key aspects and findings of previous papers that investigate the desirable timing of decisions for firms constituting dual-channel supply chains. The table suggests that all previous papers consider the Stackelberg game as the determination process of the wholesale price and do not consider the Nash bargaining game. Even though the timing of bargaining the wholesale price is a crucial practical issue for general manufacturers, the above overview indicates that no previous research investigates the ideal timing of the bargaining in a dual-channel supply chain environment. Hence, it is worth highlighting that this paper is the first to address the issue, thereby contributing to the OR literature.

3. Model

We present the assumptions and settings used for our model in this section. Table 2 summarizes the notations in the model and Fig. 1 illustrates the supply chain structure assumed in the model. We assume that a manufacturer produces a product and sells it to end-consumers both directly and via a retailer. As shown in Fig. 1, we refer to direct selling from the manufacturer as the direct channel and selling via the retailer as the retail channel. The marginal cost for the manufacturer to sell the product through the direct channel and through the retail channel is denoted by c_D and c_R, respectively. We assume that $c_D > c_R$, following the literature on manufacturers encroaching on a supply chain (e.g., Arya et al., 2007; Ha et al., 2016; Li et al., 2014). The manufacturer determines the sales price, p_D, in the direct channel. Meanwhile, the manufacturer and the retailer bargain the wholesale price of the product, w, in the retail channel. After observing the wholesale price determined in the bargaining, the retailer determines the retail price, p_R, reselling the product. We assume that the retailer determines the retail price only after the retailer observes the wholesale price, which is a typical assumption in previous supply chain models (e.g., Cai, 2010; Li et al., 2019a; Xiong et al., 2012). Throughout the paper, we call p_R and p_D the retail price and the direct price, respectively.

We assume the following inverse demand function forms of the two distribution channels:[4]

$$\begin{aligned} p_R &= a - b(q_R + \theta q_D) \\ p_D &= a - b(q_D + \theta q_R), \end{aligned} \tag{1}$$

where q_R and q_D denote the quantity sold from the retail channel and from the direct channel, respectively. The positive parameter $\theta \in (0, 1)$ is the degree of substitution of the products between the two channels. Therefore, the products supplied from the two channels become more differentiated as θ decreases and approaches zero. a is a positive constant greater than c_D that captures the market size. b is a positive constant measuring the price sensitivity to the demand.

We use the linear demand function represented by Eq. (1) because previous OR models on supply chain management employ linear demand functions (e.g., Cai, 2010; Li et al., 2019a; Yang et al., 2018). This form of the demand function means that the products supplied from the two channels are differentiated in terms of variety, but not quality. Namely, the function indicates that the value of the product supplied from the direct channel is not necessarily lower than that from the retail channel because channel preference varies across consumers. In reality, some consumers dislike offline shopping in retail stores because of shopping costs or inconveniences in stores such as queuing, while other consumers dislike online shopping because they want to see the merchandise, receive service from store staff and bring their purchases home immediately rather than paying shipping costs and enduring delivery time. Also because of the variety of consumers' channel preference, we employ the form of the demand function in Eq. (1).

We restate the inverse demand functions in Eq. (1) as the following demand functions:

$$\begin{aligned} q_R &= ((1-\theta)a - p_R + \theta p_D)/(b(1-\theta^2)) \\ q_D &= ((1-\theta)a - p_D + \theta p_R)/(b(1-\theta^2)). \end{aligned} \tag{2}$$

Using Eq. (2), we state manufacturer's and retailer's profits, Π and π, as:

$$\begin{aligned} \Pi &= (w - c_R)q_R + (p_D - c_D)q_D \\ &= (w - c_R)((1-\theta)a - p_R + \theta p_D)/\big(b\big(1-\theta^2\big)\big) \\ &\quad + (p_D - c_D)((1-\theta)a - p_D + \theta p_R)/\big(b\big(1-\theta^2\big)\big) \end{aligned} \tag{3}$$

$$\begin{aligned} \pi &= (p_R - w)q_R \\ &= (p_R - w)((1-\theta)a - p_R + \theta p_D)/\big(b\big(1-\theta^2\big)\big). \end{aligned} \tag{4}$$

Using Eqs. (3) and (4), we formulate the bargaining problem. Specifically, we formulate the problem as Nash bargaining, which is a common process of determining profit allocation in a supply chain (e.g., Modak & Kelle, 2019; Qing et al., 2017; Yang et al., 2018).[5] In Nash bargaining, there are generally two possible negotiation outcomes that should be considered. The first outcome in

[4] We derive the linear-form demand function of Eq. (1) if the utility function of a consumer denoted by U is specified as: $U = a(q_R + q_D) - b(q_R^2 + q_D^2 + 2\theta q_R q_D)/2$. Given this function, consumer surplus denoted by S is described as: $S = U - (p_R q_R + p_D q_D) = a(q_R + q_D) - b(q_R^2 + q_D^2 + 2\theta q_R q_D)/2 - p_R q_R - p_D q_D$. The consumer maximizes S by solving $\partial S/\partial q_R = \partial S/\partial q_D = 0$, which yields Eq. (1). See Ingene and Parry (2004, Chapter 11) for more detail about the relationship between the utility function and the demand function.

[5] While the Nash bargaining solution was originally developed in cooperative game theory, the solution is interpreted as the subgame perfect Nash equilibrium in a sequential decision-making problem to allocate a fixed payoff between players in a noncooperative game (Rubinstein, 1982). The framework connecting cooperative and noncooperartive game theories is called the Nash program. Accordingly, we can interpret the Nash solution of bargaining on the wholesale price in our model as the equilibrium of a noncooperative game, in which the manufacturer and the retailer choose their best response strategies regarding the decision of the wholesale price, respectively.

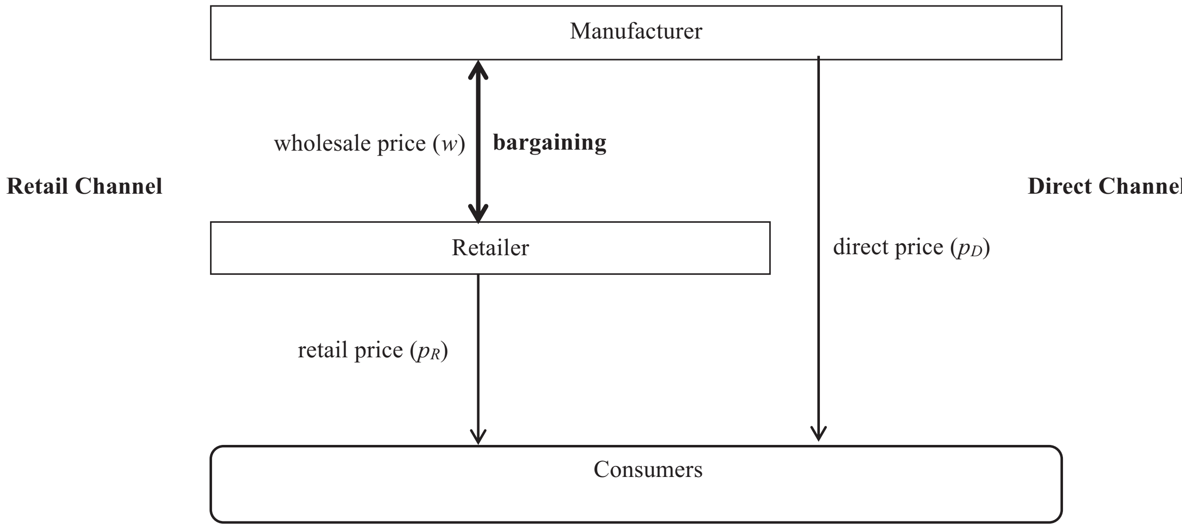

Fig. 1. Supply chain structure.

the context of our model is that the manufacturer and the retailer reach an agreement that the manufacturer sells products to the retailer, while the second one is that they fail to reach such an agreement and no product is sold through the retailer. Accordingly, let Π and π respectively denote the profits of the manufacturer and the retailer under the agreement, and $\bar{\Pi}$ and $\bar{\pi}$ respectively denote the disagreement points for the manufacturer and the retailer, which are profits when the negotiation breaks down. $\bar{\Pi}$ varies according to when the wholesale price is bargained between the manufacturer and the retailer. By contrast, $\bar{\pi}=0$ because no alternative manufacturer exists in our single dual-channel supply chain model.

The objective function that is maximized through the bargaining is stated as:

$$\left(\Pi-\bar{\Pi}\right)^{\gamma}(\pi-\bar{\pi})^{1-\gamma}. \tag{5}$$

Eq. (5) is called the Nash product, which is the objective function of the problem of Nash bargaining (e.g., Nash, 1950). $\gamma \in (0, 1)$ denotes the bargaining power of the manufacturer. Because γ and $1-\gamma$ are interpreted as the bargaining power of the manufacturer and of the retailer, respectively, the power of the manufacturer is higher and the power of the retailer is lower as γ increases, and vice versa. The wholesale price, w, is chosen so that it maximizes the Nash product of Eq. (5).

We assume that exogenous parameters satisfy the following inequality:

$$\gamma > 1-\sqrt{2\left(1-\theta^2\right)/\left(2-\theta^2\right)}. \tag{6}$$

Inequality (6) guarantees that the manufacturer distributes products through both channels in equilibrium.[6] The intuition behind the meaning of this inequality is as follows. If γ is sufficiently small so that the value is almost equal to 0, the bargaining induces the retailer to extract most of the profit generated from the sales through the retail channel, leaving little profit with the manufacturer. In addition, because the manufacturer and the retailer compete to sell products in the dual-channel supply chain, the demand for the product sold from the direct channel directly by the manufacturer falls substantially if the product from the retail channel sells well. In this situation, the manufacturer can increase its own profit by not selling products through the retail channel and instead, dedicating these sales to direct selling through the direct channel. In summary, if Inequality (6) was not met, the manufacturer would lose its incentive to sell products in the retail channel. If the manufacturer ceased to supply products through the retail channel, our model would become meaningless because the wholesale price, which is the most important control variable in our model, disappears. Therefore, we impose Inequality (6) as the assumption that the manufacturer is sufficiently powerful so that it has an incentive to supply products through both channels.

4. Basic results

Based on the settings in the preceding section, we derive the manufacturer's and retailer's payoffs by the sequence of their decisions. Because the aim of this paper is to determine the desirable timing for the manufacturer to bargain the wholesale price, we consider the following five sequences of pricing, which are denoted by Sequences I, II, III, IV, and V. In Sequence I, the manufacturer and the retailer bargain w first, the manufacturer determines p_D second, and the retailer determines p_R third. In Sequence II, the manufacturer determines p_D and bargains w with the retailer first, and the retailer determines p_R second. In Sequence III, the manufacturer determines p_D first, the manufacturer and the retailer bargain w second, and the retailer determines p_R third. In Sequence IV, the manufacturer and the retailer bargain w first, the retailer determines p_R second, and the manufacturer determines p_D third. In Sequence V, the manufacturer and the retailer bargain w first, and the retailer and the manufacturer respectively determine p_R and p_D second. The respective timelines of these five sequences are illustrated in Fig. 2. Hereafter, we attach superscript I, II, III, IV, or V to the equilibrium variables and payoffs to distinguish the sequences. The next lemma presents the equilibrium results by sequence. (All proofs are in the appendix uploaded as supplementary material on the web.)

Lemma 1. *The equilibrium profits and control variables by the sequence of the variables being determined are derived as shown in Table 3.*

Comparison of the equilibrium variables in Lemma 1 gives the following proposition.

[6] Indeed, if Inequality (6) is satisfied, all equilibrium payoffs of Π^{I}, Π^{II}, Π^{III}, Π^{IV}, and Π^{V} shown in Lemmas 1 and 2 later are greater than $(a-c_D)^2/(4b)$, which is the profit the manufacturer earns by only selling products through the direct channel.

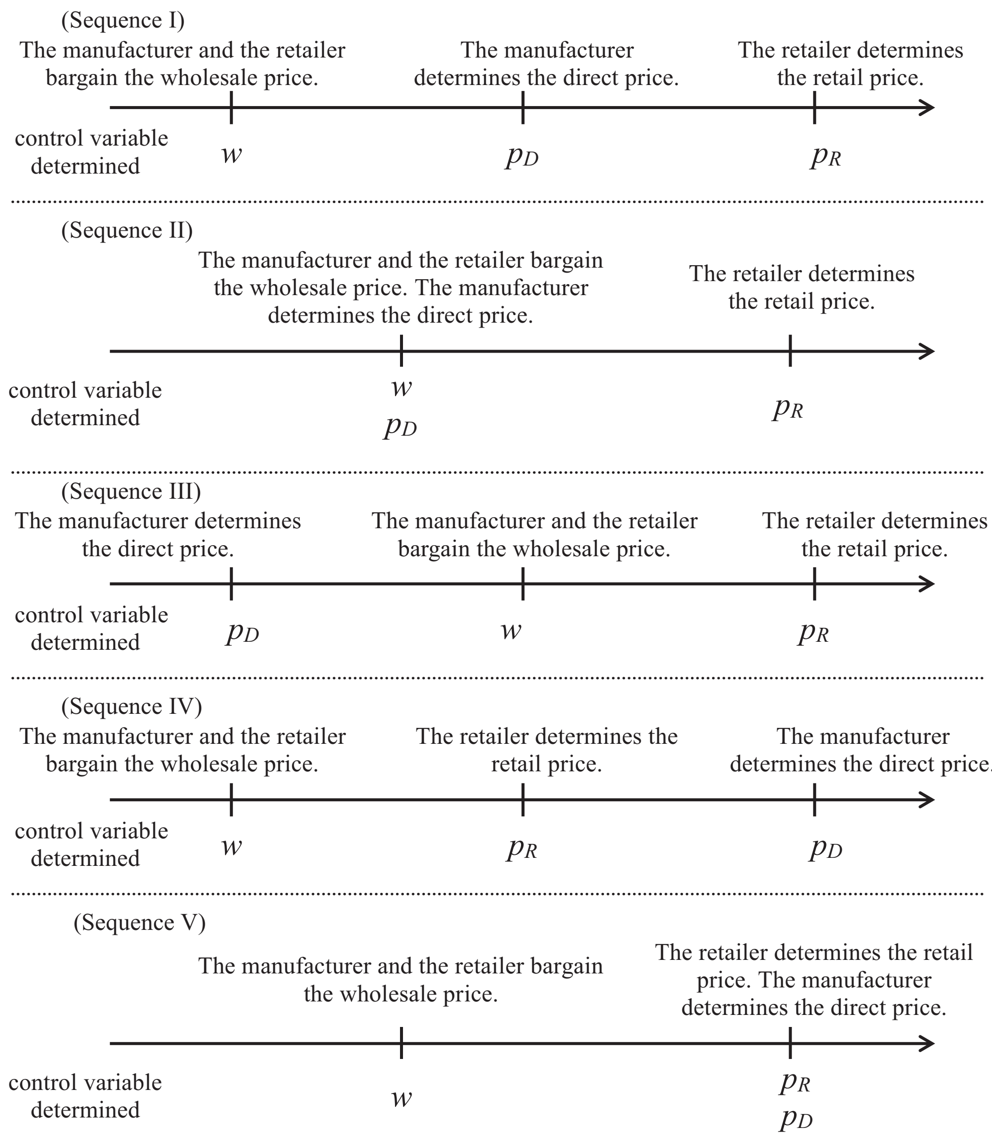

Fig. 2. Timeline.

Proposition 1. *The following relationships regarding the equilibrium profits hold.*

$\Pi^{I} > \Pi^{III} > \Pi^{II}$
$\Pi^{V} > \Pi^{IV}$
$\pi^{IV} > \pi^{V} > \pi^{I}$
$\pi^{III} = \pi^{II} > \pi^{I}$

Proposition 1 yields the following theorem, which is the managerial guideline for a manufacturer.

Theorem 1. *The manufacturer should bargain on the wholesale price before setting the direct price to maximize its profit.*

Theorem 1 derived from Proposition 1 is the central result of this paper: the proposition shows that the manufacturer achieves its maximum profit in Sequences I or V, in which the manufacturer bargains the wholesale price at the earliest timing among the five possible sequences.

The rationale behind this central result is as follows. If the manufacturer bargains on the wholesale price before determining its direct price, then the manufacturer will be able to flexibly adjust the direct price even if the bargaining breaks down. This option of adjusting the direct price enhances the manufacturer's disagreement point in the bargaining, enabling the manufacturer to gain a larger allocation of the surplus. By contrast, if bargaining on the wholesale price after or simultaneously with determining the direct price, the manufacturer will not be able to adjust the direct price if the negotiation breaks down. This leads to a worsening of the manufacturer's disagreement point, reducing its surplus. Hence, bargaining on the wholesale price before determining the direct price earns the manufacturer a higher profit.

Next, we conduct a sensitivity analysis regarding how the difference in the manufacturer's profit for the different bargaining timings depends on exogenous parameters. We have the following proposition.

Proposition 2. $|\Pi^{i} - \Pi^{j}|$ *($i =$ I, II, III, IV, V; $j =$ I, II, III, IV, V; $i \neq j$) is:*

(i) *increasing in a*
(ii) *increasing in c_D*
(iii) *decreasing in c_R.*

Proposition 2 suggests that the manufacturer needs to pay attention to the timing of bargaining especially when a or c_D is high or c_R is low. That is, as the retail channel earns the manufacturer

Table 3
Equilibrium profits and control variables by the sequence.

(Sequence I): w is determined first, p_D is determined second, and p_R is determined third.
$\Pi^{\mathrm{I}} = \frac{(a-c_D)^2}{4b} + \frac{\gamma(4(1-\theta^2)-\gamma(2-\theta^2)+\sqrt{(2-\theta^2)(\gamma^2(2-\theta^2)+8(1-\gamma)(1-\theta^2))})(a-c_R-\theta(a-c_D))^2}{32b(1-\theta^2)^2}$
$\pi^{\mathrm{I}} = \frac{((2-\gamma)(2-\theta^2)+\sqrt{(2-\theta^2)(\gamma^2(2-\theta^2)+8(1-\gamma)(1-\theta^2))})^2(a-c_R-\theta(a-c_D))^2}{64b(1-\theta^2)(2-\theta^2)^2}$
$w^{\mathrm{I}} = \frac{a+c_R}{2} - \frac{(\sqrt{(2-\theta^2)(\gamma^2(2-\theta^2)+8(1-\gamma)(1-\theta^2))}-\gamma(2-\theta^2))(a-c_R-\theta(a-c_D))}{8(1-\theta^2)}$
${p_R}^{\mathrm{I}} = \frac{a+c_R}{2} + \frac{((2-\theta^2)(2+\gamma-2\theta^2)-\sqrt{(2-\theta^2)(\gamma^2(2-\theta^2)+8(1-\gamma)(1-\theta^2))})(a-c_R-\theta(a-c_D))}{8(1-\theta^2)(2-\theta^2)}$
${p_D}^{\mathrm{I}} = \frac{a+c_D}{2} - \frac{\theta(\sqrt{(2-\theta^2)(\gamma^2(2-\theta^2)+8(1-\gamma)(1-\theta^2))}-\gamma(2-\theta^2))(a-c_R-\theta(a-c_D))}{8(1-\theta^2)(2-\theta^2)}$
(Sequence II): p_D and w are determined first, and p_R is determined second.
$\Pi^{\mathrm{II}} = (a-c_D)^2/(4b)+(\gamma(2-\gamma)(2-\theta^2)-\theta^2)(a-c_R-\theta(a-c_D))^2/(16b(1-\theta^2)^2)$
$\pi^{\mathrm{II}} = (2-\gamma)^2(a-c_R-\theta(a-c_D))^2/(16b(1-\theta^2))$
$w^{\mathrm{II}} = (a+c_R)/2-(1-\gamma)(2-\theta^2)(a-c_R-\theta(a-c_D))/(4(1-\theta^2))$
${p_R}^{\mathrm{II}} = (a+c_R)/2+(\gamma-\theta^2)(a-c_R-\theta(a-c_D))/(4(1-\theta^2))$
${p_D}^{\mathrm{II}} = (a+c_D)/2-\theta(1-\gamma)(a-c_R-\theta(a-c_D))/(4(1-\theta^2))$
(Sequence III): p_D is determined first, w is determined second, and p_R is determined third.
$\Pi^{\mathrm{III}} = (a-c_D)^2/(4b)+\gamma(2-\gamma)(a-c_R-\theta(a-c_D))^2/(8b(1-\theta^2))$
$\pi^{\mathrm{III}} = (2-\gamma)^2(a-c_R-\theta(a-c_D))^2/(16b(1-\theta^2))$
$w^{\mathrm{III}} = (a+c_R)/2-(1-\gamma)(a-c_R-\theta(a-c_D))/2$
${p_R}^{\mathrm{III}} = (a+c_R)/2+\gamma(a-c_R-\theta(a-c_D))/4$
${p_D}^{\mathrm{III}} = (a+c_D)/2$
(Sequence IV): w is determined first, p_R is determined second, and p_D is determined third.
$\Pi^{\mathrm{IV}} = \frac{(a-c_D)^2}{4b} + \frac{\gamma((2-\theta^2)^2(1-\theta^2)-2\gamma+2\sqrt{\gamma^2+(1-\gamma)(1-\theta^2)(2-\theta^2)^2})(a-c_R-\theta(a-c_D))^2}{4b(1-\theta^2)^2(8-5\theta^2+\theta^4)}$
$\pi^{\mathrm{IV}} = \frac{(2-\theta^2)(2-\gamma+\sqrt{\gamma^2+(1-\gamma)(1-\theta^2)(2-\theta^2)^2})^2(a-c_R-\theta(a-c_D))^2}{2b(1-\theta^2)(8-5\theta^2+\theta^4)^2}$
$w^{\mathrm{IV}} = \frac{a+c_R}{2} - \frac{(2(2-\theta^2)\sqrt{\gamma^2+(1-\gamma)(1-\theta^2)(2-\theta^2)^2}-4\gamma+\theta^2+2\gamma\theta^2-\theta^4)(a-c_R-\theta(a-c_D))}{2(1-\theta^2)(8-5\theta^2+\theta^4)}$
${p_R}^{\mathrm{IV}} = \frac{a+c_R}{2} + \frac{((1-\theta^2)(4-\theta^2)+2\gamma-2\sqrt{\gamma^2+(1-\gamma)(1-\theta^2)(2-\theta^2)^2})(a-c_R-\theta(a-c_D))}{2(1-\theta^2)(8-5\theta^2+\theta^4)}$
${p_D}^{\mathrm{IV}} = \frac{a+c_D}{2} - \frac{\theta((3-\theta^2)\sqrt{\gamma^2+(1-\gamma)(1-\theta^2)(2-\theta^2)^2}-(2-3\theta^2+\theta^4+\gamma(3-\theta^2)))(a-c_R-\theta(a-c_D))}{2(1-\theta^2)(8-5\theta^2+\theta^4)}$
(Sequence V): w is determined first, and p_D and p_R are determined second.
$\Pi^{\mathrm{V}} = \frac{(a-c_D)^2}{4b} + \frac{\gamma(8(1-\theta^2)-\gamma(2+\theta^2)^2+(2+\theta^2)\sqrt{16(1-\gamma)(1-\theta^2)+\gamma^2(2+\theta^2)^2})(a-c_R-\theta(a-c_D))^2}{8b(1-\theta^2)^2(8+\theta^2)}$
$\pi^{\mathrm{V}} = \frac{((2-\gamma)(2+\theta^2)+\sqrt{16(1-\gamma)(1-\theta^2)+\gamma^2(2+\theta^2)^2})^2(a-c_R-\theta(a-c_D))^2}{4b(1-\theta^2)(8+\theta^2)^2}$
$w^{\mathrm{V}} = \frac{a+c_R}{2} - \frac{(2\theta^2(1-\theta^2)-\gamma(8+2\theta^2-\theta^4)+(4-\theta^2)\sqrt{16(1-\gamma)(1-\theta^2)+\gamma^2(2+\theta^2)^2})(a-c_R-\theta(a-c_D))}{4(1-\theta^2)(8+\theta^2)}$
${p_R}^{\mathrm{V}} = \frac{a+c_R}{2} + \frac{(2(4-3\theta^2-\theta^4)+\gamma(2+\theta^2)^2-(2+\theta^2)\sqrt{16(1-\gamma)(1-\theta^2)+\gamma^2(2+\theta^2)^2})(a-c_R-\theta(a-c_D))}{4(1-\theta^2)(8+\theta^2)}$
${p_D}^{\mathrm{V}} = \frac{a+c_D}{2} - \frac{\theta(3\sqrt{16(1-\gamma)(1-\theta^2)+\gamma^2(2+\theta^2)^2}-4(1-\theta^2)-3\gamma(2+\theta^2))(a-c_R-\theta(a-c_D))}{4(1-\theta^2)(8+\theta^2)}$

a higher profit, the manufacturer can generate a higher profit by expediting the bargaining timing of the wholesale price.

We close this section by confirming whether the equilibrium results presented above are stable in the price-setting scenario considered in this section. Specifically, we confirm that the retailer purchases products from the manufacturer in the retail channel at the wholesale price of w, but not in the direct channel at the direct price of p_D. The following corollary proves that the retailer never deviates from the equilibrium.

Corollary 1. *$w^i < {p_D}^i$ holds in equilibrium for all cases (i = I, II, III, IV, V), meaning that the retailer always purchases products in the retail channel, not in the direct channel.*

5. Alternative scenario: Quantity setting

Up to the previous section, we considered the scenario in which the control variable at the retail market level is a price. It has been shown in the game-theoretic literature that equilibrium results often change significantly if a control variable in a model is changed from the price to the quantity. Therefore, we consider an alternative scenario in this section in which the control variable of the manufacturer is the quantity of products supplied through the direct channel (q_D) and that of the retailer is the quantity of products supplied through the retail channel (q_R). Using Eq. (1), we state the manufacturer's and retailer's profits, Π and π, as:

$$\Pi = (w - c_R)q_R + (p_D - c_D)q_D$$
$$= (w - c_R)q_R + (a - b(q_D + \theta q_R) - c_D)q_D \quad (7)$$

$$\pi = (p_R - w)q_R$$
$$= (a - b(q_R + \theta q_D) - w)q_R. \quad (8)$$

Solving the bargaining problem in a similar way to that in the previous section, we obtain equilibrium profits by the sequence of decisions, which are summarized in the following lemma.

Lemma 2. *When the control variables of the manufacturer and the retailer are quantities, equilibrium profits and control variables by the sequence of the variables being determined are derived as shown in Table 4.*

Comparison of the manufacturer's profits in the five sequences shown in Lemma 2 gives the following proposition.

Proposition 3. *When the control variables of the manufacturer and the retailer are quantities, the following relationships regarding the equilibrium profits hold.*

$\Pi^{\mathrm{IV}} > \Pi^{\mathrm{I}} > \Pi^{\mathrm{III}} > \Pi^{\mathrm{II}}$
$\Pi^{\mathrm{I}} > \Pi^{\mathrm{V}}$
$\pi^{\mathrm{II}} > \pi^{\mathrm{I}} > \pi^{\mathrm{V}}$
$\pi^{\mathrm{II}} > \pi^{\mathrm{IV}} > \pi^{\mathrm{V}}$
$\pi^{\mathrm{II}} > \pi^{\mathrm{III}}$

Proposition 3 yields the following theorem, which is the managerial guideline for a manufacturer.

Theorem 2. *The manufacturer should bargain on the wholesale price before setting the quantity sold in the direct channel to maximize its profit.*

Table 4
Equilibrium profits and control variables by the sequence in the quantity-setting scenario.

(Sequence I): w is determined first, q_D is determined second, and q_R is determined third.
$\Pi^{\mathrm{I}} = (a-c_D)^2/(4b) + \gamma(2-\gamma-\theta^2+\sqrt{2(1-\gamma)(2-\theta^2)+\gamma^2})(a-c_R-\theta(a-c_D))^2/(4b(2-\theta^2)^2)$
$\pi^{\mathrm{I}} = (2-\gamma+\sqrt{2(1-\gamma)(2-\theta^2)+\gamma^2})^2(a-c_R-\theta(a-c_D))^2/(16b(2-\theta^2)^2)$
$w^{\mathrm{I}} = (a+c_R)/2-(\sqrt{2(1-\gamma)(2-\theta^2)+\gamma^2}-\gamma)(a-c_R-\theta(a-c_D))/(2(2-\theta^2))$
${q_R}^{\mathrm{I}} = (2-\gamma+\sqrt{2(1-\gamma)(2-\theta^2)+\gamma^2})(a-c_R-\theta(a-c_D))/(4b(2-\theta^2))$
${q_D}^{\mathrm{I}} = (2(a-c_D)-\theta(a-c_R))/(2b(2-\theta^2))$
(Sequence II): q_D and w are determined first, and q_R is determined second.
$\Pi^{\mathrm{II}} = (a-c_D)^2/(4b)+(4\gamma-2\gamma^2-\theta^2)(a-c_R-\theta(a-c_D))^2/(4b(2-\theta^2)^2)$
$\pi^{\mathrm{II}} = (2-\gamma)^2(a-c_R-\theta(a-c_D))^2/(4b(2-\theta^2)^2)$
$w^{\mathrm{II}} = (a+c_R)/2-(1-\gamma)(a-c_R-\theta(a-c_D))/(2-\theta^2)$
${q_R}^{\mathrm{II}} = (2-\gamma)(a-c_R-\theta(a-c_D))/(2b(2-\theta^2))$
${q_D}^{\mathrm{II}} = (2(a-c_D)-\theta(a-c_R))/(2b(2-\theta^2))$
(Sequence III): q_D is determined first, w is determined second, and q_R is determined third.
$\Pi^{\mathrm{III}} = (a-c_D)^2/(4b)+\gamma(2-\gamma)(a-c_R-\theta(a-c_D))^2/(4b(2-(2-\gamma)\gamma\theta^2))$
$\pi^{\mathrm{III}} = (2-\gamma)^2(a-c_R-\theta(a-c_D))^2/(4b(2-(2-\gamma)\gamma\theta^2)^2)$
$w^{\mathrm{III}} = (a+c_R)/2-(1-\gamma)(a-c_R-\theta(a-c_D))/(2-(2-\gamma)\gamma\theta^2)$
${q_R}^{\mathrm{III}} = (2-\gamma)(a-c_R-\theta(a-c_D))/(2b(2-(2-\gamma)\gamma\theta^2))$
${q_D}^{\mathrm{III}} = (2(a-c_D)-\gamma(2-\gamma)\theta(a-c_R))/(2b(2-(2-\gamma)\gamma\theta^2))$
(Sequence IV): w is determined first, q_R is determined second, and q_D is determined third.
$\Pi^{\mathrm{IV}} = (a-c_D)^2/(4b)+\gamma(2-\gamma)(a-c_R-\theta(a-c_D))^2/(b(8-5\theta^2))$
$\pi^{\mathrm{IV}} = 2(2-\gamma)^2(2-\theta^2)(a-c_R-\theta(a-c_D))^2/(b(8-5\theta^2)^2)$
$w^{\mathrm{IV}} = (a+c_R)/2-(8-3\theta^2-4\gamma(2-\theta^2))(a-c_R-\theta(a-c_D))/(2(8-5\theta^2))$
${q_R}^{\mathrm{IV}} = 2(2-\gamma)(a-c_R-\theta(a-c_D))/(b(8-5\theta^2))$
${q_D}^{\mathrm{IV}} = ((8-(1+2\gamma)\theta^2)(a-c_D)-2(2-\gamma)\theta(a-c_R))/(2b(8-5\theta^2))$
(Sequence V): w is determined first, and q_D and q_R are determined second.
$\Pi^{V} = (a-c_D)^2/(4b)+\gamma(2-\gamma)(a-c_R-\theta(a-c_D))^2/(b(8-3\theta^2))$
$\pi^{V} = 4(2-\gamma)^2(a-c_R-\theta(a-c_D))^2/(b(8-3\theta^2)^2)$
$w^{\mathrm{V}} = (a+c_R)/2-(8-\theta^2-2\gamma(4-\theta^2))(a-c_R-\theta(a-c_D))/(2(8-3\theta^2))$
${q_R}^{\mathrm{V}} = 2(2-\gamma)(a-c_R-\theta(a-c_D))/(b(8-3\theta^2))$
${q_D}^{\mathrm{V}} = ((8+(1-2\gamma)\theta^2)(a-c_D)-2(2-\gamma)\theta(a-c_R))/(2b(8-3\theta^2))$

Because the profit of the manufacturer is the highest in Sequence IV in Proposition 3, the managerial implication that the manufacturer should bargain on the wholesale price before determining its control variable in the direct channel is robust. Consequently, Theorem 2 together with Theorem 1 lead us to conclude that no matter whether the control variable of the supply chain members is the price or the quantity, the manufacturer should bargain the wholesale price at the earliest timing from the strategic viewpoint.

Next, we provide a rationale for the change in the ranking of the retailer's profits between Propositions 1 and 3 using insights gained in the game-theoretic literature. Above all, Gal-Or (1985) analytically demonstrates that the first-mover advantage and the second-mover advantage are exchanged between the quantity-setting scenario and the price-setting scenario when two firms compete. Specifically, Gal-Or (1985) demonstrates that the second-mover advantage arises in a price-setting scenario. Moreover, Theorem III in Hamilton and Slutsky (1990, p. 36) proves that firms with the second-mover advantage have incentives to make their decisions sequentially and therefore stagger their decision timings. The inequality on p. 405 in van Damme and Hurkens (2004) also confirms this result. By contrast, in a quantity-setting scenario, Gal-Or (1985) shows that first-mover advantage for a firm arises and Theorem II in Hamilton and Slutsky (1990, p. 36) proves that firms with the first-mover advantage have an incentive to make simultaneous decisions and to synchronize their decisions.[7] The application of this insight by Gal-Or (1985) to our model suggests that the retailer has an incentive to stagger its decision with the manufacturer in the price-setting scenario considered in Section 4. Consistent with this insight, Proposition 1 shows that the retailer prefers Sequence IV, in which the retailer staggers the bargaining timing with the timing of direct pricing by the manufacturer, but does not synchronize it. By contrast, Proposition 3 indicates that the retailer prefers Sequence II in the quantity-setting scenario, in which the manufacturer and the retailer synchronize their decision timings for q_D and w. This result is also consistent with the previous insight gained in the above game-theoretic literature (e.g., Gal-Or, 1985; Hamilton & Slutsky, 1990; van Damme & Hurkens, 2004).

Similarly to the price-setting game, the following proposition with respect to exogenous parameters holds, indicating that the manufacturer should pay attention to the bargaining timing especially when the retail channel earns the manufacturer a higher profit.

Proposition 4. $|\Pi^i - \Pi^j|$ *($i = $ I, II, III, IV, V; $j = $ I, II, III, IV, V; $i \neq j$) in the quantity-setting scenario is:*

(i) *increasing in a*
(ii) *increasing in c_D*
(iii) *decreasing in c_R.*

6. Extension: Retailer's timing choice

In this section, we extend the basic model by applying an observable delay game proposed by Hamilton and Slutsky (1990) to our dual-channel model. The observable delay game is composed of the following two stages. In stage one, the manufacturer and the retailer simultaneously announce the timing of when they will choose their decision variables in the next stage and are committed to this choice. In stage two, following the announcement, the manufacturer and the retailer choose their decision variables, each knowing when the rival will make its choice. We assume that the

[7] Gal-Or (1985) further explains that the fundamental reason for why the first-mover advantage and the second-mover advantage are exchanged between the quantity-setting and the price-setting scenarios is that prices and quantities are respectively characterized by "strategic complements" and "strategic substitutes", which are originally proposed by Bulow et al. (1985).

second stage includes a continuous timeline to describe realistic decision-making in a supply chain. At a point of the timeline in the second stage, the manufacturer and the retailer respectively set decision variables. This framework allows the retailer to choose the timing of its decision.

First, we apply the observable delay game to the price-setting scenario, which was modeled in Section 4. Proposition 1 suggests that either Sequence I or Sequence V enables the manufacturer to generate the highest profit. Hence, let us first consider the case in which the manufacturer's profit is highest in Sequence I. In this case, the manufacturer bargains the wholesale price, w, before setting the direct price, p_D, aiming to attain Sequence I. However, if p_D is set after the bargaining of w, the retailer will accelerate the timing of setting the retail price, p_R, before the manufacturer sets p_D, to attain Sequence IV, as the retailer can earn a higher profit in this sequence than in Sequence I. Consequently, Sequence I no longer constitutes the subgame perfect Nash equilibrium (SPNE) in the observable delay game. Next, suppose that the manufacturer's profit is the highest in Sequence V. In this case, the manufacturer again sets p_D after bargaining w so as to attain Sequence V. However, the retailer accelerates its timing of setting the retail price and sets p_R before p_D is set because, as Proposition 1 suggests, the retailer achieves higher profit in Sequence IV than in Sequence V. Hence, Sequence V never constitutes the SPNE, similar to Sequence I in the previous case. In summary, if the manufacturer sets p_D after bargaining w, the manufacturer and the retailer have incentives to set the direct price and the retail price as early as possible, meaning that the two firms expedite their pricing decisions as each attempts to establish price before the other does.[8] This indicates that there is no stable timing—from which neither firm has an incentive to deviate—in the observable delay game of the price-setting scenario.

Second, we apply the observable delay game to the quantity-setting scenario considered in Section 5. As Proposition 3 indicates that the manufacturer's profit is highest in Sequence IV, the manufacturer sets q_D after bargaining w, aiming to attain Sequence IV. Following the same logic as in the price-setting scenario, we arrive at the result that as long as $\pi^{\mathrm{IV}} > \pi^{\mathrm{I}}$ holds, Sequence IV is the equilibrium timing from which neither the manufacturer nor the retailer deviates. However, Proposition 3 does not prove that $\pi^{\mathrm{IV}} > \pi^{\mathrm{I}}$ holds in all range of exogenous parameters, indicating that Sequence IV cannot be the equilibrium always. Hence, we conclude that no stable timing arises that always constitutes the SPNE irrespective of the exogenous parameters in the observable delay game.

Although we find that no equilibrium timing exists in the observable delay game, the basic model utilized up to the previous section suggests that as long as the timing of the retailer's pricing decision is correctly anticipated by the manufacturer, the manufacturer's timing strategy should be to bargain on the wholesale price before setting the direct price and then to set the direct price immediately after the bargaining has been settled. The effectiveness of this strategy for the manufacturer when the timing of the retailer's pricing is anticipated has been demonstrated, which is the main contribution of this paper.[9]

7. Conclusion

In this paper, we explore the optimal timing for a manufacturer to bargain a wholesale price with a retailer in a dual-channel supply chain environment. To address the problem, we construct a game-theoretic model in which the manufacturer can sell products through both direct and retail channels, assuming that the manufacturer determines the direct price in the direct channel and the retailer determines the retail price in the retail channel, while the manufacturer and the retailer bargain the wholesale price. Our model yields the clear-cut result that the manufacturer achieves its highest profit by bargaining the wholesale price before determining the direct price. Moreover, we show that this result still holds if the control variables at the retail market level are not prices but quantities. Consequently, the result gives the managerial implication that if a manufacturer using a dual-channel supply chain can choose the timing to negotiate the wholesale price with a retailer, the manufacturer should have the opportunity before determining the direct price or the quantity of products sold directly to consumers.

We note that the current paper yields a result that is different from previous research on timing decision on the wholesale price in a dual-channel supply chain. As reviewed in Section 2, previous work has provided the managerial implication that a manufacturer should determine the direct price before the wholesale price, which is an opposite result to the one in this paper. More specifically, previous research has shown that if the manufacturer can unilaterally dictate the wholesale price as in the form of a simple manufacturer's Stackelberg model, the manufacturer should determine the direct price before the wholesale price. By contrast, however, if the manufacturer needs to negotiate the wholesale price with a retailer who has some power to influence the price, then the manufacturer should negotiate the wholesale price before setting the direct price, which is the central message of the current study. A rationale for the difference in the results is as follows. As mentioned in the first section, if the manufacturer cannot dictate the wholesale price completely at its own will, but instead must bargain the wholesale price with the retailer, precommitment to a particular direct price can restrict its future behavior, thereby worsening its disagreement point in the bargaining. Hence, the desirable timing for the manufacturer to make its decision on the wholesale price depends on the process of how the wholesale price is determined. To sum up, our result indicates that when making a decision concerning a wholesale price, a manufacturer should also examine how the price is formed, namely, whether the manufacturer unilaterally imposes it on a retailer or bargains it with a retailer.

We explore possible future research directions before closing the paper. In the game theory literature, it has been shown that bargaining power can be interpreted as the degree of risk aversion of a player (Binmore, Rubinstein & Wolinsky, 1986). Accordingly, the introduction of uncertain factors into the present model will enable us to examine how the risk attitude of supply chain members influences their equilibrium profits. This extension would require a substantial reconstruction of the present model, which would change the model into a totally new one. Hence, this development is another issue that is reserved to a future study.

Acknowledgments

The author gratefully acknowledges three anonymous reviewers for their insightful comments. Needless to say, the author is solely

[8] The mechanism behind the two firms' behavior is associated with the first-mover advantage caused by the characteristics of strategic substitutes of the decision variables, as suggested by Bulow et al. (1985) and Gal-Or (1985).

[9] Moreover, as shown in Table 1, most previous papers that examine the optimal timing of decisions in supply chains consider only one firm's optimal timing, not that of all supply chain members (e.g., Chen et al, 2018a, 2019; Li and Chen, 2018; Li et al., 2019a, Li et al., 2019c; Liu and Ke, 2020; Yan et al., 2020). In other words, previous models examining the optimal decision timing in supply chains usually do not consider an observable delay game. This is because the purpose of the previous studies is to provide managerial implications for at least one supply chain member regarding when it should set its decision variable, thereby establishing decision guidelines useful to that member. Following such previous papers, this paper also aims to propose a managerial guideline concerning when only one supply chain member (i.e., a manufacturer) should bargain the wholesale price.

responsible for any remaining errors. The author also greatly appreciates Financial support of Grant-in Aid for Scientific Research (B) (20H01551, 17H02528) and (C) (18K01568) from the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ejor.2020.05.004.

References

Alawneh, F., & Zhang, G. (2018). Dual-channel warehouse and inventory management with stochastic demand. *Transportation Research Part E: Logistics and Transportation Review, 112*, 84–106.
Arya, A., Mittendorf, B., & Sappington, D. E. (2007). The bright side of supplier encroachment. *Marketing Science, 26*(5), 651–659.
Batarfi, R., Jaber, M. Y., & Zanoni, S. (2016). Dual-channel supply chain: A strategy to maximize profit. *Applied Mathematical Modelling, 40*(21–22), 9454–9473.
Binmore, K., Rubinstein, A., & Wolinsky, A. (1986). The Nash bargaining solution in economic modelling. *RAND Journal of Economics, 17*(2), 176–188.
Brooker, K. (1999). E-rivals seem to have Home Depot awfully nervous. *Fortune , 140*(4), 28–29.
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.
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.
Chai, J., Yan, W., Li, Y., Palmer, M., & Huang, Q. (2020). Selling vertically differentiated products under one channel or two? A quality segmentation model for differentiated distribution channels. *Journal of the Operational Research Society* in press. doi:10.1080/01605682.2019.1605469.
Chen, H., Yan, Y., Ma, N., & Yang, L. (2019). Coopetition strategy and pricing timing in an outsourcing supply chain with uncertain operation risks. *IEEE Transactions on Fuzzy Systems, 27*(5), 979–993.
Chen, J., Chen, B., & Li, W. (2018a). Who should be pricing leader in the presence of customer returns? *European Journal of Operational Research, 265*(2), 735–747.
Chen, J., Liang, L., Yao, D.-. Q., & Sun, S. (2017). Price and quality decisions in dual-channel supply chains. *European Journal of Operational Research, 259*(3), 935–948.
Chen, J., Pun, H., & Li, W. (2018b). Using online channel to defer the launch of discount retailing store. *Transportation Research Part E: Logistics and Transportation Review, 120*, 96–115.
Chen, J., Zhang, H., & Sun, Y. (2012). Implementing coordination contracts in a manufacturer Stackelberg dual-channel supply chain. *Omega , 40*(5), 571–583.
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.
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.
Cui, Q. (2019). Quality investment, and the contract manufacturer's encroachment. *European Journal of Operational Research, 279*(2), 407–418.
Dell, M., & Fredman, C. (1999). *Direct from Dell: Strategies that revolutionized an industry*. HarperBusiness.
Dumrongsiri, A., Fan, M., Jain, A., & Moinzadeh, K. (2008). A supply chain model with direct and retail channels. *European Journal of Operational Research, 187*(3), 691–718.
Ertek, G., & Griffin, P. M. (2002). Supplier- and buyer-driven channels in a two-stage supply chain. *IIE Transactions, 34*(8), 691–700.
Esenduran, G., Lu, L. X., & Swaminathan, J. M. (2020). Buyback pricing of durable goods in dual distribution channels. *Manufacturing & Service Operations Management, 22*(2), 412–428.
Feng, Q., Lai, G., & Lu, L. X. (2015). Dynamic bargaining in a supply chain with asymmetric demand information. *Management Science, 61*(2), 301–315.
Feng, Q., & Lu, L. X. (2012). The strategic perils of low cost outsourcing. *Management Science, 58*(6), 1196–1210.
Gal-Or, E. (1985). First mover and second mover advantages. *International Economic Review, 26*(3), 649–653.
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.
Guan, H., Gurnani, H., Geng, X., & Luo, Y. (2019). Strategic inventory and supplier encroachment. *Manufacturing & Service Operations Management, 21*(3), 536–555.
Guan, X., Liu, B., Chen, Y.-. J., & Wang, H. (2020). Inducing supply chain transparency through supplier encroachment. *Production and Operations Management, 29*(3), 725–749.
Guo, L., & Iyer, G. (2013). Multilateral bargaining and downstream competition. *Marketing Science, 32*(3), 411–430.
Ha, A., Long, X., & Nasiry, J. (2016). Quality in supply chain encroachment. *Manufacturing & Service Operations Management, 18*(2), 280–298.
Hamilton, J. H., & Slutsky, S. M. (1990). Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. *Games and Economic Behavior, 2*(1), 29–46.
Hao, Z., & Jiang, L. (2019). Direct selling by suppliers improves system-wide information flow. *Operations Research Letters, 47*(4), 305–310.
He, B., Gan, X., & Yuan, K. (2019). Entry of online presale of fresh produce: A competitive analysis. *European Journal of Operational Research, 272*(1), 339–351.
He, Y., Huang, H., & Li, D. (2019). Inventory and pricing decisions for a dual-channel supply chain with deteriorating products. *Operational Research: An International Journal* in press. doi:10.1007/s12351-018-0393-2.
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*(1), 113–126.
Huang, S., Guan, X., & Xiao, B. (2018). Incentive provision for demand information acquisition in a dual-channel supply chain. *Transportation Research Part E: Logistics and Transportation Review, 116*, 42–58.
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.
Ingene, C. A., & Parry, M. E. (2004). *Mathematical models of distribution channels*. Springer.
Krishnan, T. V., & Soni, H. (1997). Guaranteed profit margins: A demonstration of retailer power. *International Journal of Research in Marketing, 14*(1), 35–56.
Kurata, H., Yao, D.-. Q., & 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.
Lan, Y., Li, Y., & Papier, F. (2018). Competition and coordination in a three-tier supply chain with differentiated channels. *European Journal of Operational Research, 269*(3), 870–882.
Li, B., & Jiang, Y. (2019). Impacts of returns policy under supplier encroachment with risk-averse retailer. *Journal of Retailing and Consumer Services, 47*, 104–115.
Li, G., Li, L., & Sun, J. (2019a). Pricing and service effort strategy in a dual-channel supply chain with showrooming effect. *Transportation Research Part E: Logistics and Transportation Review, 126*, 32–48.
Li, G., Zhang, X., Chiu, S.-. M., Liu, M., & Sethi, S. P. (2019b). Online market entry and channel sharing strategy with direct selling diseconomies in the sharing economy era. *International Journal of Production Economics, 218*, 135–147.
Li, G., Zhang, X., & Liu, M. (2019c). E-tailer's procurement strategies for drop-shipping: Simultaneous vs. sequential approach to two manufacturers. *Transportation Research Part E: Logistics and Transportation Review, 130*, 108–127.
Li, T., Xie, J., Zhao, X., & Tang, J. (2016). On supplier encroachment with retailer's fairness concerns. *Computers & Industrial Engineering, 98*, 499–512.
Li, W., & Chen, J. (2018). Pricing and quality competition in a brand-differentiated supply chain. *International Journal of Production Economics, 202*, 97–108.
Li, Y., Lin, Z., Xu, L., & Swain, A. (2015b). "Do the electronic books reinforce the dynamics of book supply chain market?"–A theoretical analysis. *European Journal of Operational Research, 245*(2), 591–601.
Li, Z., Gilbert, S. M., & Lai, G. (2014). Supplier encroachment under asymmetric information. *Management Science, 60*(2), 449–462.
Li, Z., Gilbert, S. M., & Lai, G. (2015a). Supplier encroachment as an enhancement or a hindrance to nonlinear pricing. *Production and Operations Management, 24*(1), 89–109.
Lin, X., Zhou, Y.-. W., & Hou, R. (2020). Impact of a "buy-online-and-pickup-in-store" channel on price and quality decisions in a supply chain. *European Journal of Operational Research* in press. doi:10.1016/j.ejor.2020.03.064.
Liu, J., & Ke, H. (2020). Firms' pricing strategies under different decision sequences in dual-format online retailing. *Soft Computing, 24*, 7811–7826.
Lovejoy, W. S. (2010). Bargaining chains. *Management Science, 56*(12), 2282–2301.
Matsui, K. (2016). Asymmetric product distribution between symmetric manufacturers using dual-channel supply chains. *European Journal of Operational Research, 248*(2), 646–657.
Matsui, K. (2017). When should a manufacturer set its direct price and wholesale price in dual-channel supply chains? *European Journal of Operational Research, 258*(2), 501–511.
Matsui, K. (2018). When and what wholesale and retail prices should be set in multi-channel supply chains? *European Journal of Operational Research, 267*(2), 540–554.
Modak, N. M., & Kelle, P. (2019). Managing a dual-channel supply chain under price and delivery-time dependent stochastic demand. *European Journal of Operational Research, 272*(1), 147–161.
Nagarajan, M., & Bassok, Y. (2008). A bargaining framework in supply chains: The assembly problem. *Management Science, 54*(8), 1482–1496.

Nagarajan, M., & Sošić, G. (2008). Game-theoretic analysis of cooperation among supply chain agents: Review and extensions. *European Journal of Operational Research, 187*(3), 719–745.
Nash, J. (1950). The bargaining problem. *Econometrica : journal of the Econometric Society , 18*(2), 155–162.
Perlman, Y., Ozinci, Y., & Westrich, S. (2019). Pricing decisions in a dual supply chain of organic and conventional agricultural products. *Annals of Operations Research* in press. doi:10.1007/s10479-019-03169-3.
Pu, X., Sun, S., & Han, G. (2019). Differentiated-product distribution in a dual-channel supply chain. *Managerial and Decision Economics, 40*(4), 363–373.
Qing, Q., Deng, T., & Wang, H. (2017). Capacity allocation under downstream competition and bargaining. *European Journal of Operational Research, 261*(1), 97–107.
Rodríguez, B., & Aydın, G. (2015). Pricing and assortment decisions for a manufacturer selling through dual channels. *European Journal of Operational Research, 242*(3), 901–909.
Rubinstein, A. (1982). Perfect equilibrium in a bargaining model. *Econometrica : journal of the Econometric Society , 50*(1), 97–110.
Safdar, K., & Mattioli, D. (2019). Nike to stop selling directly to Amazon. *Wall Street Journal*. November 13 https://www.wsj.com/articles/nike-to-stop-selling-directly-to-amazon-11573615633 .
Song, Z., Tang, W., & Zhao, R. (2019). Encroachment and canvassing strategy in a sea-cargo service chain with empty container repositioning. *European Journal of Operational Research, 276*(1), 175–186.
Sternad, D. (2019). *Effective management: Developing yourself, others and organizations* (English Edition). UK: Macmillan Education.
Tagashira, T., & Minami, C. (2019). The effect of cross-channel integration on cost efficiency. *Journal of Interactive Marketing, 47*, 68–83.
Tsay, A., & Agrawal, N. (2004). Channel conflict and coordination in the e-commerce age. *Production and Operations Management, 13*(1), 93–110.
van Damme, E., & Hurkens, S. (2004). Endogenous price leadership. *Games and Economic Behavior, 47*(2), 404–420.
Wang, J., Yan, Y., Du, H., & Zhao, R. (2020). The optimal sales format for green products considering downstream investment. *International Journal of Production Research, 58*(4), 1107–1126.
Wang, Y., Niu, B., Guo, P., & Song, J.-S. J. (2020). Direct sourcing or agent sourcing? Contract negotiation in procurement outsourcing. *Manufacturing & Service Operations Management* in press. doi:10.1287/msom.2019.0843.
Wei, C., Asian, S., Ertek, G., & Hu, Z.-. H. (2019). Location-based pricing and channel selection in a supply chain: A case study from the food retail industry. *Annals of Operations Research* in press. doi:10.1007/s10479-018-3040-7.
Xia, J., & Niu, W. (2019). Adding clicks to bricks: An analysis of supplier encroachment under service spillovers. *Electronic Commerce Research and Applications, 37*, 100876.
Xiao, T., & Shi, J. (2016). Pricing and supply priority in a dual-channel supply chain. *European Journal of Operational Research, 254*(3), 813–823.
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.
Xu, J., Qi, Q., & Bai, Q. (2018). Coordinating a dual-channel supply chain with price discount contracts under carbon emission capacity regulation. *Applied Mathematical Modelling, 56*, 449–468.
Yan, N., Liu, Y., Xu, X., & He, X. (2020). Strategic dual-channel pricing games with e-retailer finance. *European Journal of Operational Research, 283*(1), 138–151.
Yan, W., Xiong, Y., Chu, J., Li, G., & Xiong, Z. (2018). Clicks versus Bricks: The role of durability in marketing channel strategy of durable goods manufacturers. *European Journal of Operational Research, 265*(3), 909–918.
Yan, Y., Zhao, R., & Chen, H. (2018). Prisoner's dilemma on competing retailers' investment in green supply chain management. *Journal of Cleaner Production, 184*, 65–81.
Yan, Y., Zhao, R., & Lan, Y. (2017). Asymmetric retailers with different moving sequences: Group buying vs. individual purchasing. *European Journal of Operational Research, 261*(3), 903–917.
Yan, Y., Zhao, R., & Liu, Z. (2018). Strategic introduction of the marketplace channel under spillovers from online to offline sales. *European Journal of Operational Research, 267*(1), 65–77.
Yang, H., Luo, J., & Zhang, Q. (2018). Supplier encroachment under nonlinear pricing with imperfect substitutes: Bargaining power versus revenue-sharing. *European Journal of Operational Research, 267*(3), 1089–1101.
Yao, D.-. Q., & Liu, J. J. (2003). Channel redistribution with direct selling. *European Journal of Operational Research, 144*(3), 646–658.
Yu, D. Z., Cheong, T., & Sun, D. (2017). Impact of supply chain power and drop-shipping on a manufacturer's optimal distribution channel strategy. *European Journal of Operational Research, 259*(2), 554–563.
Yu, Y., Sun, L., & Guo, X. (2019). Dual-channel decision in a shopping complex when considering consumer channel preference. *Journal of the Operational Research Society* in press. doi:10.1080/01605682.2019.1621221.
Yue, X., & Liu, J. J. (2006). Demand forecast sharing in a dual-channel supply chain. *European Journal of Operational Research, 174*(1), 646–667.
Zennyo, Y. (2020). Strategic contracting and hybrid use of agency and wholesale contracts in e-commerce platforms. *European Journal of Operational Research, 281*(1), 231–239.
Zhang, J., Li, S., Zhang, S., & Dai, R. (2019a). Manufacturer encroachment with quality decision under asymmetric demand information. *European Journal of Operational Research, 273*(1), 217–236.
Zhang, Q., Tang, W., Zaccour, G., & Zhang, J. (2019b). Should a manufacturer give up pricing power in a vertical information-sharing channel? *European Journal of Operational Research, 276*(3), 910–928.
Zhang, S., & Zhang, J. (2020). Agency selling or reselling: E-tailer information sharing with supplier offline entry. *European Journal of Operational Research, 280*(1), 134–151.
Zhang, S., Zhang, J., & Zhu, G. (2019c). Retail service investing: An anti-encroachment strategy in a retailer-led supply chain. *Omega , 84*, 212–231.
Zheng, B., Yu, N., Jin, L., & Xia, H. (2019). Effects of power structure on manufacturer encroachment in a closed-loop supply chain. *Computers & Industrial Engineering, 137*, 106062.
Zhou, J., Zhao, R., & Wang, W. (2019). Pricing decision of a manufacturer in a dual-channel supply chain with asymmetric information. *European Journal of Operational Research, 278*(3), 809–820.