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DUAL CHANNEL SALES IN SUPPLY CHAIN: LIVE STREAMING OR TRADITIONAL E-COMMERCE

Xuejun Zhou[1,*], Zhibing Liu[2], Jie Liu[1] and Chen Pan[1]

Abstract. In recent years, live streaming is becoming a popular channel to sell products all over the world. Compared to traditional e-commerce channel, live streaming channel may not only bring consumers more shopping convenience, but also pose consumers more privacy concern. This paper considers a supply chain consisting of a manufacturer and an e-tailer who sells through dual channels (*i.e.*, live streaming and traditional e-commerce) to explore how shopping convenience and privacy concern affect the optimal decisions. We build game models of two pricing (exogenous and endogenous) and two incentive contracts (wholesale price and two-part tariff). We find that the optimal promotion efforts are decreasing in shopping convenience while increasing in privacy concerns under the wholesale price contract, and independent of them under the two-part tariff contract when pricing is not a decision (such as iPhone); the optimal promotion efforts are increasing in shopping convenience while decreasing in privacy concern when pricing is a decision (such as the seasonal products). Whether the retail pricing is a decision or not, supply chain coordination can be achieved by the two-part tariff contract, but not through the wholesale price contract. Further, the two-part tariff contract is more favorable to the manufacturer if the exogenously given retail price is low, and the wholesale price contract is more favorable to the manufacturer if the retail price is high; the two-part tariff contract is always more beneficial for the supply chain than the wholesale price contract. Finally, we extend our analysis to relax a more realistic form with a variable effort elasticity and verify the robustness of the theoretical results.

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1. Introduction

In recent years, with the popularity of smart mobile phones and the advance of short video technologies, the live streaming has witnessed explosive growth. For example, Statistics show that as of March 2020, the number of live streaming users was 265 million, accounting for 29.3% of the total Internet users in China.[1]

Especially during the COVID-19 epidemic, live streaming, as a new online contactless sales mode, has attracted more and more attention. With the boom of live streaming, platforms such as Taobao, JD.com,

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[1] College of Mathematics and Statistics, Huanggang Normal University, Hubei 438000, P.R. China.

[2] School of Mathematical Sciences, Jiangsu Second Normal University, Nanjing 211200, P.R. China.

*Corresponding author: zhouxj@hgnu.edu.cn

[1]https://www.sohu.com/a/391817965_190241 (Accessed 28 April, 2020).

TikTok, Amazon and YouTube have also launched the sales mode of the live broadcast room. For instance, according to statistics, in 2021, the number of live streaming of TikTok exceeded 75 million, and the number of commodity links exceeded 390 million.[2] The introduction of live streaming by e-tailers to sell products brings both opportunities and challenges to traditional e-commerce.

Many e-tailers sell their products through both the traditional e-commerce channel as well as the live streaming channel. In the traditional e-commerce channel, e-tailers wholesale products from the manufacturers, and sell them at a retail price through traditional online platforms such as official websites, Tmall, JD.com, Amazon, mobile APP, and mini program, and then deliver the products to consumers through express logistics to complete the transaction. In the live streaming channel, e-tailers hire anchors to sell wholesale products from the manufacturers in the live broadcast rooms. The anchors can communicate with consumers "face to face" in the live broadcast rooms, and answer consumers' questions about the product through timely interaction with consumers, and show the effect of the product "visible". Compared with the traditional e-commerce channel, the live streaming channel can better help the retailers get in touch with consumers directly and improve the consumers' shopping convenience. For example, a report showed that the market of live streaming in China achieved CNY 1.2 trillion in 2021, which is expected to rise to CNY 1.51 trillion in 2022.[3] What's more surprising is that on "Double 11" in 2018, a live broadcast led to CNY 267 million in sales, with CNY 330 million of products sold in one day. On the other hand, some consumers are highly worried that their private information (such as home address details, personal shopping histories, personal purchasing preferences, etc.) may be divulged during the e-payment process and monitored by the live streaming. Bansel *et al.* [4], Cheah *et al.* [7], and Choi [9] demonstrate that privacy concern reduces consumers' shopping intention in online transactions using empirical and theoretical methods respectively. For the traditional e-commerce channel, other payment methods, such as Alipay or credit card, can be used, and are processed by a third party. Even though they might not be as serious as they are with live streaming, privacy concerns are still present with traditional e-commerce. Therefore, consumers may struggle with the tradeoff between shopping convenience and privacy concerns between the live streaming channel and the traditional e-commerce channel.

In practice, manufacturers generally manage retail channels through contracts to coordinate supply chain and improve its efficiency. There are many kinds of common contracts in supply chain. Our study considers two typical contracts, namely wholesale price contract and two-part tariff contract. The wholesale price contract has a double marginalization effect of reducing system profits, but the manufacturers still prefer to provide the wholesale price contract with the e-tailers because this contract is simple and easy to implement [5]. Compared with the wholesale price contract, the two-part tariff contract can coordinate the supply chain and achieve optimal channel profits [16]. The two-part tariff contract requires the e-tailer to pay a fixed fee to the manufacturer for the right to sell the product, and then the manufacturer sells the product to the e-tailer at a preset wholesale price [6, 12]. Moreover, two-part tariff contract is easy to coordinate supply chain and can effectively motivate retailers, so it is widely used and plays a great role in retail channel management practice. For the supply chain system in which multiple e-commerce channels jointly sell one manufacturer's products, the non-cooperative game between channels will lead to the complexity and difficulty of coordination. Therefore, it is of great significance to study how channel competition affects the coordination design and operation performance of different contracts.

Motivated by the above considerations, we build a supply chain analysis model involving a manufacturer and an e-tailer selling products *via* dual channel (*i.e.*, live streaming channel and traditional e-commerce channel) to explore how shopping convenience and privacy concern affect the optimal decisions under two contracts (*i.e.*, wholesale price contract and two-part tariff contract) and two pricing (exogenous and endogenous). In particular, our research attempts to address the following questions: (1) What are the optimal decisions? How would the optimal decisions depend on shopping convenience and privacy concern? (2) How to coordinate the dual channel supply chain? Can the classic incentive alignment contracts like wholesale price and two-part

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[2] https://new.qq.com/rain/a/20220210A08JA800 (Accessed 10 February, 2022).
[3] https://www.askci.com/news/chanye/20220318/1451401746320_2.shtml (Accessed 1 July 2022).

tariff help to achieve coordination? (3) Which contract is preferable from the perspective of the supply chain participants?

To address these questions, we solve the four models using backward induction to obtain the optimal decisions and the corresponding supply chain participant profits, and perform a sensitivity analysis of them with respect to the key parameters. We generate a number of interesting findings and insights. First, when the retail price is exogenously given, the optimal promotion efforts are negatively related to shopping convenience and positively related to privacy concerns under the wholesale price contract, and they are independent of shopping convenience and privacy concerns under the two-part tariff contract; When the retail price is endogenous, the optimal promotion efforts are all positively related to shopping convenience and negatively related to privacy concerns under both wholesale price and two-part tariff contracts. Second, whether the retail selling price is endogenous or exogenous, supply chain coordination can be achieved by the two-part tariff contract, but not through the wholesale price contract. Third, the two-part tariff contract is more favorable to the manufacturer if the exogenously given retail price is low, and the wholesale price contract is more favorable to the manufacturer if the retail price is high; whether the retail selling price is endogenous or exogenous, the two-part tariff contract is always more beneficial for the supply chain than the wholesale price contract.

This paper makes some theoretical and practical contributions. The first is to explicitly explores the live streaming and traditional e-commerce dual channel supply chain system with a focal point on shopping convenience and privacy concerns levels. The second is to derive some novel insights which contribute to the supply chain management literature as well as help advance our knowledge of live streaming and traditional e-commerce dual channel systems management in practice.

The rest of this paper is organized as follows: We first outline the literature related to our work in Section 2, following which, we present our model in Section 3 and give the equilibrium and analysis in Section 4. We then discuss our findings and key insights in Section 5, and relax some assumptions to extend our analysis in Section 6 before offering our conclusions and suggestions for future research in Section 7. All the proofs are presented in the Appendix.

2. Literature review

Our study involves many aspects, such as live streaming, traditional e-commerce, supply chain coordination, shopping convenience, privacy concern and dual channels. In order to focus on the topic, in this section, we mainly review the literature from the three aspects of live streaming, supply chain coordination and dual channel, and locate our work in the literature.

The first stream of related literature is about live streaming. Live streaming is a new form of online shopping, which allows customers to communicate with streamers in real time [19]. One focus of the study on live streaming is the factors that affect consumers' shopping behaviors, such as consumers' willingness to use [8], consumers' trust [13] and influencer effect [14]. For example, Park and Lin [21] focus on live streaming shopping with internet celebrities in China as they investigated the effects of different matches on consumer attitudes. Another focus is that the popularity of live streaming increases the integration of platforms with it. For instance, Chen and Lin [8] investigate how customer behavior is impacted by platform-generated elements as flow, social engagement, and endorsement. Sun *et al.* [25] believe that elements of live streaming shopping platforms, such as IT visibility, have a significant impact on consumer behavior. Li *et al.* [18] create a theoretical framework to explain how live-streaming services affect user engagement. Our study is most related to the research of Zhang *et al.* [34] in exploring the intersection of the live streaming and traditional e-commerce; however, we focus on analytically highlighting the influences of privacy concern, shopping convenience, and the dual channel, while they investigate how the live streaming affect the operation strategy selection for the members of an e-commerce platform supply chain by introducing the live streaming into an e-commerce platform supply chain.

The second stream of related literature is about supply chain coordination. Supply chain coordination is an interdependent behavior of supply chain participants working together to achieve goals [2]. The dependency between supply chain members can be managed through some coordination means and mechanisms, such as the use of contracts to manage supply and demand relations and control risks, so as to improve the performance of the supply chain [9]. The objectives of supply chain contracts are to increase the total supply chain profit, to reduce overstock/understock costs and to share the risks among the supply chain partners [27]. This paper involves two types of contracts, namely wholesale price contract and two-part tariff contract. Regarding the wholesale price contract, Yan *et al.* [32] design two coordination contracts based on revenue sharing and wholesale price for the decentralized decision making in fresh agricultural product supply chain. Sarkar and Bhala [24] show that a wholesale price contract can sometimes coordinate a decentralised channel in a manufacturer-led supply chain. Regarding the two-part tariff contract, Qian *et al.* [22] investigate the environmental performance and channel profit under the wholesale price contract and two-part tariff contract in a sustainable supply chain. Ji and Liu [17] study whether the two-part tariff can achieve the purpose of reducing risks and coordinating supply chain. Our study is similar to the research of Choi [9] in exploring the coordination mechanisms in dual channel system; however, we focus on analytically highlighting the traditional e-commerce channel and the live streaming channel, while they study Mobile App channel and online website channel.

The three stream of related literature is on dual channels. Recent years, many firms adopt more than one single channel to sell their products and attract consumer demand. In particular, the deep development of the Internet has enhanced the framework of world trade, and many firms have embraced online channels and mobile channels in addition to traditional retail channels [10,23]. Previous studies focus on three critical facets in dual channels, *i.e.*, competition and coordination, pricing strategies and consumer shopping behaviors. For competition and coordination, Xu *et al.* [30] study competition between homogenous retailers, Yang *et al.* [33] examine competition and coordination between upstream seller and downstream buyer, David and Adida [11] study competition and coordination among all supply chain members, Amrouche *et al.* [1] explore coordination between e-commerce online channel and traditional offline channel. For pricing strategies, Xia *et al.* [29] study the pricing power under dual channels and find that pricing power affect manufacturers' motivation for dual-channel development. Matsui [20] shows that when implementing a multi-channel sales strategy, manufacturers publish direct prices before or after setting wholesale prices for retailers in order to maximize profits. Wang *et al.* [28] find that if manufacturers can always achieve higher profits if they announce pricing decisions before physical retailers. Yan *et al.* [31] examine when to and how to make pricing decisions in a dual channel supply chain. For consumer shopping behaviors, Hsiao and Chen [15] study the characteristics of consumers who prefer online shopping and consumers who prefer offline shopping. Balakrishnan *et al.* [3] examine the phenomenon of consumers browsing products in physical retail stores and then switching to online shopping to place orders. Our study belongs the above three facets of studies in dual channels. For competition and coordination, we discuss competition and coordination between manufacturers and e-tailers in dual channels. We also examine exogenous and endogenous pricing, and study the influences of privacy concern and shopping convenience on consumer behaviors.

3. Model description

We consider a supply chain including a manufacturer and an e-tailer. The product is produced by the manufacturer at a unit cost of c and supplies to the e-tailer at a unit wholesale price of w. The e-tailer adopts two sales channels, namely the live streaming (L) channel (*e.g.*, the TikTok) and the traditional e-commerce (T) channel (*e.g.*, the official company website). We assume that the e-tailer sells the product to the market at retail price p in both the live streaming channel and the traditional e-commerce channel. For example, HUAWEI sells mobile phones (such as HUAWEI Mate 50) to e-tailers at a certain wholesale price, and then e-tailers sell them to users at a uniform price of CNY 4999 through online stores or live streaming rooms. Figure 1 shows structure diagram of the supply chain under our exploration.

3.1. Notation and assumptions

In order to facilitate the subsequent research, we make the following model assumptions:

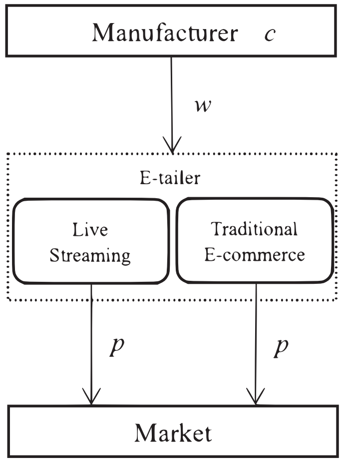


FIGURE 1. Structure diagram of the supply chain.

TABLE 1. Summary of notations.

w	Wholesale price of the product
p	Retail price of the product
D_i	Demand for the product with respect to the channel i, $i = L, T$
a_i	Basic scale of demand for the product with respect to the channel i, $i = L, T$
c	Unit cost of the product
b	Price sensitivity with respect to the traditional e-commerce channel
s_i	Shopping convenience level with respect to the channel i, $i = L, T$
h_i	Privacy concern with respect to the channel i, $i = L, T$
e_i	Promotion effort with respect to the channel i, $i = L, T$
k_i	Constant of promotion effort with respect to the channel i, $i = L, T$
T	Fixed credit transfer
π_M	Profit of the manufacturer
π_E	Profit of the e-tailer
π_{SC}	Profit of the supply chain

– Assume that $p > w > c$ to ensure the marginal profit is positive so that all the profits of supply chain participants are nonnegative.
– Assume that the customers in the live streaming channel are more sensitive to the retail price than in the traditional e-commerce channel. Statistics show that 70% of the customers of live streaming channel are low-income people, for whom low price is the main factor to attract them.[4]
– Assume that the live streaming channel brings consumers more shopping convenience but poses consumers more privacy concern compared to the traditional e-commerce channel.
– Assume that the costs of transportation and storage of the products is zero.
– Assume that the manufacturer and e-tailer are risk neutral.
– Assume that no information asymmetry exists among supply chain participants.
– Assume that the products in dual channels are homogenous.

Table 1 presents an overview of the model parameters.

[4]http://www.ifastdata.com/data/upload/ueditor/20211009/616104925d62a.pdf (Accessed 13 April 2022).

3.2. Promotion effort

In practice, the e-tailer needs to exert promotion effort in each channel in order to manage demand and maximize profit. In the traditional e-commerce channel, the e-tailers make efforts to increase the sales of their products by advertising, creating beautiful web pages, spending points for redemption, membership benefits and so on. In the live-streaming channel, the e-tailers increase sales of merchandise through efforts such as hiring well-known anchors, sales talk, and live studio set-up. In our study, e_L and e_T denote the promotion efforts for the live streaming channel and the traditional e-commerce channel, respectively. Exerting the promotion effort requires a cost, which we denote the costs by $k_L e_L^2/2$ and $k_T e_T^2/2$ for the live streaming channel and the traditional e-commerce channel, respectively. $k_L, k_T \geq 1$ are positive constants. Similar with Taylor [26], we assume the case when the costs are both convex increasing. With loss of generality, we assume the costs take this quadratic form. Define the first-order derivatives of $k_L e_L^2/2$ and $k_T e_T^2/2$ as follows and they are both increasing functions: $k_L e_L$ and $k_T e_T$.

3.3. Customer demand

As stated in the introduction, a higher shopping convenience level and a lower privacy concern level lead to a higher demand for products in the live streaming channel and traditional e-commerce channel. Moreover, the demand is generally negatively related to the retailer price of product, and positively related to promotion effort. For ease of exposition, we therefore model the demands of the live streaming channel and the traditional e-commerce channel as functions of retailer price, shopping convenience level, privacy concern and promotion effort, respectively:

$$D_L = a_L - p + s_L - h_L + e_L, \tag{1}$$

and

$$D_T = a_T - bp + s_T - h_T + e_T. \tag{2}$$

Where a_L, a_T denote the basic scale of demands for the live streaming channel and the traditional e-commerce channel, respectively. Similar with Choi [9], we assume that a_L, a_T are large enough to ensure $a_i - p - h_i > 0$, $i = L, T$ such that the ultimate demands are nonnegative. $b \in (0, 1)$ reflects the price sensitivity with respect to the traditional e-commerce channel, and that for the live streaming channel is scaled to be 1. Herein, b less than 1 reflects the second hypothesis in the previous subsection. $s_L > s_T > 0$ represent the shopping convenience levels inherent to the live streaming channel and the traditional e-commerce channel, respectively; clearly, the shopping convenience level increases demand; the values for s_L and s_T are related to the utility of the consumer in terms of the convenience they experience while shopping. $h_L > h_T > 0$ represent the privacy concerns inherent to the live streaming channel and the traditional e-commerce channel, respectively; intuitively, the privacy concern decreases demand, for example, customers may worry that their private information, such as home addresses, personal purchasing histories, preferences, etc., would be recorded and may be stolen by others while they are shopping. $e_L, e_T > 0$ represent the promotion efforts for the live streaming channel and the traditional e-commerce channel, respectively. In this demand curve we assume that, like e_L, e_T has a leading coefficient of 1 (*i.e.*, effort sensitivity of demand equals 1). In fact, the results for arbitrary sensitivity coefficient can be obtained through a scaling of the equilibrium effort and corresponding adjustments of other related coefficients. Furthermore, to explore the impacts of a flexible sensitivity on the results, we extend the demand function to a more realistic form with a variable promotion effort elasticity in Section 6, and present how the sensitivity coefficients of e_L and e_T affect the equilibrium strategies.

3.4. Incentive contracts

To achieve channel coordination, we examine two different representative incentive contracts, *i.e.*, wholesale pricing contract (W) and two-part tariff contract (T). Supply chain coordination is a key topic in classical supply chain system management. In general, supply chain coordination should meet the following requirements: First, the optimal decision of supply chain agent in decentralized system setting is the same as that in centralized system setting; Second, all supply chain agents can achieve the corresponding minimum (expected profit target), that is, fulfill the participation constraint [9]. The key to realize coordination of supply chain is to realize the optimality of the system and meet the minimum profit requirements of individuals so that they are willing to join the supply chain. Under the wholesale pricing contract, the manufacturer offers a wholesale price w to the e-tailer for each unit of product supplied. This is the simplest supply contract commonly adopted and most widely observed in the real world, in which there is only one single contract parameter w. Under the two-part tariff contract, the manufacturer attracts the e-tailer to order more products by lowering the wholesale price, so the e-tailer's revenue increases due to the lower wholesale price, and the e-tailer offers a certain pre-determined fixed credit transfer T to the manufacturer to ensure the manufacturer can get a certain amount of compensation for the revenue loss caused by the lower wholesale price.

The sale of different types of products by e-tailers causes the supply chain to face the issue of whether retail price is a decision, namely exogenous pricing and endogenous pricing. With the exogenous pricing, the retail selling price is exogenously given and the e-tailer simply sells the product to the market at the given price. This usually occurs when a product's selling price is determined strategically by a powerful brand (such as the iPhone), or by the government or the market (*e.g.*, newspaper). For example, the iPhone 14 Pro costs from USD 999 either on Amazon Live or on the official store in the United States.[5] Another example, the 53 degree Feitian Moutai in August 2023 is priced at about CNY 2089 whether on Tiktok or on JD.com in China. With the endogenous pricing, the product's retail selling price is endogenously. This commonly happens in our real markets, such as seasonal products (*e.g.*, mangoes). When the fruit growers give a wholesale price of mangoes, the e-tailers determine the retail price with the goal of maximizing its own profit.

3.5. Profits of the participants

Accordingly, the profits of supply chain participants under two incentive contracts can be described. Under the Contract W, the profits of the manufacturer and the e-tailer are as follows

$$\pi_M = (w - c)(D_L + D_T), \tag{3}$$

and

$$\pi_E = (p - w)(D_L + D_T) - \frac{k_L e_L^2}{2} - \frac{k_T e_T^2}{2}\cdot \tag{4}$$

Under the Contract T, the profits of the manufacturer and the e-tailer are as follows

$$\pi_M = (w - c)(D_L + D_T) + T, \tag{5}$$

and

$$\pi_E = (p - w)(D_L + D_T) - T - \frac{k_L e_L^2}{2} - \frac{k_T e_T^2}{2}\cdot \tag{6}$$

In the two contracts, the profit of the supply chain is equal to the sum of π_M and π_E, and can be expressed as follows

$$\pi_{\mathrm{SC}} = (p - c)(D_L + D_T) - \frac{k_L e_L^2}{2} - \frac{k_T e_T^2}{2}\cdot \tag{7}$$

[5]https://www.apple.com/shop/buy-iphone/iphone-14-pro (Accessed 8 September, 2022).

4. Equilibrium and analysis

In this section, we first examine the equilibrium solutions for two contracts with two pricing options, and then analyze their sensitivities regarding key parameters.

For ease of exposition, we define indexes i and j, where $i \in \{E, D\}$ represents the exogenous pricing ($i = E$) or endogenous pricing ($i = D$), and $j \in \{W, T\}$ denotes the manufacturer and the e-tailer choose wholesale pricing contract ($j = W$) or two-part tariff contract ($j = T$). For example, index EW represents the case where the manufacturer and the e-tailer choose wholesale pricing contract with the exogenous pricing.

The sequence of events is summarized as follows. In the Case EW, the manufacturer determines w by maximizing its own profit in the first stage, and e_L and e_T are decided by maximizing the e-tailer's profit in the second stage; in the Case ET, the manufacturer determines w by maximizing its own profit in the first stage, and e_L and e_T are decided by maximizing the profit of the supply chain in the second stage; in the Case DW, the manufacturer firstly determines w by maximizing its own profit in the first stage, and the e-tailer decides p, e_L and e_T by maximizing its own profit in the second stage; in the Case DT, the manufacturer firstly determines w by maximizing its own profit in the first stage, p, e_L and e_T are decided by maximizing the profit of the supply chain in the second stage.

Backward induction can be used to solve the four cases. Herein, we take the Case EW as an example to carry out formal analysis. The similar analysis and the equilibrium solutions of the other three cases (ET, DW, DT) are also available.

We solve the equilibrium of the Case EW by a backward induction method in detail.

Checking the Hessian matrix of π_E^{EW} with respect to e_L and e_T:

$$\begin{pmatrix} -k_L & 0 \\ 0 & -k_T \end{pmatrix}, \tag{8}$$

we find it is negatively definite. This shows that π_E^{EW} is a jointly concave function of e_L and e_T. Thus, solving the first-order conditions yields the optimal promotion efforts:

$$\frac{\partial \pi_E^{\mathrm{EW}}}{\partial e_L} = 0 \Rightarrow e_L^* = \frac{p-w}{k_L}, \tag{9}$$

$$\frac{\partial \pi_E^{\mathrm{EW}}}{\partial e_T} = 0 \Rightarrow e_T^* = \frac{p-w}{k_T}\cdot \tag{10}$$

By substituting e_L^* and e_T^* into π_M^{EW}, then π_M^{EW} is concave in w. we can solve the first-order optimality condition for w:

$$\frac{\partial \pi_M^{\mathrm{EW}}}{\partial w} = 0 \Rightarrow w = \frac{A}{2B} + \frac{p+c}{2}, \tag{11}$$

where $A = a_L + a_T + s_L + s_T - h_L - h_T - (1+b)p$, $B = \frac{1}{k_L} + \frac{1}{k_T}$.

By substituting w into e_L^* and e_T^*, then we can obtain the optimal promotion efforts:

$$e_L = \frac{1}{2k_L}\left(p - c - \frac{A}{B}\right), \tag{12}$$

$$e_T = \frac{1}{2k_T}\left(p - c - \frac{A}{B}\right)\cdot \tag{13}$$

Substituting w, e_L and e_T into π_M, π_E and π_{SC}, we can obtain the profits of the manufacturer, the e-tailer and the supply chain in the Case EW:

$$\pi_M^{\mathrm{EW}} = \frac{1}{2}\left[\frac{A^2}{k_L B^2} + A(p-c) + \frac{(p-c)^2}{k_T}\right], \tag{14}$$

TABLE 2. The sensitivity analysis towards the optimal decisions and corresponding profits.

Parameter	w^{EW}	e_L^{EW}	e_T^{EW}	π_M^{EW}	π_E^{EW}	$\pi_{\mathrm{SC}}^{\mathrm{EW}}$	w^{ET}	e_L^{ET}	e_T^{ET}	π_M^{ET}	$\pi_{\mathrm{SC}}^{\mathrm{ET}}$	w^{DW}
$s_L \uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	–	–	$\uparrow$	$\uparrow$	$\uparrow$
$s_T \uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	–	–	$\uparrow$	$\uparrow$	$\uparrow$
$h_L \uparrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	–	–	$\downarrow$	$\downarrow$	$\downarrow$
$h_T \uparrow$	$\downarrow$	$\uparrow$	$\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	–	–	$\downarrow$	$\downarrow$	$\downarrow$
Parameter	p^{DW}	e_L^{DW}	e_T^{DW}	π_M^{DW}	π_E^{DW}	$\pi_{\mathrm{SC}}^{\mathrm{DW}}$	w^{DT}	p^{DT}	e_L^{DT}	e_T^{DT}	π_M^{DT}	$\pi_{\mathrm{SC}}^{\mathrm{DT}}$
$s_L \uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$
$s_T \uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$
$h_L \uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$
$h_T \uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$

Notes. $\uparrow$ means the decision (such as p) increases with the parameter (such as a_L); $\downarrow$ means the decision decreases with the parameter; "–" denotes "no effect".

$$\pi_E^{\mathrm{EW}} = \frac{3\,(c-p)^2}{8\,k_T} - \frac{A^2\,{k_L}^3}{2\,(k_L+k_T)^2} - \frac{(c-p+A\,k_L)\,(c-p+5\,A\,k_L)}{8\,k_L} + \frac{A\,k_L\,(8\,c-8\,p+9\,A\,k_L)}{8\,k_L+8\,k_T}, \tag{15}$$

$$\pi_{\mathrm{SC}}^{\mathrm{EW}} = \frac{A(p-c)}{k_L B} - \frac{(p-c)^2}{k_T} - \frac{[A-B(p-c)]^2}{8B}. \tag{16}$$

The equilibrium of the Cases ET, DW and DT by a backward induction method are presented in the Appendix A. The optimal decisions and the profits of the supply chain participants of all four cases are summarized as Lemma 1.

Lemma 1. *The optimal solutions to the wholesale price, retail price, and promotion efforts, and the profits of the manufacturer, e-tailer, supply chain are summarized as follows.*

In the Case EW, $w = \frac{A}{2B} + \frac{p+c}{2}$, $e_L = \frac{1}{2k_L}(p-c-\frac{A}{B})$, $e_T = \frac{1}{2k_T}(p-c-\frac{A}{B})$, $\pi_M^{\mathrm{EW}} = \frac{1}{2}[\frac{A^2}{k_L B^2} + A(p-c) + \frac{(p-c)^2}{k_T}]$, $\pi_E^{\mathrm{EW}} = \frac{3\,(p-c)^2}{8\,k_T} - \frac{A^2\,{k_L}^3}{2\,(k_L+k_T)^2} - \frac{(c-p+A\,k_L)\,(c-p+5\,A\,k_L)}{8\,k_L} + \frac{A\,k_L\,(8\,c-8\,p+9\,A\,k_L)}{8\,k_L+8\,k_T}$, $\pi_{\mathrm{SC}}^{\mathrm{EW}} = \frac{A(p-c)}{k_L B} - \frac{(p-c)^2}{k_T} - \frac{[A-B(p-c)]^2}{8B}$. *In the Case* ET, $w = p - \frac{2T+B(p-c)^2}{2A+2B(p-c)}$, $e_L = \frac{p-c}{k_L}$, $e_T = \frac{p-c}{k_T}$, $\pi_M^{\mathrm{ET}} = \pi_{\mathrm{SC}}^{\mathrm{ET}} = A(p-c) + \frac{(p-c)^2}{2}B$. *In the Case* DW, $w = \frac{(A_L+A_T)[(1+b)+B]+c(1+b)^2}{(1+b)[2(1+b)+B]}$, $p = \frac{(A_L+A_T)[3(1+b)^2+(1+b)B-B^2]+c(1+b)^2[(1+b)-B]}{(1+b)[4(1+b)^2-B^2]}$, $e_L = \frac{(1+b)[A_L+A_T-(1+b)c]}{k_L[4(1+b)^2-B^2]}$, $e_T = \frac{(1+b)[A_L+A_T-(1+b)c]}{k_T[4(1+b)^2-B^2]}$, $\pi_M^{\mathrm{DW}} = \frac{(1+b)\,[B+(1+b)]\,[(A_L+A_T)-cB]\,[A_L+A_T-(1+b)c]}{[2(1+b)-B]\,[2(1+b)+B]^2}$, $\pi_E^{\mathrm{DW}} = \frac{(1+b)^3[(A_L+A_T)-cB][(A_L+A_T)+cB-2c(1+b)]}{[4(1+b)^2+B^2]^2} - \frac{B(1+b)^2[A_L+A_T-(1+b)c]^2}{2[4(1+b)^2-B^2]^2}$, $\pi_{\mathrm{SC}}^{\mathrm{DW}} = \frac{k_L k_T(1+b)[2B+3(1+b)][A_L+A_T-(1+b)c]^2}{2[2(1+b)-B][2(1+b)+B]^2}$. *In the Case* DT, $w = \frac{A_L+A_T+c(1+b)-cB}{2(1+b)-B} - \frac{2[2(1+b)-B]^2 T+[A_L+A_T+c(1+b)-cB]^2}{2[2(1+b)-B](A_L+A_T)(1+b)+2c[2(1+b)-B][(1+b)-B]}(\frac{1}{k_L} - \frac{1}{k_T})$, $p = \frac{[A_L+A_T+(1+b)c]-Bc}{2(1+b)-B}$, $e_L = \frac{A_L+A_T-(1+b)c}{k_L[2(1+b)-B]}$, $e_T = \frac{A_L+A_T-(1+b)c}{k_T[2(1+b)-B]}$, $\pi_M^{\mathrm{DT}} = \pi_{\mathrm{SC}}^{\mathrm{DT}} = \frac{[A_L+A_T+c(1+b)-cB]^2}{2[2(1+b)-B]^2}(\frac{1}{k_T} - \frac{1}{k_L}) + [A_L + A_T + \frac{A_L+A_T+c(1+b)-cB}{2(1+b)-B}(1+b-B)]\frac{A_L+A_T-c(1+b)}{2(1+b)-B}$. *Where* $A = a_L + a_T + s_L + s_T - h_L - h_T - (1+b)p$, $B = \frac{1}{k_L} + \frac{1}{k_T}$, $A_L = a_L + s_L - h_L$, $A_T = a_T + s_T - h_T$.

Lemma 1 shows that there exists a unique optimal solution to the wholesale price, retail price, and promotion efforts under four different cases.

Moreover, using the optimal decisions and corresponding profits of all four cases, we conduct a sensitivity analysis towards them. Corollary 1 summarizes the major findings and trends.

Corollary 1. *The impact of* s_L, s_T, h_L *and* h_T *on the optimal solutions to* w, p, e_L *and* e_T *and profits of the supply chain participants* π_M, π_E *and* π_{SC} *are summarized in Table 2.*

Corollary 1 shows the sensitivity of the wholesale prices, retail prices, promotion efforts, and profits of supply chain participants with respect to shopping convenience and privacy concerns in four cases. To be specific, under the Contract W with exogenous pricing, the promotion efforts are decreasing in shopping convenience while increasing in privacy concerns, however, the wholesale price, the profits of the manufacturer, e-tailer and supply chain are all increasing in shopping convenience while decreasing in privacy concerns. Intuitively, when the retail price of products is given exogenously, the more convenient the e-retail channel shopping is, the less promotion effort is required, while consumers' privacy concerns require more effort. Furthermore, more promotion efforts lead to more promotion cost, and e-tailer may drive down the wholesale price through the constraints of contract to obtain greater marginal profit in order to improve its profit. Accordingly, the wholesale price decreases as promotion efforts increases, that is, the wholesale price is increasing in shopping convenience while decreasing in privacy concerns. What's more, increased shopping convenience and reduced privacy concerns will both lead to increased demand, which increase the profits of supply chain participants. Under the Contract T with exogenous pricing, the wholesale price, the promotion efforts independent of shopping convenience and privacy concerns, and the profits of the manufacturer and supply chain are all increasing in shopping convenience while decreasing in privacy concerns. From the mathematical formulas of promotion efforts, it can be found that they are only positively related to a given retail price. This suggests that under the Contract T, the promotion efforts of channels selling special products controlled by a giant brand (*e.g.*, i-phone) or a government (*e.g.*, newspaper) have nothing to do with shopping convenience and privacy concerns. Under the Contracts W and T with endogenous pricing, the wholesale price, the retailer price, the promotion efforts and the profits of the manufacturer, e-tailer and supply chain are all increasing in shopping convenience while decreasing in privacy concerns. The increase in the service capability of dual channels (*i.e.*, the increase in shopping convenience and the decrease in privacy concerns), the increase in strategic retail prices, leads to the increase in wholesale prices. Furthermore, increased shopping convenience and reduced privacy concerns will both lead to increased demand, which increase the profits of supply chain participants.

5. Comparison and implications

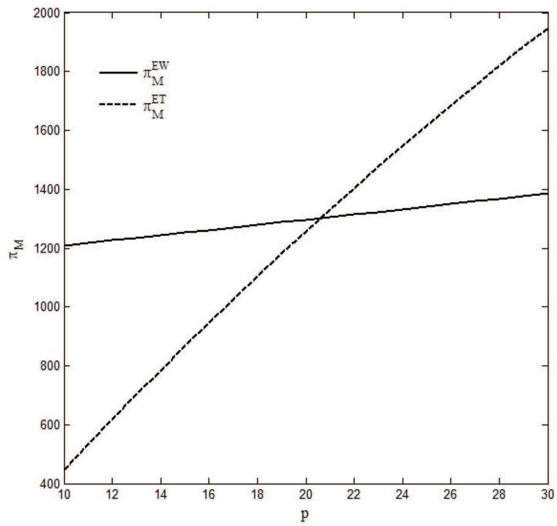
In this subsection, we will examine two issues, one on how to achieve coordination in a dual-channel supply chain, and the other on which of the two contracts is more beneficial to the supply chain participants.

5.1. Supply chain coordination

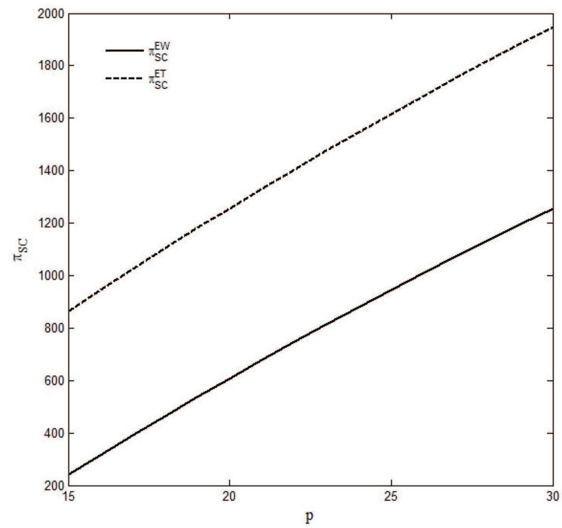
First, we study the coordination of the dual channel supply chain. Theorem 1 shows the findings on channel coordination with the exogenous and endogenous pricing.

Theorem 1. *With the exogenous or endogenous pricing, the Contract W fails to coordinate the supply chain; supply chain coordination can be achieved by* $w = c$ *and* $\overline{\pi}_M \leq T \leq \pi_{\mathrm{SC}} - \overline{\pi}_E$ *under the Contract T, where* $\overline{\pi}_M$ *and* $\overline{\pi}_E$ *denote the minimum profits of the manufacturer and e-tailer under the Contract T, respectively.*

Theorem 1 states that the Contract T can coordinate the supply chain while the Contract W cannot, regardless of whether the retail selling price is exogenously given or endogenously decided. The Contract T can be helpful for the manufacturer and e-tailer to achieve supply chain coordination. To avoid the double marginalization effect, the manufacturer must supply at cost under Contract T, which is a requirement of the contract setting. A credit transfer is then made available to the manufacturer as compensation under Contract T. Additionally, the double marginalization effect may be eliminated by Contract W. However, the manufacturer will make no profit as a result, which does not meet the minimum profit requirement. The supply chain is therefore not coordinated by Contract W. Therefore, in order to optimize the performance of the dual channel supply chain system, e-tailers should carefully select the appropriate supply contracts. The two-part tariff contract in particular is a strong candidate to support.



(a)



(b)

FIGURE 2. Comparison of the profits of supply chain participants with the exogenous pricing. (a) Comparison of π_M^{EW} and π_M^{ET}. (b) Comparison of $\pi_{\text{SC}}^{\text{EW}}$ and $\pi_{\text{SC}}^{\text{ET}}$.

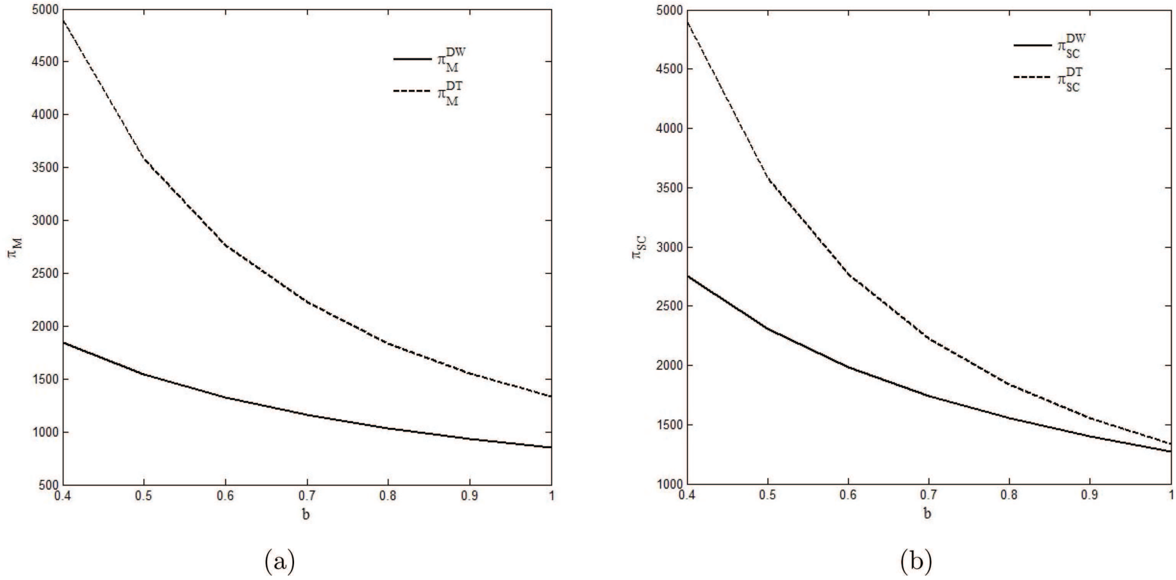
5.2. Profit comparison

In this subsection, we compare the profits of supply chain participants under two types of contracts with exogenous pricing and endogenous pricing respectively in order to study which contract is more favorable to supply chain participants under a particular pricing way. Theorem 2 presents the findings.

Theorem 2. *With the exogenous pricing, the manufacturer's profit under the Contract W is greater than that under the Contract T if the retail price is set lower, the manufacturer's profit under contract T is greater than the profit under contract W if the retail price is set higher; The e-tailer's profit under the Contract W is always greater than that under the Contract T; The profit of the supply chain under the Contract T is always greater than that under the Contract W. With the endogenous pricing, the manufacturer's profit under the Contract T is always greater than that under the Contract W; The e-tailer's profit under the Contract W is always greater than that under the Contract T; The profit of the supply chain under the Contract T is always greater than that under the Contract W.*

Numerical experiments are used to prove Theorem 2. We conduct numerical experiments in the following way: With the exogenous pricing, we focus on the influence of the exogenous retail pricing on the profits of supply chain participants, and the values of other parameters set as $a_L = 50$, $a_T = 50$, $s_L = 1.2$, $s_T = 1$, $h_L = 1.2$, $h_T = 1$, $k_L = 1.2$, $k_T = 1$, $c = 5$, $b = 0.5$ (the numerical results are shown in Fig. 2); With the endogenous pricing, we focus on the influence of the price sensitivity coefficient on the profits of supply chain participants, and the values of other parameters set as $a_L = 50$, $a_T = 50$, $s_L = 1.2$, $s_T = 1$, $h_L = 1.2$, $h_T = 1$, $k_L = 1.2$, $k_T = 1$, $c = 5$ (the numerical results are shown in Fig. 3).

Theorem 2 reveals the contract that supply chain participants expect from their own profits with the exogenous and endogenous pricing. When a given retail price is low, the manufacturer expects a wholesale price contract, otherwise it expects a two-part tariff contract. The reason for this result is that a lower given retail price leads to more promotion effort under a wholesale price contract and a higher retail price leads to more promotion effort under a two-part tariff contract (see Prop. 1 in Appendix A). What's more, the promotion



(a) (b)

FIGURE 3. Comparison of the profits of supply chain participants with the endogenous pricing. (a) Comparison of π_M^{DW} and π_M^{DT}. (b) Comparison of $\pi_{\mathrm{SC}}^{\mathrm{DW}}$ and $\pi_{\mathrm{SC}}^{\mathrm{DT}}$.

efforts are made by e-tailer, and the manufacturer is certainly willing to reap the benefits. With the exogenous or endogenous pricing, the two-part tariff contract is always more beneficial for the supply chain than the wholesale price contract. The key driver for these results is that the wholesale price contract has the double marginalization effect of reducing the profit of the supply chain system, leading to the decrease of the demand, while the two-part tariff contract eliminated this double marginalization effect, increases the demand, and thus improves the profit of the supply chain. From the perspective of supply chain coordination and the benefit of the supply chain, the two-part tariff contract is a good choice compared with the wholesale price contract.

Figures 2 and 3 not only numerically verify the conclusions in Theorem 2, but also reveal the impact of key parameters on the profits of the supply chain participants. An intuitive phenomenon can be seen in Figure 2, where the profits of both the manufacturer and the supply chain increase with a given retail price. From Figure 3, it can be found that the profits of both the manufacturer and supply chain decrease with sensitivity of the strategic retail price with respect to the traditional e-commerce channel. The possible reason for this interesting phenomenon is that when consumers in the traditional e-commerce channel are too sensitive to the retail price, the demand inevitably decrease, which may reduce the profits of both manufacturer and supply chain.

6. Extension

In Section 3.2, we assume that the coefficients of the promotion efforts in both demand functions are 1. Indeed, the impact of channel promotion efforts on demand may be somewhat elasticity. For example, in the live streaming channel, product sales may be increased by hiring well-known Internet celebrities with traffic. In the traditional e-commerce channel, it is also possible to increase sales by placing products near the top of the search list. Therefore, we change the effort-sensitive parameter from one to a general value to reflect this elasticity. That is, the demand functions become

$$D_L = a_L - p + s_L - h_L + fe_L, \tag{17}$$

Table 3. The sensitivity analysis towards the optimal decisions and corresponding profits in the extended models.

Parameter	w^{EEW}	e_L^{EEW}	e_T^{EEW}	π_M^{EEW}	π_E^{EEW}	$\pi_{\text{SC}}^{\text{EEW}}$	w^{EET}	e_L^{EET}	e_T^{EET}	π_M^{EET}	$\pi_{\text{SC}}^{\text{EET}}$	w^{EDW}
$s_L \uparrow$	↑	↓	↓	↑	↑	↑	↑	–	–	↑	↑	↑
$s_T \uparrow$	↑	↓	↓	↑	↑	↑	↑	–	–	↑	↑	↑
$h_L \uparrow$	↓	↑	↑	↓	↓	↓	↓	–	–	↓	↓	↓
$h_T \uparrow$	↓	↑	↑	↓	↓	↓	↓	–	–	↓	↓	↓
$f \uparrow$	↓	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↓
$g \uparrow$	↓	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↓
Parameter	p^{EDW}	e_L^{EDW}	e_T^{EDW}	π_M^{EDW}	π_E^{EDW}	$\pi_{\text{SC}}^{\text{EDW}}$	w^{EDT}	p^{EDT}	e_L^{EDT}	e_T^{EDT}	π_M^{EDT}	$\pi_{\text{SC}}^{\text{EDT}}$
$s_L \uparrow$	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
$s_T \uparrow$	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
$h_L \uparrow$	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
$h_T \uparrow$	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
$f \uparrow$	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑
$g \uparrow$	↑	↑	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑

Notes. ↑ means the decision (such as p) increases with the parameter (such as a_L); ↓ means the decision decreases with the parameter; "–" denotes "no effect".

and

$$D_T = a_T - bp + s_T - h_T + ge_T, \tag{18}$$

where $f, g > 0$ denote the degrees of effort-sensitive, which are one in the benchmark model.

To conveniently call the extended model, we add a letter "E" before the case name of the base models, for example, the extended model with exogenously pricing under the wholesale price contract is called as Case EEW.

We use a similar backward induction approach as in the benchmark cases to solve the extend models. Among the solutions of the extend models, we find that the optimal decisions and the profits of the supply chain participants with exogenous pricing are structurally the same as in the benchmark models, with $(p - w^*)$ replaced by $f(p - w^*)$ or $g(p - w^*)$ in the Case EEW (detailed in the Appendix A), and with $(p - c)$ replaced by $f(p - c)$ or $g(p - c)$ in the Case EET; however, the optimal decisions and the profits of the supply chain participants with endogenous pricing are more verbose than those of the benchmark models.

Next, we perform sensitivity analysis on the optimal decisions and the profits of the supply chain participants to examine the impact of key parameters on them in the extended models. Corollary 2 summarizes the major findings and trends.

Corollary 2. *The impact of s_L, s_T, h_L, h_T, f and g on the optimal solutions to w, p, e_L and e_T and profits of the supply chain participants π_M, π_E and π_{SC} in the extended models are summarized in Table 3.*

We take the Case EEW as an example to prove the sensitivity analysis results of Corollary 2 in the Appendix A.

The rows 2–5 and 9–12 of Table 3 show that the sensitivity of the optimal decisions and the profits of the supply chain participants in the extended models with respect to shopping convenience and privacy concerns is the same as Table 2. This finding indicates that an elastic promotion efforts does not qualitatively change the theoretical results. The rows 6–7 and 13–14 of Table 3 show that the larger the degrees of effort-sensitive, all other decisions and profits become larger in the four extended models except the wholesale price reduction. Actually, greater promotion efforts sensitivity implies that the same effort leads to greater demand growth, which makes promotion efforts more efficient and thus leads to an increase in retail prices and profits for supply chain participants. Moreover, increased demand due to e-tailers' promotion efforts could give them more bargaining power to drive down the wholesale prices.

To conclude, this extension shows that even a variable effort elasticity does not qualitatively change the theoretical results obtained with the coefficients of the promotion efforts 1 in the demand function.

7. Conclusions

Live streaming has seen explosive growth in recent years. Many e-retailers sell their products through both traditional e-commerce channel as well as live streaming channel. Compared to traditional e-commerce channel, live streaming channel can improve shopping convenience, but can also increase privacy concern. On the other hand, incentive contracts are generally used to manage the retail channels in order to improve the efficiency of the supply chain. Motivated by the above considerations, we developed an analytical supply chain model to explore how shopping convenience and privacy concern affect optimal decision making under two contracts (*i.e.*, wholesale price contract and two-part tariff contract) for dual channels (*i.e.*, live streaming channel and traditional e-commerce channel). We discovered the following findings. First, when the retail price is exogenously given, the optimal promotion efforts are negatively related to shopping convenience and positively related to privacy concerns under the wholesale price contract, and they are independent of shopping convenience and privacy concerns under the two-part tariff contract; With both exogenous and endogenous pricing and under both wholesale price and two-part tariff contracts, the optimal wholesale prices, retail prices, promotion efforts and the profits of supply chain participants are all positively related to shopping convenience and negatively related to privacy concerns. Second, whether the retail selling price is endogenous or exogenous, supply chain coordination can be achieved by the two-part tariff contract, but surprisingly not commonly seen contracts like the wholesale price contract. Third, the two-part tariff contract is more favorable to the manufacturer if the exogenously given retail price is low, and the wholesale price contract is more favorable to the manufacturer if the retail price is high; whether the retail selling price is endogenous or exogenous, the two-part tariff contract is always more beneficial for the supply chain than the wholesale price contract. Further, we discover that the theoretical results hold when we extend the model to include a variable effort elasticity. Our theoretical findings are also confirmed to be robust.

This paper discussed the dual channel supply chain system of live streaming and traditional e-commerce, focusing on coordination, privacy concern and shopping convenience. These findings and insights not only contribute to the supply chain management literature, but will also help advance our knowledge of the dual channel supply chain system management of live streaming and traditional e-commerce in practice.

The aforementioned findings can also be used to infer some management implications. Promotion efforts is closely related to product types and contracts forms. When pricing is not a decision (for example, for those products with a standard price, such as iPhone or newspapers), promotion efforts are decreased with shopping convenience and increased with privacy concerns under a wholesale price contract, and they are not related to shopping convenience and privacy concern. However, when pricing is a decision (for example, for those seasonal products with fluctuating market price), promotion efforts are increased with shopping convenience and decreased with privacy concerns. The e-tailers and supply chain managers should choose the right supply contracts (for example, the two-part tariff contract) in order to maximize the dual channel supply chain system's profit and performance.

Finally, we offer some suggestions for upcoming work. Although a deterministic demand model is taken into account in this paper, some products' demand may be ambiguous. Future studies could also look at how supply chain choose while creating others incentive contracts.

Appendix A.

Solving the equilibrium of Case ET

As the Hessian matrix of π_{SC} with respect to e_L and e_T:

$$\begin{pmatrix} -k_L & 0 \\ 0 & -k_T \end{pmatrix}, \tag{A.1}$$

is negatively definite, π_{SC} is a jointly concave function of e_L and e_T. Then, we solve the first-order conditions yields the optimal promotion efforts

$$\frac{\partial \pi_{\mathrm{SC}}}{\partial e_L} = 0 \Rightarrow e_L = \frac{p-c}{k_L}, \tag{A.2}$$

$$\frac{\partial \pi_{\mathrm{SC}}}{\partial e_T} = 0 \Rightarrow e_T = \frac{p-c}{k_T}\cdot \tag{A.3}$$

Because π_M^{ET} is monotonically increasing with respect to w, the optimal wholesale price for the manufacturer should be p; However, for e-tailer, if the wholesale price is set to p, the profit is negative. Taking these two aspects into consideration, the optimal wholesale price needs to ensure that the e-tailer's profit is greater than 0. Then, let $\pi_E^{\mathrm{ET}} \geq 0$, we can get the optimal wholesale price is

$$w^* = p - \frac{T + \frac{k_L e_L^2}{2} + \frac{k_T e_T^2}{2}}{A + e_L + e_T}\cdot \tag{A.4}$$

Substituting e_L and e_T into w^*, the optimal wholesale price can be written as

$$w = p - \frac{2T + B(p-c)^2}{2A + 2B(p-c)}\cdot \tag{A.5}$$

Therefore, substituting w, e_L and e_T into π_M, π_E and π_{SC}, we have the profits of the manufacturer, the e-tailer, and the supply chain in the Case ET:

$$\pi_M^{\mathrm{ET}} = \pi_{\mathrm{SC}}^{\mathrm{ET}} = A(p-c) + \frac{(p-c)^2}{2}B, \qquad \pi_E^{\mathrm{ET}} = 0. \tag{A.6}$$

Solving the equilibrium of Case DW

Since the Hessian matrix of π_E^{DW} with respect to e_L and e_T:

$$\begin{pmatrix} -k_L & 0 \\ 0 & -k_T \end{pmatrix}, \tag{A.7}$$

is negatively definite, π_E^{DW} is a jointly concave function of e_L and e_T. Thus, we solve the first-order conditions yields the optimal promotion efforts

$$\frac{\partial \pi_E^{\mathrm{DW}}}{\partial e_L} = 0 \Rightarrow e_L^* = \frac{p-w}{k_L}, \tag{A.8}$$

$$\frac{\partial \pi_E^{\mathrm{DW}}}{\partial e_T} = 0 \Rightarrow e_T^* = \frac{p-w}{k_T}\cdot \tag{A.9}$$

Substituting e_L^* and e_T^* into π_E^{DW}, we solve the first-order condition for p yields the optimal retail price

$$p^* = \frac{[A_L + A_T + (1+b)w] - Bw}{2(1+b) - B}, \tag{A.10}$$

where $A_L = a_L + s_L - h_L$, $A_T = a_T + s_T - h_T$.

Next we have the optimal promotion efforts by substituting p^* into e_L^* and e_T^*

$$e_L^* = \frac{[A_L + A_T - (1+b)w]k_T}{2k_Lk_T(1+b) - (k_L + k_T)}, \tag{A.11}$$

$$e_T^* = \frac{[A_L + A_T - (1+b)w]k_L}{2k_Lk_T(1+b) - (k_L + k_T)}\cdot \tag{A.12}$$

After substituting e_L^*, e_T^* and p^* into π_M^{DW}, we find that π_M^{DW} is concave in w. Thus, we solve the first-order condition for w

$$\frac{\partial \pi_M^{\mathrm{DW}}}{\partial w} = 0 \Rightarrow w = \frac{(A_L + A_T)[(1+b) + B] + c(1+b)^2}{(1+b)[2(1+b) + B]}\cdot \tag{A.13}$$

Substituting w into e_L^*, e_T^* and p^*, we have the optimal retail price

$$p = \frac{(A_L + A_T)\left[3(1+b)^2 + (1+b)B - B^2\right]}{(1+b)[4(1+b)^2 - B^2]} + \frac{c(1+b)[(1+b) - B]}{4(1+b)^2 - B^2}, \tag{A.14}$$

and the optimal promotion efforts

$$e_L = \frac{(1+b)[A_L + A_T - (1+b)c]}{k_L[4(1+b)^2 - B^2]}, \tag{A.15}$$

$$e_T = \frac{(1+b)[A_L + A_T - (1+b)c]}{k_T[4(1+b)^2 - B^2]}\cdot \tag{A.16}$$

Finally, we have the profit of the manufacturer, the e-tailer and the supply chain in the Case DW by substituting e_L, e_T, w and p into π_M, π_E and π_{SC}:

$$\pi_M^{\mathrm{DW}} = \frac{(1+b)\,[B + (1+b)]\,[(A_L + A_T) - cB]\,[A_L + A_T - (1+b)c]}{[2(1+b) - B]\,[2(1+b) + B]^2}, \tag{A.17}$$

$$\pi_E^{\mathrm{DW}} = \frac{(1+b)^3[(A_L + A_T) - cB][(A_L + A_T) + cB - 2c(1+b)]}{[4(1+b)^2 + B^2]^2} - \frac{B(1+b)^2[A_L + A_T - (1+b)c]^2}{2[4(1+b)^2 - B^2]^2}, \tag{A.18}$$

$$\pi_{\mathrm{SC}}^{\mathrm{DW}} = \frac{k_Lk_T(1+b)[2B + 3(1+b)][A_L + A_T - (1+b)c]^2}{2[2(1+b) - B][2(1+b) + B]^2}\cdot \tag{A.19}$$

Solving the equilibrium of Case DT

As the Hessian matrix of π^{SC} with respect to e_L and e_T:

$$\begin{pmatrix} -k_L & 0 \\ 0 & -k_T \end{pmatrix}, \tag{A.20}$$

is negatively definite, π^{SC} is a jointly concave function of e_L and e_T. Thus, we solve the first-order conditions yields the optimal promotion efforts

$$\frac{\partial \pi^{\mathrm{SC}}}{\partial e_L} = 0 \Rightarrow e_L^* = \frac{p-c}{k_L}, \tag{A.21}$$

$$\frac{\partial \pi^{\mathrm{SC}}}{\partial e_T} = 0 \Rightarrow e_T^* = \frac{p-c}{k_T}\cdot \tag{A.22}$$

Substituting e_L^* and e_T^* into π^{SC}, we solve the first-order optimality condition for p yields the optimal retail price

$$p = \frac{[A_L + A_T + (1+b)c] - Bc}{2(1+b) - B}\cdot \tag{A.23}$$

Thus, the optimal promotion efforts are

$$e_L = \frac{A_L + A_T - (1+b)c}{k_L[2(1+b) - B]}, \tag{A.24}$$

and

$$e_T = \frac{A_L + A_T - (1+b)c}{k_T[2(1+b) - B]}. \tag{A.25}$$

Since π_M^{DT} is monotonically increasing with respect to w, the optimal wholesale price for the manufacturer should be p; However, for e-tailer, if the wholesale price is set to p, the profit is negative. Taking these two aspects into consideration, the optimal wholesale price needs to ensure that the e-tailer's profit is greater than 0. Then, let $\pi_E^{\mathrm{DT}} \geq 0$, we can get the optimal wholesale price is

$$w^* = p - \frac{T + \frac{k_L e_L^2}{2} + \frac{k_T e_T^2}{2}}{A_L + A_T - (1+b)p + e_L + e_T}. \tag{A.26}$$

Substituting p, e_L and e_T into w^*, the optimal wholesale price can be written as

$$w = \frac{A_L + A_T + c(1+b) - cB}{2(1+b) - B} \tag{A.27}$$

$$- \frac{2[2(1+b) - B]^2 T + [A_L + A_T + c(1+b) - cB]^2}{2[2(1+b) - B](A_L + A_T)(1+b) + 2c[2(1+b) - B][(1+b) - B]}\left(\frac{1}{k_L} - \frac{1}{k_T}\right). \tag{A.28}$$

We have the profit of the manufacturer, the e-tailer and the supply chain in the Case ET by substituting p, w, e_L and e_T into π_M, π_E and π_{SC}:

$$\pi_M^{\mathrm{DT}} = \pi_{\mathrm{SC}}^{\mathrm{DT}} = \frac{[A_L + A_T + c(1+b) - cB]^2}{2[2(1+b) - B]^2}\left(\frac{1}{k_T} - \frac{1}{k_L}\right) \tag{A.29}$$

$$+ \left[A_L + A_T + \frac{A_L + A_T + c(1+b) - cB}{2(1+b) - B}(1 + b - B)\right]\frac{A_L + A_T - c(1+b)}{2(1+b) - B}, \tag{A.30}$$

$$\pi_E^{\mathrm{DT}} = 0. \tag{A.31}$$

Proof of Corollary 1. In the Case EW, we use the derivative rule of the composite function to have

$$\frac{\partial w^{\mathrm{EW}}}{\partial s_L} = \underbrace{\frac{\partial w^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial w^{\mathrm{EW}}}{\partial s_T} = \underbrace{\frac{\partial w^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} > 0, \tag{A.32}$$

$$\frac{\partial w^{\mathrm{EW}}}{\partial h_L} = \underbrace{\frac{\partial w^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial w^{\mathrm{EW}}}{\partial h_T} = \underbrace{\frac{\partial w^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} < 0. \tag{A.33}$$

$$\frac{\partial e_L^{\mathrm{EW}}}{\partial s_L} = \underbrace{\frac{\partial e_L^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} < 0, \qquad \frac{\partial e_L^{\mathrm{EW}}}{\partial s_T} = \underbrace{\frac{\partial e_L^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} < 0, \tag{A.34}$$

$$\frac{\partial e_L^{\mathrm{EW}}}{\partial h_L} = \underbrace{\frac{\partial e_L^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} > 0, \qquad \frac{\partial e_L^{\mathrm{EW}}}{\partial h_T} = \underbrace{\frac{\partial e_L^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} > 0. \tag{A.35}$$

$$\frac{\partial e_T^{\mathrm{EW}}}{\partial s_L} = \underbrace{\frac{\partial e_T^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} < 0, \qquad \frac{\partial e_T^{\mathrm{EW}}}{\partial s_T} = \underbrace{\frac{\partial e_T^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} < 0, \tag{A.36}$$

$$\frac{\partial e_T^{\mathrm{EW}}}{\partial h_L} = \underbrace{\frac{\partial e_T^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} > 0, \qquad \frac{\partial e_T^{\mathrm{EW}}}{\partial h_T} = \underbrace{\frac{\partial e_T^{\mathrm{EW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} > 0. \tag{A.37}$$

$$\frac{\partial \pi_M^{\mathrm{EW}}}{\partial s_L} = \underbrace{\frac{\partial \pi_M^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial \pi_M^{\mathrm{EW}}}{\partial s_T} = \underbrace{\frac{\partial \pi_M^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} > 0, \tag{A.38}$$

$$\frac{\partial \pi_M^{\mathrm{EW}}}{\partial h_L} = \underbrace{\frac{\partial \pi_M^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial \pi_M^{\mathrm{EW}}}{\partial h_T} = \underbrace{\frac{\partial \pi_M^{\mathrm{EW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} < 0, \tag{A.39}$$

where $\frac{\partial \pi_M^{\mathrm{EW}}}{\partial A} = \frac{A}{k_L B^2} + \frac{p-c}{2} > 0$.

We conduct numerical experiments to verify $\frac{\partial \pi_E^{\mathrm{EW}}}{\partial s_L} > 0$, $\frac{\partial \pi_E^{\mathrm{EW}}}{\partial s_T} > 0$, $\frac{\partial \pi_E^{\mathrm{EW}}}{\partial h_L} < 0$, $\frac{\partial \pi_E^{\mathrm{EW}}}{\partial h_T} < 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EW}}}{\partial s_L} > 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EW}}}{\partial s_T} > 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EW}}}{\partial h_L} < 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EW}}}{\partial h_T} < 0$ in which the parameters are set as $a_L = 50$, $a_T = 50$, $k_L = 1.2$, $k_T = 1$, $p = 10$, $c = 5$. For example, in order to verify $\frac{\partial \pi_E^{\mathrm{EW}}}{\partial s_L} > 0$, we fix the values of the parameters $s_T = 1.0$, $h_L = 1.2$ and $h_T = 1.0$, and change the value of the parameter s_L from 0.1 to 1.2.

In the Case ET, we use the derivative rule of the composite function to have

$$\frac{\partial w^{\mathrm{ET}}}{\partial s_L} = \underbrace{\frac{\partial w^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial w^{\mathrm{ET}}}{\partial s_T} = \underbrace{\frac{\partial w^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} > 0, \tag{A.40}$$

$$\frac{\partial w^{\mathrm{ET}}}{\partial h_L} = \underbrace{\frac{\partial w^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial w^{\mathrm{ET}}}{\partial h_T} = \underbrace{\frac{\partial w^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} < 0. \tag{A.41}$$

$$\frac{\partial \pi_M^{\mathrm{ET}}}{\partial s_L} = \underbrace{\frac{\partial \pi_M^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial \pi_M^{\mathrm{ET}}}{\partial s_T} = \underbrace{\frac{\partial \pi_M^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} > 0, \tag{A.42}$$

$$\frac{\partial \pi_M^{\mathrm{ET}}}{\partial h_L} = \underbrace{\frac{\partial \pi_M^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial \pi_M^{\mathrm{EW}}}{\partial h_T} = \underbrace{\frac{\partial \pi_M^{\mathrm{ET}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} < 0. \tag{A.43}$$

In the Case DW, we use the derivative rule of the composite function to have

$$\frac{\partial w^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial w^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial w^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial w^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.44}$$

$$\frac{\partial w^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial w^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial w^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial w^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.45}$$

$$\frac{\partial p^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial p^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial p^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial p^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.46}$$

$$\frac{\partial p^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial p^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial p^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial p^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.47}$$

$$\frac{\partial e_L^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial e_L^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial e_L^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial e_L^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.48}$$

$$\frac{\partial e_L^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial e_L^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial e_L^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial e_L^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.49}$$

$$\frac{\partial e_T^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial e_T^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial e_T^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial e_T^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.50}$$

$$\frac{\partial e_T^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial e_T^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial e_T^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial e_T^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.51}$$

$$\frac{\partial \pi_M^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial \pi_M^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial \pi_M^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial \pi_M^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.52}$$

$$\frac{\partial \pi_M^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial \pi_M^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial \pi_M^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial \pi_M^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.53}$$

$$\frac{\partial \pi_E^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial \pi_E^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial \pi_E^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial \pi_E^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.54}$$

$$\frac{\partial \pi_E^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial \pi_E^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial \pi_E^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial \pi_E^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.55}$$

$$\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial s_L} = \underbrace{\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial s_T} = \underbrace{\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.56}$$

$$\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial h_L} = \underbrace{\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial h_T} = \underbrace{\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{DW}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.57}$$

In the Case DT, we use the derivative rule of the composite function to have

$$\frac{\partial p^{\mathrm{DT}}}{\partial s_L} = \underbrace{\frac{\partial p^{\mathrm{DT}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial p^{\mathrm{DT}}}{\partial s_T} = \underbrace{\frac{\partial p^{\mathrm{DT}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.58}$$

$$\frac{\partial p^{\mathrm{DT}}}{\partial h_L} = \underbrace{\frac{\partial p^{\mathrm{DT}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial p^{\mathrm{DT}}}{\partial h_T} = \underbrace{\frac{\partial p^{\mathrm{DT}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.59}$$

$$\frac{\partial e_L^{\mathrm{DT}}}{\partial s_L} = \underbrace{\frac{\partial e_L^{\mathrm{DT}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial e_L^{\mathrm{DT}}}{\partial s_T} = \underbrace{\frac{\partial e_L^{\mathrm{DT}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.60}$$

$$\frac{\partial e_L^{\mathrm{DT}}}{\partial h_L} = \underbrace{\frac{\partial e_L^{\mathrm{DT}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial e_L^{\mathrm{DT}}}{\partial h_T} = \underbrace{\frac{\partial e_L^{\mathrm{DT}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.61}$$

$$\frac{\partial e_T^{\mathrm{DT}}}{\partial s_L} = \underbrace{\frac{\partial e_T^{\mathrm{DT}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial e_T^{\mathrm{DT}}}{\partial s_T} = \underbrace{\frac{\partial e_T^{\mathrm{DT}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial s_T}}_{>0} > 0, \tag{A.62}$$

$$\frac{\partial e_T^{\mathrm{DT}}}{\partial h_L} = \underbrace{\frac{\partial e_T^{\mathrm{DT}}}{\partial A_L}}_{>0} \cdot \underbrace{\frac{\partial A_L}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial e_T^{\mathrm{DT}}}{\partial h_T} = \underbrace{\frac{\partial e_T^{\mathrm{DT}}}{\partial A_T}}_{>0} \cdot \underbrace{\frac{\partial A_T}{\partial h_T}}_{<0} < 0. \tag{A.63}$$

We also conduct numerical experiments to verify $\frac{\partial w^{\mathrm{DT}}}{\partial s_L} > 0$, $\frac{\partial w^{\mathrm{DT}}}{\partial s_T} > 0$, $\frac{\partial w^{\mathrm{DT}}}{\partial h_L} < 0$, $\frac{\partial w^{\mathrm{DT}}}{\partial h_T} < 0$, $\frac{\partial \pi_M^{\mathrm{DT}}}{\partial s_L} > 0$, $\frac{\partial \pi_M^{\mathrm{DT}}}{\partial s_T} > 0$, $\frac{\partial \pi_M^{\mathrm{DT}}}{\partial h_L} < 0$, $\frac{\partial \pi_M^{\mathrm{DT}}}{\partial h_T} < 0$ in which the parameter settings are the same as in the Case EW.

Note that in the proof of the sensitivity of the Cases DW and DT, we can recall the assumption $k_L, k_T \geq 1$. This assumption can guarantee $2(1+b) > B$ holds, so that the derivatives of the above decisions and profits with respect to A_L and A_T can be ensured to be positive. □

Proof of Theorem 1. In the Case EW, we have the optimal promotion efforts of the supply chain

$$e_L^{\mathrm{SC}*} = \frac{p - w^*}{k_L}, \qquad e_T^{\mathrm{SC}*} = \frac{p - w^*}{k_T}. \tag{A.64}$$

In the Case ET, we also have the optimal promotion efforts of the e-tailers

$$e_L^* = \frac{p - c}{k_L}, \qquad e_T^* = \frac{p - c}{k_T}. \tag{A.65}$$

When the Contract W is adopted, we find that it can not make $e_L^{\mathrm{SC}*} = e_L^*$ and $e_T^{\mathrm{SC}*} = e_T^*$, and meanwhile fulfill the minimum profit requirements. As a result, the wholesale price contract fails to coordinate the supply chain system.

When the Contract T is adopted, if $w = c$ holds, and then $e_L^{\mathrm{SC}*} = e_L^*$ and $e_T^{\mathrm{SC}*} = e_T^*$. On the other hand, the minimum profit requirements are not met. As a result, under the Contract T, the credit transfer is critically important as it can flexibly divide the profit of the supply chain between the manufacturer and the e-tailer. For the manufacturer, the credit transfer T is required more than its minimum profit $\overline{\pi}_M$. For the e-tailer, its profit $\pi_{\mathrm{SC}} - T$ is required larger than its minimum profit $\overline{\pi}_E$. Accordingly, we combine $T \geq \overline{\pi}_M$ and $\pi_{\mathrm{SC}} - T \geq \overline{\pi}_E$, and have $\overline{\pi}_M \leq T \leq \pi_{\mathrm{SC}} - \overline{\pi}_E$.

In the Case DW, we have the optimal promotion efforts of the supply chain

$$e_L^{\mathrm{SC}*} = \frac{[A_L + A_T - (1+b)w*]k_T}{2k_L k_T(1+b) - (k_L + k_T)}, \tag{A.66}$$

$$e_T^{\mathrm{SC}*} = \frac{[A_L + A_T - (1+b)w*]k_L}{2k_L k_T(1+b) - (k_L + k_T)}. \tag{A.67}$$

In the Case DT, we also have the optimal promotion efforts of the e-tailer

$$e_L^* = \frac{k_T[A_L + A_T - (1+b)c]}{2k_L k_T(1+b) - (k_L + k_T)}, \tag{A.68}$$

$$e_T^* = \frac{k_L[A_L + A_T - (1+b)c]}{2k_L k_T(1+b) - (k_L + k_T)}. \tag{A.69}$$

When the Contract W is adopted, we find that it can not make $e_L^{\mathrm{SC}*} = e_L^*$ and $e_T^{\mathrm{SC}*} = e_T^*$, and meanwhile fulfill the minimum profit requirements. As a result, the wholesale price contract fails to coordinate the supply chain system.

When the Contract T is adopted, if $w = c$ holds, and then $e_L^{\mathrm{SC}*} = e_L^*$ and $e_T^{\mathrm{SC}*} = e_T^*$. On the other hand, the minimum profit requirements are not met. As a result, under the Contract T, the credit transfer is critically important as it can flexibly divide the profit of the supply chain between the manufacturer and the e-tailer. For the manufacturer, the credit transfer T is required more than its minimum profit $\overline{\pi}_M$. For the e-tailer, its profit $\pi_{\mathrm{SC}} - T$ is required larger than its minimum profit $\overline{\pi}_E$. Accordingly, we combine $T \geq \overline{\pi}_M$ and $\pi_{\mathrm{SC}} - T \geq \overline{\pi}_E$, and have $\overline{\pi}_M \leq T \leq \pi_{\mathrm{SC}} - \overline{\pi}_E$. □

Proof of Corollary 2. By using the backward induction, the solutions of the extended Cases EEW are summarized as: The wholesale price $w = \frac{k_L k_T A}{3(f^2k_T+g^2k_L))} + \frac{2p+c}{3}$, the promotion efforts $e_L = \frac{f(p-c)}{3k_L} - \frac{fk_Lk_TA}{3k_L(f^2k_T+g^2k_L)}$, $e_T = \frac{g(p-c)}{3k_T} - \frac{gk_Lk_TA}{3k_T(f^2k_T+g^2k_L)}$, the profit of the manufacturer $\pi_M = \frac{2g^2(p-c)^2}{9k_T} + \frac{[2k_LA+f^2(p-c)](k_LA+2f^2(p-c))}{9f^2k_L} - \frac{2g^2k_L^2A^2}{9f^2(f^2k_T+g^2k_L)}$, the profit of the e-tailer $\pi_E = \frac{[5k_Lk_TA+(f^2k_T+g^2k_L)(p-c)][(f^2k_T+g^2k_L)(p-c)-k_Lk_TA]}{18k_Lk_T(f^2k_T+g^2k_L)}$, the profit of the supply chain $\frac{5f^2(p-c)^2}{18k_L} + \frac{f^2k_T^2A^2}{18g^2(f^2k_T+g^2k_L)} - \frac{14g^2k_TA(p-c)+5g^4(p-c)^2-k_T^2A^2}{18g^2k_T}$.

In the extended Case EEW, we use the derivative rule of the composite function to have

$$\frac{\partial w^{\mathrm{EEW}}}{\partial s_L} = \underbrace{\frac{\partial w^{\mathrm{EEW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} > 0, \qquad \frac{\partial w^{\mathrm{EEW}}}{\partial s_T} = \underbrace{\frac{\partial w^{\mathrm{EEW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} > 0, \tag{A.70}$$

$$\frac{\partial w^{\mathrm{EEW}}}{\partial h_L} = \underbrace{\frac{\partial w^{\mathrm{EEW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} < 0, \qquad \frac{\partial w^{\mathrm{EEW}}}{\partial h_T} = \underbrace{\frac{\partial w^{\mathrm{EEW}}}{\partial A}}_{>0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} < 0. \tag{A.71}$$

$$\frac{\partial w^{\mathrm{EEW}}}{\partial f} = \frac{-6fk_T}{9(f^2k_T+g^2k_L)^2} < 0, \qquad \frac{\partial w^{\mathrm{EEW}}}{\partial g} = \frac{-6gk_L}{9(f^2k_T+g^2k_L)^2} < 0 \tag{A.72}$$

$$\frac{\partial e_L^{\mathrm{EEW}}}{\partial s_L} = \underbrace{\frac{\partial e_L^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} < 0, \qquad \frac{\partial e_L^{\mathrm{EEW}}}{\partial s_T} = \underbrace{\frac{\partial e_L^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} < 0, \tag{A.73}$$

$$\frac{\partial e_L^{\mathrm{EEW}}}{\partial h_L} = \underbrace{\frac{\partial e_L^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} > 0, \qquad \frac{\partial e_L^{\mathrm{EEW}}}{\partial h_T} = \underbrace{\frac{\partial e_L^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} > 0. \tag{A.74}$$

$$\frac{\partial e_T^{\mathrm{EEW}}}{\partial s_L} = \underbrace{\frac{\partial e_T^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_L}}_{>0} < 0, \qquad \frac{\partial e_T^{\mathrm{EEW}}}{\partial s_T} = \underbrace{\frac{\partial e_T^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial s_T}}_{>0} < 0, \tag{A.75}$$

$$\frac{\partial e_T^{\mathrm{EEW}}}{\partial h_L} = \underbrace{\frac{\partial e_T^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_L}}_{<0} > 0, \qquad \frac{\partial e_T^{\mathrm{EEW}}}{\partial h_T} = \underbrace{\frac{\partial e_T^{\mathrm{EEW}}}{\partial A}}_{<0} \cdot \underbrace{\frac{\partial A}{\partial h_T}}_{<0} > 0. \tag{A.76}$$

$$\frac{\partial e_L^{\mathrm{EEW}}}{\partial g} = \frac{2g}{3(f^2k_T+g^2k_L)^2} > 0, \qquad \frac{\partial e_T^{\mathrm{EEW}}}{\partial f} = \frac{2f}{3(f^2k_T+g^2k_L)^2} > 0. \tag{A.77}$$

We also conduct numerical experiments to verify $\frac{\partial e_L^{\mathrm{EEW}}}{\partial f} > 0$, $\frac{\partial e_T^{\mathrm{EEW}}}{\partial g} > 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial s_L} > 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial s_T} > 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial h_L} < 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial h_T} < 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial s_L} > 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial s_T} > 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial f} > 0$, $\frac{\partial \pi_M^{\mathrm{EEW}}}{\partial g} > 0$, $\frac{\partial \pi_E^{\mathrm{EEW}}}{\partial h_L} < 0$, $\frac{\partial \pi_E^{\mathrm{EEW}}}{\partial h_T} < 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EEW}}}{\partial s_L} > 0$, $\frac{\partial \pi_E^{\mathrm{EEW}}}{\partial f} > 0$, $\frac{\partial \pi_E^{\mathrm{EEW}}}{\partial g} > 0$ $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EEW}}}{\partial s_T} > 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EEW}}}{\partial h_L} < 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EEW}}}{\partial h_T} < 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EEW}}}{\partial f} > 0$, $\frac{\partial \pi_{\mathrm{SC}}^{\mathrm{EEW}}}{\partial g} > 0$ in which the parameters are set as $a_L = 50$, $a_T = 50$, $k_L = 1.2$, $k_T = 1$, $p = 10$, $c = 5$. For example, in order to verify $\frac{\partial \pi_E^{\mathrm{EEW}}}{\partial f} > 0$, we fix the values of the parameters $s_L = 1.2$, $s_T = 1.0$, $h_L = 1.2$, $h_T = 1.0$ and $g = 1.0$ and change the value of the parameter f from 0.1 to 1.0.

The solution of the optimal decisions and the profits and the sensitivity analysis of parameters in the extended Cases EET, EDW and EDT are similar to Case EEW shown in detail above. □

Innovation effort comparison

Proposition 1. *With the exogenous pricing, $e_i^{\mathrm{EW}} > e_i^{\mathrm{ET}} (i = L, T)$ holds if $p > \Theta$, and $e_i^{\mathrm{EW}} < e_i^{\mathrm{ET}} (i = L, T)$ holds if $p < \Theta$; With the endogenous pricing, $e_i^{\mathrm{DW}} < e_i^{\mathrm{DT}} (i = L, T)$ always holds.*

Proof of Proposition 1. First, we compare e_L^{EW} and e_L^{ET}, and let $e_L^{\mathrm{EW}} > e_L^{\mathrm{ET}}$.

$$\frac{1}{2k_L}\left(p - c - \frac{A}{B}\right) > \frac{p-c}{k_L} \tag{A.78}$$

$$\Leftrightarrow p - c - \frac{A}{B} > 2(p-c) \tag{A.79}$$

$$\Leftrightarrow (1 + b - B)p > A_L + A_T - BC \tag{A.80}$$

$$\Leftrightarrow p > \frac{A_L + A_T - BC}{1 + b - B} \triangleq \Theta. \tag{A.81}$$

Therefore, $e_L^{\mathrm{EW}} > e_L^{\mathrm{ET}}$ holds if $p > \Theta$, $e_L^{\mathrm{EW}} < e_L^{\mathrm{ET}}$ holds if $p < \Theta$.

The comparison of e_T^{EW} and e_T^{ET} is exactly similar with the comparison of e_L^{EW} and e_L^{ET}, and likewise, $e_T^{\mathrm{EW}} > e_T^{\mathrm{ET}}$ holds if $p > \Theta$, $e_T^{\mathrm{EW}} < e_T^{\mathrm{ET}}$ holds if $p < \Theta$.

Second, we compare e_L^{DW} and e_L^{DT}, and let $e_L^{\mathrm{DW}} < e_L^{\mathrm{DT}}$.

$$\frac{(1+b)\frac{1}{k_L}[A_L + A_T - (1+b)c]}{4(1+b)^2 - B^2} < \frac{\frac{1}{k_L}[A_L + A_T - (1+b)c]}{2(1+b) - B} \tag{A.82}$$

$$\Leftrightarrow 1 + b < 2(1+b) + B \tag{A.83}$$

$$\Leftrightarrow 1 + b + B > 0. \tag{A.84}$$

Therefore, $e_L^{\mathrm{DW}} < e_L^{\mathrm{DT}}$ always holds.

The comparison of e_T^{DW} and e_T^{DT} is exactly similar with the comparison of e_L^{DW} and e_L^{DT}, and likewise, $e_T^{\mathrm{DW}} < e_T^{\mathrm{DT}}$ always holds. □

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References

[1] N. Amrouche, Z. Pei and R. Yan, Mobile channel and channel coordination under different supply chain contexts. *Ind. Mark. Manage.* **84** (2020) 165–182.
[2] Arshinder, A. Kanda and S.G. Deshmukh, Supply chain coordination: perspectives, empirical studies and research directions. *Int. J. Prod. Econ.* **115** (2008) 316–335.
[3] A. Balakrishnan, S. Sundaresan and B. Zhang, Browse-and-switch: retail-online competition under value uncertainty. *Prod. Oper. Manage.* **23** (2014) 1129–1145.
[4] G. Bansel, F.M. Zahedi and D. Gefen, The role of privacy assurance mechanisms in building trust and the moderating role of privacy concern. *Eur. J. Inf. Syst.* **24** (2015) 624–644.
[5] G.P. Cachon, Supply chain coordination with contracts. *Handb. Oper. Res. Manage. Sci.* **11** (2003) 227–339.
[6] G.P. Cachon and A.G. Kok, Competing manufacturers in a retail supply chain: on contractual form and coordination. *Manage. Sci.* **56** (2010) 571–589.
[7] J.-H. Cheah, X.-J. Lim, H. Ting, Y. Liu and S. Quach, Are privacy concerns still relevant? Revisiting consumer behaviour in omnichannel retailing. *J. Retail. Consum. Serv.* **65** (2022) 102242.
[8] C.C. Chen and Y.C. Lin, What drives live-stream usage intention? The perspectives of flow, entertainment, social interaction, and endorsement. *Telemat. Inf.* **35** (2018) 293–303.
[9] T.-M. Choi, Mobile-app-online-website dual channel strategies: privacy concerns, e-payment convenience, channel relationship, and coordination. *IEEE Trans. Syst. Man Cybern.: Syst.* **51** (2021) 7008–7016.

[10] X. Cui, Q. Xie, J. Zhu, M.A. Shareef, M.A.S. Goraya and M.S. Akram, Understanding the omnichannel customer journey: the effect of online and offline channel interactivity on consumer value co-creation behavior. *J. Retail. Consum. Serv.* **65** (2022) 102869.
[11] A. David and E. Adida, Competition and coordination in a two-channel supply chain. *Prod. Oper. Manage.* **24** (2015) 1358–1370.
[12] Q. Feng and L.X. Lu, Supply chain contracting under competition: bilateral bargaining vs. Stackelberg. *Prod. Oper. Manage.* **22** (2013) 661–675.
[13] L. Guo, X. Hu, J. Lu and L. Ma, Effects of customer trust on engagement in live streaming commerce: mediating role of swift guanxi. *Internet Res.* **31** (2021) 1718–1744.
[14] F. Hou, Z. Guan, B. Li and A. Chong, Factors influencing people's continuous watching intention and consumption intention in live streaming: evidence from China. *Internet Res.* **30** (2019) 141–163.
[15] L. Hsiao and Y.J. Chen, Strategic motive for introducing internet channels in a supply chain. *Prod. Oper. Manage.* **23** (2014) 36–47.
[16] A.P. Jeuland and S.M. Shugan, Managing channel profits. *Mark. Sci.* **27** (2008) 52–69.
[17] C. Ji and X. Liu, Design of risk sharing and coordination mechanism in supply chain under demand and supply uncertainty. *RAIRO: Oper. Res.* **56** (2022) 123–143.
[18] Y. Li, X. Li and J. Cai, How attachment affects user stickiness on live streaming platforms: a socio-technical approach perspective. *J. Retail. Consum. Serv.* **60** (2021) 102478.
[19] B. Lu and Z. Chen, Live streaming commerce and consumers purchase intention: an uncertainty reduction perspective. *Inf. Manage.* **58** (2021) 103509.
[20] K. Matsui, When should a manufacturer set its direct price and wholesale price in dual-channel supply chains? *Eur. J. Oper. Res.* **258** (2017) 501–511.
[21] H.J. Park and L.M. Lin, The effects of match-ups on the consumer attitudes toward internet celebrities and their live streaming contents in the context of product endorsement. *J. Retail. Consum. Serv.* **52** (2020) 101934.
[22] X. Qian, F.T.S. Chan, J. Zhang, M. Yin and Q. Zhang, Channel coordination of a two-echelon sustainable supply chain with a fair-minded retailer under cap-and-trade regulation. *J. Clean. Prod.* **244** (2020) 118715.
[23] R. Rai, M.K. Tiwari, D. Ivanov and A. Dolgui, Machine learning in manufacturing and industry 4.0 applications. *Int. J. Prod. Res.* **59** (2021) 4773–4778.
[24] S. Sarkar and S. Bhala, Coordinating a closed loop supply chain with fairness concern by a constant wholesale price contract. *Eur. J. Oper. Res.* **295** (2021) 140–156.
[25] Y. Sun, X. Shao, X. Li, Y. Guo and K. Nie, How live streaming influences purchase intentions in social commerce: an it affordance perspective. *Electron. Commer. Res. Appl.* **37** (2019) 100886.
[26] T.A. Taylor, Supply chain coordination under channel rebates with sales effort effects. *Manage. Sci.* **48** (2002) 992-1007.
[27] A. Tsay, The quantity flexibility contract and supplier-customer incentives. *Manage. Sci.* **45** (1999) 1339–1358.
[28] C. Wang, M. Leng and L. Liang, Choosing an online retail channel for a manufacturer: direct sales or consignment? *Int. J. Prod. Econ.* **195** (2018) 338–358.
[29] Y. Xia, T. Xiao and G.P. Zhang, Distribution channel strategies for a manufacturer with complementary products. *Decis. Sci.* **44** (2013) 39–56.
[30] J. Xu, Y. Huang, E. Avgerinos, G. Feng and F. Chu, Dual-channel competition: the role of quality improvement and price-matching. *Int. J. Prod. Res.* **60** (2022) 3705–3727.
[31] N. Yan, Y. Liu, X. Xu and X. He, Strategic dual-channel pricing games with e-retailer finance. *Eur. J. Oper. Res.* **283** (2019) 138–151.
[32] B. Yan, X. Chen, C. Cai and S. Guan, Supply chain coordination of fresh agricultural products based on consumer behavior. *Comput. Oper. Res.* **123** (2020) 105038.
[33] Z. Yang, X. Hu, H. Gurnani and H. Guan, Multichannel distribution strategy: selling to a competing buyer with limited supplier capacity. *Manage. Sci.* **64** (2017) 2199–2218.
[34] X. Zhang, H. Chen and Z. Liu, Operation strategy in an e-commerce platform supply chain: whether and how to introduce live streaming services? *Int. Trans. Oper. Res.* (2022). DOI: 10.1111/itor.13186.