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Pricing and Service Effort Decisions of Book Dual-Channel Supply Chains with Showrooming Effect Based on Cost-Sharing Contracts

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Abstract: It is becoming increasingly difficult to ignore circular and sustainable economies. A traditional chain transits to a dual-channel supply chain, extending its online channel for more customers, and keeping its offline channel so as to reduce resource utilization for sustainable business. However, there exists some conflict between offline and online channels, such as the showrooming effect (i.e., customers visit an offline store to experience products but then buy them online with a lower price). This work studies a three-echelon book dual-channel supply chain involving an author, an online publisher and an offline retailer. Based on Stackelberg game theory, it investigates the optimal pricing solutions and the optimal retailer's service effort level with two copyright models and considers the showrooming effect based on either decentralized or centralized decision-making. Afterwards, it develops a cost-sharing contract to make them achieve Pareto optimality. Furthermore, this research studies the influence of the showrooming effect on the optimal decisions and the profits of each member through theoretical and numerical analyses. The findings show that a well-designed contract can lead dual-channel members to cut down the negative impact of the showrooming effect and realize the win–win situation. Finally, it proposes some managerial insights and possible directions for the future.

Keywords: pricing; coordination; dual channel; sustainable supply chain; service effort; showrooming effect

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1. Introduction

E-commerce is on the rise with the growth of information technology and the Internet. In the face of increasingly fierce market competition, more and more enterprises keep some offline business, while developing online sales platforms as new direct sales or distribution channels, which is called a dual channel [1]. However, the higher the penetration rate of online channels into the market, the higher the acceptance of online channels by the customers. Showrooming is the phenomenon of customers visiting an offline store to experience products and then buying online at lower prices—especially in the industries of clothes, cosmetics, books, etc. [2]. Showrooming has gradually shifted between traditional offline stores and online sales. After nearly two decades of rapid development in the e-commerce industry, consumers can use mobile phones, laptops and other mobile terminals to place an order anytime and anywhere. Hence, consumers can even purchase the same product online in brick-and-mortar stores of offline retailers. This almost cost-free cross-channel purchase behavior has led to increasingly fierce conflicts between offline retailers and online manufacturers. Therefore, showrooming has become a hot pain point in both academics and industry.

Meanwhile, it is well known that the rapid economic growth has promoted the quick growth of the cultural industry. As the carrier of cultural dissemination, books undertake the important responsibility of disseminating knowledge. The book publishing industry

will usher in new opportunities. In particular, there is an increasingly popular business of selling physical books via online channels, such as Dangdang and JD in China and Amazon in the US [3]. With respect to other dual-channel supply chains (DSCs), there is a significant showrooming phenomenon in book DSCs due to a deep discount provided by online sellers. For instance, thirty-nine percent of people who buy books from Amazon browsed the book in a local bookstore before buying it from Amazon [4]. Furthermore, there are two main copyright contracts in real book industry, including the royalty contract and the buyout contract [5]. In the royalty contract, the author can acquire the payment with a fixed royalty percentage for each sold book, whereas they will obtain a total payment for the copyright. For example, JD in China will pay one author 8% of each sold book with a selling price that is USD 20 under the royalty contract or will defray him with a fixed cost that is USD 10,000 under the buyout contract.

With the showrooming effect, many offline bookstores contribute more customers to the online platforms through their promotion and physical experience, while having to undertake more operational costs, which leads to some conflicts between online publishers and offline book retailers. To coordinate the supply chain members, some contracts are introduced, such as cost-sharing contracts, revenue-sharing contracts, and wholesale price contracts [3]. For instance, Samsung sends their own employees to the traditional channel to help selling or offers them professional training to improve offline service levels, thus sharing the service costs [6]. However, to the best of our knowledge, there is little research on the coordination of book DSCs under the two copyright models that take the showrooming effect into account.

This work studies a three-echelon book DSC consisting of an author, an online book publisher and a traditional offline retailer, in which the author sells his copyright to the publisher with the royalty or buyout contract, the publisher sells physical books online and distributes them to the offline retailer with a wholesale price, and the retailer determines the offline sales price for readers.

This study aims to consider the showrooming effect, analyzing the optimal online and offline pricings and service effort decisions so as to optimize the profits of DSC members based on the decentralized or the centralized mechanisms. It develops cost-sharing contracts to coordinate DSC members and make them achieve Pareto optimality. It also studies the influence of the showrooming effect on the optimal solutions and optimal objectives of DSC members, respectively.

This research contributes to the study of supply chain coordination in the field of book dual-channel supply chains with the showrooming effect, conducts a deep investigation of the impacts of the showrooming effect on supply chain decisions and performance and provides some scientific and reasonable support for decision makers.

The remainder of this work is arranged as follows. The previous studies in the field of DSCs are reviewed so as to highlight the innovation and the contribution of this study. Section 3 describes the research problem and related notation. Based on the research problem, the corresponding models are formulated and analyzed in Section 4. Section 5 demonstrates numerical cases to provide an intuitive illustration of the theoretical results and to find out additional insights. Finally, conclusions are made and some managerial insights and future research directions are proposed in Section 6.

2. Literature Review

There are three main streams of previous studies that are close to this work. The first stream is the literature on DSCs. The second stream is related to the showrooming effect from DSCs. The last stream focuses on contract coordination in order to make DSC members realize mutual benefit.

2.1. Dual-Channel Supply Chain

Early studies on DSCs occurred after the year 2000. For instance, Chiang et al. [7] provided a strategic study of DSC design. Chiang and Monahan [8] proposed an inventory

model in a two-echelon DSC and concluded that a dual-channel strategy outperformed both pure-retail and pure-direct sales. Dumrongsiri et al. [9] proposed a DSC wherein manufacturers sold products to retailers and online customers. The findings showed that the revenues of the manufacturers would rise when the retailers improved their service quality, while the increase of the customers' service sensitivity could benefit both members. Dan et al. [10] studied the optimal pricing and service level under a centralized or a decentralized DSC based on the two-stage optimization technique and investigated the influences of the service level and the customer channel preference on their pricing decisions. Li et al. [11] focused on a DSC wherein the manufacturer produced green products out of environmental consideration. They analyzed the pricing and greening decisions based on the centralized and decentralized mechanisms with a consistent pricing strategy. Zhou, Guo and Zhou [6] focused on a two-stage DSC, in which a manufacturer sold products online and distributed products to an offline retailer. The retailer provided customers some presales services, leading to a positive impact on the customer's demand. Niu et al. [12] introduced an analytical model to investigate the dual-sourcing decision of an original equipment manufacturer in the presence of a competitive supplier, as well as a noncompetitive supplier, who nevertheless suffered from an unreliable production yield. Esenduran et al. [13] concluded that the timing of buyback pricing decisions for used durable goods would reduce the profitability of buyback programs in dual-distribution channels with dealers and rental agencies. He et al. [14] focused on a single-retailer/single-vendor dual-channel supply chain model, in which the vendor sold deteriorating products through its direct online channel and indirect retail channel. Xu et al. [15] introduced a DSC consisting of a supplier and a capital-shortage retailer, wherein the retailer could make an application for internal financing from the supplier. This work investigated the impacts of two kinds of behaviors on inventory, ordering and service effort decisions in decentralized and centralized decision-making. Xu, Tang, Lin and Lu [1] developed a DSC including a capital-shortage retailer and a fund-sufficient supplier, in which the retailer could adopt internal financing from the supplier.

However, little attention has been paid on the research of book supply chains, especially book dual-channel supply chains. Liu [16] studied the investment decision-making problems of big data information and its effects on the coordination and pricing rules of book single-channel supply chains. Hou and Zeng [17] developed a Stackelberg game model for a book online supply chain to investigate how reference price effects affect retailer and publisher pricing strategies. Mai, Zhang and Sun [3] studied books in both e-book and paper formats, in which book publishers sold their products to online retailers and then sold to online customers through resale and agency sales. All these studies mainly focused on book single-channel supply chains. Hence, this study focuses on a three-echelon book dual-channel supply chain, in which the author sells the copyright to the publisher with either a royalty contract or a buyout contract, then the publisher sells physical books online and distributes physical books to the offline retailer with a wholesale price, and, finally, the retailer put them into stores for sale.

2.2. Showrooming Effect

It is well known that the showrooming effect makes retailers' offline stores act as the showrooms of products. The retailer has to undertake expensive service costs without the corresponding sales. There exist some studies on the showrooming effect. For instance, Balakrishnan et al. [18] studied an economic model incorporating the customer's uncertainty of purchasing the product online and permitted product returns so as to test the impact of the browse-and-switch option on the pricing decisions and profits. Rapp et al. [19] confirmed the negative relationship between perceived showrooming and salesperson performance. Mehra et al. [20] concluded that the showrooming behavior was detrimental to the offline stores.

Li et al. [21] considered the impact of the showrooming effect on the pricing and service effort strategies of supply chain entities in DSCs, such as no service pre-event and

post-event. Liu, Lu and Qi [2] studied the showrooming effect on a DSC with omnichannels based on the pricing decisions for the two channels, as well as the associated cross-channel return policy. Ma et al. [22] analyzed pricing and service effort decisions in DSCs with the showrooming effect. Basak et al. [23] investigated the effect of wholesale prices by the manufacturer on the selling prices of the products in a multichannel environment affected by showrooming. Jiao and Hu [24] analyzed different product value information that consumers could learn by visiting a BM retailer and researching an online retailer and studied consumers' show/webrooming behavior in a unified model. Wang and Wang [25] revisited the showrooming effect on online and offline channels and investigated the effect of in-store service. They claimed that the store should reduce the price, as it was not effective to reduce the showrooming behavior by improving the in-store service when the customer was undertaking a high cost to visit the offline store. Thus, this study will investigate the impacts of the showrooming effect on the optimal decisions and the profit of each member in a book DSC.

2.3. Contract Coordination

There is no doubt that the centralized decision-making can help supply chain members realize the best supply chain profit, but it does not design specific mechanisms to distribute the total profit. Thus, contracts play an important role in profit allocation in order to make the supply chain members realize Pareto optimality.

There have been extensive studies on quantity discount, buyback, revenue sharing, cost sharing and quantity flexibility for supply chain coordination. For instance, Weng [26] studied a supply chain including a supplier and a group of homogeneous buyers and developed a decision model so as to investigate the impact of the joint decision policies on the channel coordination. Chen et al. [27] studied a distribution channel and claimed that the optimal profits can be achieved in a decentralized system only if the coordination is realized with fixed charges and a novel discount-pricing strategy. Giannoccaro and Pontrandolfo [28] focused on a three-echelon supply chain with the revenue-sharing mechanism, and concluded that they could raise the profits of all the supply chain members by adjusting the contract parameters and achieve the system efficiency. Cachon and Lariviere [29] discussed some strengths and limitations of revenue-sharing contracts in supply chain coordination. Ding and Chen [30] focused on a three-stage supply chain with short-lifecycle products, and developed a flexible return policy by setting up the pricing rules and postponed the price of the final contract. Feng et al. [31] proposed a revenue-sharing contract with reliability in an n-echelon supply chain and concluded that revenue-sharing contracts were limited in terms of encouraging the members to improve their reliability. Recently, Zhong et al. [32] focused on a three-stage logistics service supply chain, discussing the impact of revenue-sharing contracts on their decisions and profits. Zhong et al. [33] investigated an agricultural products E-commerce supply chain and adopted a game theory to study the appropriate type of subsidies for the maximum benefits. Yang et al. [34] analyzed a BOPS (buy online and pick up in store) supply chain, taking into account the product return risk, and discussed the equilibrium results of two omnichannel integration modes which were managed by either the manufacturer or the retailer, respectively. They introduced a wholesale price contract to help the BOPS members realize the win–win status.

Furthermore, cost-sharing contracts are widely used in supply chains so as to reduce the cost pressure on supply chain members. For instance, Chao et al. [35] analyzed two contractual agreements in which product recall costs could be shared between a manufacturer and a supplier so as to induce quality improvement effort. Leng and Parlar [36] developed appropriate buy-back and lost-sales cost-sharing contracts to coordinate the assembly supply chain so that the system-wide expected profit was maximized. Recently, Chakraborty et al. [37] investigated how a retailer and each of two competing manufacturers can benefit from collaborative product quality improvement strategies in a supply chain based on a cost-sharing contract. Li et al. [38] tested the impact of revenue-sharing

and cost-sharing contracts offered by a retailer on emission reduction efforts and firms' profitability. Rodriguez-Pereira et al. [39] focused on a multicountry disaster-preparedness partnership and adopted a cost-sharing mechanism to achieve superior solutions compared to other methodologies, with respect to the proposed equity metrics. Hence, this study will adopt a cost-sharing contract to realize the coordination of the book DSC members with showrooming effect under either the royalty or buyout copyright models.

2.4. Comparative Analysis

According to the above literature analysis, it can be known that there has been relatively sufficient discussion on DSCs. However, there are few studies focused on the pricing and service effort decisions of book DSC members using Stackelberg game theory, or which have analyzed the showrooming effect on the optimal solutions and objectives of the book DSC members with the royalty and the buyout contracts for the author, or which have explored the DSC member coordination through a cost-sharing contract so as to reach Pareto optimality for all DSC members. This work analyzes the three-echelon book DSC, taking into account the showrooming effect, in which the author sells the copyright to the publisher with a royalty or a buyout contract. Table 1 lists the comparison of this work with respect to the related studies.

Table 1. Comparison of this work with respect to the related studies.

Related Studies	Decision Variables	Channel Type	Showrooming Effect	Contract Strategy	Game Model
Dan, Xu and Liu [10]	offline and online selling prices; service level	dual channel	×	×	Stackelberg game
Feng, Moon and Ryu [31]	wholesale price; ordering decision; reliability	single channel	×	revenue-sharing contract	×
Li, Zhu, Jiang and Li [11]	online and offline pricing; green degree decision	dual channel	×	two-part tariff	Stackelberg game
Mehra, Kumar and Raju [20]	offline and online pricing, service level; channel choice	dual channel	√	×	Hotelling game
Zhong, Guo, Wang and Tang [32]	ordering decision; service level	single channel	×	revenue-sharing contract	Stackelberg game
Ma, Li and Wang [22]	emission reduction; service effort level	dual channel	√	wholesale price contract	Dynamic game
Zhong, Lai, Guo and Tang [33]	selling prices; wholesale price; sales effort level	single channel	×	wholesale price contract	Stackelberg game
Wang and Wang [25]	online and offline selling prices; service level; channel choice	dual channel	√	×	Stackelberg game

Table 1. *Cont.*

Xu, Tang, Lin and Lu [1]	online and offline selling prices; wholesale price; sales effort level	dual channel	×	supplier-revenue sharing contract	Stackelberg game
Yang, Lai and Tang [34]	selling price; sales effort level	buy online and pick up in store	×	wholesale price contract	Stackelberg game
This study	online and offline selling prices; wholesale price; sales effort level	book dual channel with royalty and buyout contracts	√	cost-sharing contract	Stackelberg game

3. Problem Statement, Notation and Assumptions

In the following, the research problem is described and the corresponding assumptions are provided. In addition, some related notations are defined so as to formulate models in the next section.

This work focuses on a book DSC including a single author, a publisher and a traditional retailer, in which the author can sell the copyright to the publisher with a buyout contract or a royalty contract, then the publisher will sell books directly to customers with an online selling price and distribute books to the offline retailer with a wholesale price and, finally, the retailer puts them in offline stores for sale.

In order to clearly describe the decision sequence of DSC members, the related notations are defined in Table 2.

Table 2. Notation Definition.

Decision Variables	**Description**
p_{ri}	Offline selling price of the retailer
p_{pi}	Online selling price of the publisher
w_i	Wholesale price of the publisher
t_i	Service effort level of the retailer
Variables	Description
i	1/c/2 (3/f/4) for decentralized/centralized/coordination under royalty contract (buyout contract)
d_{ri}	Offline demand
d_{pi}	Online demand
M_i	The supply chain profit $M_i = M_{ri} + M_{pi}$
M_{ri}	The profit of the retailer
M_{pi}	The profit of the publisher
Parameters	Description
a_r	Online potential demand, $a_r > 0$
a_p	Offline potential demand, $a_p > 0$
b	Price elasticity coefficient $0 < b < 1$
c_0	Unit production cost
k_r	Growth coefficient of offline demand, $0 \leq k_r \leq 1$
k_d	Growth coefficient of online demand from showrooming effect, $0 \leq k_d < 1$
y	Unit price of royalty contract, $y < 1$
h	Proportion of $\cos t - \text{sharing}$, $0 \leq h \leq 1$
n	Copyright price under buyout contract, $n > 1$

In Table 2, the subscripts i = 1, 2, 3 and 4 represent the book DSC pricing strategy under the royalty contract without any coordination, the book DSC pricing strategy under

the royalty contract with cost-sharing coordination, the book DSC pricing strategy under the buyout contract without any coordination, and the book DSC pricing strategy under the buyout contract with cost-sharing coordination, respectively. The subscripts i = c and f represent the centralized decision-making of the book DSC under the royalty contract and the buyout contract. It is reasonable that $p_{ri} > p_{pi} > w_i > c_0 > 0$.

Furthermore, without loss of generality, some assumptions are described below.

Assumption 1. *The books sold by the publisher's online channel have the same quality as those sold by the retailer's offline channel, and all of them are physical books.*

Assumption 2. *The growth coefficient of offline demand resulting from the offline retailer's service effort is higher than that of the online demand benefitting from the showrooming effect [40]. That is,* $k_d \leq k_r - k_d$, *implying that* $k_d \leq \frac{1}{2}k_r$.

Assumption 3. *The price elasticity coefficient for the competitive channel price is much less than that of its own channel price. In this study, it assumes that* $0 \leq b \leq \frac{1}{\sqrt{2}}$.

Assumption 4. *The service effort cost of the retailer is* $\frac{1}{2}t_i^2 (t_i > 0)$.

Then, the decision orders can be stated as follows. Firstly, the author sells the copyright to the publisher with a unit price y for the royalty contract or the price n for the buyout contract. Secondly, the publisher has to determine the online price p_{ri} and the wholesale price w_i for the offline retailer. Finally, the retailer has to make the decisions of the offline selling price p_{pi} and its service effort level t_i.

In addition, this work refers to the online and offline demand functions in the study of Zhou, Guo and Zhou [6] below.

The retailer's offline demand function is

$$d_{ri} = a_r - p_{ri} + b \times p_{pi} + (k_r - k_d) \times t_i \quad (1)$$

The publisher's online demand function is

$$d_{pi} = a_p - p_{pi} + b \times p_{ri} + k_d \times t_i \quad (2)$$

It is believed that online potential demand is different from offline potential demand. To simplify the solutions and obtain more insights, it is assumed that $a_r = a_p = a$, and $a > y > 1$, which were also assumed by some related studies [6,40,41].

4. Model Formulation and Analysis

4.1. Pricing Model of the Book DSC Using the Royalty Contract

4.1.1. Pricing Strategy under Decentralized Decision-Making

In this subsection, under decentralized decision-making, the author sells the copyright to the publisher with a unit price y for the royalty contract. Based on Stackelberg game theory, the publisher has to decide its optimal online sales price and the optimal wholesale price, and then the retailer has to determine its optimal offline sales price and its optimal service effort level. The profits of the retailer and the publisher are obtained as follows.

The profit of the retailer = (the offline selling price–wholesale price) * the offline demand-retailer's service effort cost

That is,

$$M_{r1} = (p_{r1} - w_1) \times d_{r1} - \frac{1}{2}{t_1}^2 \quad (3)$$

The profit of the publisher = (wholesale price–unit production cost–unit royalty cost) * the offline demand + (the online selling price–unit production cost–unit royalty cost) * the online demand

That is,

$$M_{\mathrm{p1}} = (w_1 - c_0 - y) \times d_{\mathrm{r1}} + (p_{\mathrm{p1}} - c_0 - y) \times d_{\mathrm{p1}} \quad (4)$$

Then it provides the following proposition.

Proposition 1. *Under decentralized decision-making, there is an optimal online selling price p_{p1}^*, an optimal wholesale pricew_1^*, an optimal offline selling price p_{r1}^* and an optimal retailer's service effort level t_1^*, as follows.*

$$p_{p1}^* = [(-4(1+b)(a+y-by) + (k_d-k_r)((-1+b)^2yk_d^3 + (-1+(4-3b)b)yk_d^2k_r - k_r(a(2+b) + (2 + b - 3b^2)y + b^2yk_r^2) + k_d(a(3+b) + y + (2-3b)by + b(-2+3b)yk_r^2)))] / [(8(-1+b^2) + (k_d-k_r)^2(4-4b^2 + ((-1+b)k_d - bk_r)^2))],$$

$$w_1^* = [-((4(1+b)(a+y-by) + (k_d-k_r)(-((ab(3+b) + 4y + (-3+b)b(1+b)y)k_d) + (-1+b)(2a + (-1+b)y)k_d^3 + (a(2+b(4+b)) + (-1+b)(-2+b^2)y + (a(3-5b) - 2(-1+b)^2y)k_d^2)k_r + (a(-1+4b) + y + (-3+b)by)k_dk_r^2 + b(-a+y)k_r^3))] / [(8(-1+b^2) + (k_d-k_r)^2(4-4b^2 + ((-1+b)k_d - bk_r)^2)))],$$

$$p_{r1}^* = [(2(1+b)(a(-3+b) + (-1+b^2)y) - (k_d-k_r)((-1+b)(2a + (-1+b)y)k_d^3 + (a(3-5b) - 2(-1+b)^2y)k_d^2k_r + k_r(a(2+3b) - (-2+b+b^2)y + b(-a+y)k_r^2) + k_d(-a(1+3b) + (-1+b)(3+b)y + (a(-1+4b) + y + (-3+b)by)k_r^2)))] / [(8(-1+b^2) + (k_d-k_r)^2(4-4b^2 + ((-1+b)k_d - bk_r)^2)))],$$

$$t_1^* = [(1+b)(a + (-1+b)y)(k_d-k_r)(2-2b + (k_d-k_r)((-1+b)k_d - bk_r))] / [(8(-1+b^2) + (k_d-k_r)^2(4-4b^2 + ((-1+b)k_d - bk_r)^2)))].$$

The proofs of Proposition 1, and the following propositions and corollaries are presented in Appendix A.

4.1.2. Pricing Strategy under Centralized Decision-making

Under the centralized mechanism, the publisher and the retailer join in cooperation and determine the optimal sales prices for the online and offline channels and the service effort level simultaneously, so as to maximize their total profit.

In this case, the total profit of the publisher and the retailer is as follows.

$$M_c = (p_{rc} - c_0 - y) \times d_{rc} + (p_{pc} - c_0 - y) \times d_{pc} - \frac{1}{2}{t_c}^2 \tag{5}$$

Proposition 2. *Under centralized decision-making, there exist the optimal publisher's online sales price p_{pc}^*, the optimal retailer's offline sales price p_{rc}^* and the optimal service effort level t_c^*.*

$$p_{pc}^* = \frac{-2(a+y-by)(1+b-k_d^2) - (3a+y-by)k_dk_r + (a+y+by)k_r^2}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_dk_r + 2k_r^2}$$

$$p_{rc}^* = \frac{-2(a+y-by)(1+b-k_d^2) - (a-3(-1+b)y)k_dk_r + 2yk_r^2}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_dk_r + 2k_r^2}$$

$$t_c^* = -\frac{(1+b)(a+(-1+b)y)k_r}{2(-1+b)(1+b-k_d^2) + 2(-1+b)k_dk_r + k_r^2}$$

Based on Proposition 2, it investigates the impacts of the showrooming effect on the optimal online and offline selling prices, and the optimal service effort level in Corollary 1.

Corollary 1. *Under the royalty contract, the showrooming effect coefficient k_d has a positive impact on the optimal online selling price p_{pc}^* and negative impacts on the optimal offline selling price p_{rc}^* and the retailer's service effort level t_c^*.*

Corollary 1 implies that an increasing showrooming effect will stimulate the publisher to raise the online selling price but push the offline retailer to cut down its selling price and reduce it service effort level.

Furthermore, the difference between the optimal offline selling price p_{rc}^* and the optimal online selling price p_{pc}^* is given below.

$$p_{rc}^* - p_{pc}^* = \frac{(a + (-1+b)y)(k_r - 2k_d)k_r}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_d k_r + 2k_r^2} \tag{6}$$

Based on Assumption 2, $k_d \leq \frac{1}{2}k_r$. Hence, Corollary 2 can be obviously obtained.

Corollary 2. *Under the centralized decision-making with the royalty contract, the optimal online selling price will be close to the optimal offline selling price when the growth coefficient of offline demand resulting from the offline retailer's service effort tends to be equal to that of the online demand benefitting from the showrooming effect.*

It is well known that the supply chain profit can be at a global optimum under centralized decision-making, whereas the decentralized mechanism may lead to a local optimal solution. However, the centralized mechanism cannot provide a specific profit distribution for supply chain members, which is not helpful to the sustainable cooperation between them. Hence, it is important to introduce some contracts that coordinate supply chain members for a win–win situation.

4.1.3. Contract Coordination under the Royalty Contract

This subsection introduces a cost-sharing contract so as to make book DSC members achieve Pareto optimality. That is, the publisher will share $(1-h)$ $(0 \leq h \leq 1)$ of the retailer's service cost. In this case, the profit of the retailer = (the offline selling price–the wholesale price) * the offline demand–the cost-sharing ratio * the retailer's service effort cost. That is,

$$M_{r2} = (p_{r2} - w_2) \times d_{r2} - \frac{h}{2}{t_2}^2 \tag{7}$$

The profit of the publisher = (the wholesale price–unit production cost–unit royalty cost)* the offline demand + (the online selling price–unit production cost–unit royalty cost) * online demand–(1–cost sharing ratio) *the retailer's service effort cost. That is,

$$M_{p2} = (w_2 - c_0 - y) \times d_{r2} + (p_{p2} - c_0 - y) * d_{p2} - (1-h) \times \frac{1}{2}{t_2}^2 \tag{8}$$

Then Proposition 3 can be obtained below.

Proposition 3. *For a given h, the cost-sharing contract can realize the Pareto optimality if the wholesale price w_2 is subject to the condition of $w_2^d(h) < w_2 < w_2^u(h)$.*

Proposition 3 suggests that, for a given sharing percentage of the retailer's service effort cost, the publisher can set a wholesale price in the range $(w_2^d(h), w_2^u(h))$ for the retailer, and both of them can achieve Pareto optimality.

4.2. Pricing Model of the Book DSC Using the Buyout Contract

4.2.1. Decentralized Decision-Making with the Buyout Contract

In the following, the author sells the copyright to the publisher at a buyout cost n. Similar to the decentralized mechanism in Section 4.1.1, the publisher first confirms the

online sales price and the offline wholesale price. The retailer then determines the offline selling price and its service effort level. In this case, the profit of the retailer = (the retailer's offline selling price–the wholesale price)* the offline demand–the retailer's service effort cost. That is,

$$M_{r3} = (p_{r3} - w_3) \times d_{r3} - \frac{1}{2}{t_3}^2 \tag{9}$$

The profit of the publisher = (wholesale price–unit production cost) * the offline demand + (the online selling price–unit production cost)* the online demand– buyout cost. That is,

$$M_{\mathrm{p3}} = (w_3 - c_0) \times d_{\mathrm{r3}} + (p_{\mathrm{p3}} - c_0) \times d_{\mathrm{p3}} - n \tag{10}$$

Thus, it derives the following proposition.

Proposition 4. *Under the decentralized decision-making with the buyout contract, there is an optimal online selling price p^*_{p3}, an optimal wholesale price w^*_3, an optimal offline selling price p^*_{r3} and an optimal retailer's service effort level t^*_3.*

$$\begin{aligned} P^*_{p3} = {} & [a(-4(1+b) + (3+b)k_d^2 - (5+2b)k_d k_r + (2+b)k_r^2)] \\ & / [8(-1+b^2) + (k_d - k_r)^2(4 - 4b^2 + ((-1+b)k_d - bk_r)^2)] \end{aligned}$$

$$\begin{aligned} w^*_3 = {} & [(a(-4(1+b) + (k_d - k_r)(b(3+b)k_d - 2(-1+b)k_d^3 - (2+b(4+b) \\ & + (-5b)k_d^2)k_r + (1-4b)k_d k_r^2 + bk_r^3)))] / [8(-1+b^2) \\ & + (k_d - k_r)^2\left(4 - 4b^2 + ((-1+b)k_d - bk_r)^2\right)] \end{aligned}$$

$$\begin{aligned} t^*_3 = {} & \left[a(k_d - k_r)\left(2 - 2b^2 + (1+b)(k_d - k_r)((-1+b)k_d - bk_r)\right)\right] \\ & / [8(-1+b^2) + (k_d - k_r)^2(4 - 4b^2 + ((-1+b)k_d - bk_r)^2)] \end{aligned}$$

4.2.2. Centralized Decision-making with the Buyout Contract

In the centralized decision mechanism, the publisher and the retailer cooperate together and make the optimal decisions for the online and offline selling prices and the service effort level in order to realize their maximum total profit.

In this case, their total profit is

$$M_f = (p_{rf} - c_0) \times d_{rf} + (p_{pf} - c_0) \times d_{pf} - \frac{1}{2}{t_f}^2 - n \tag{11}$$

Similarly, one can derive the optimal solutions under the centralized decision-making with the buyout contract as follows.

Proposition 5. *Under the centralized decision-making with the buyout contract, there exist the optimal publisher's online selling price p^*_{pf}, the optimal retailer's offline selling price p^*_{rf} and the optimal service effort level t^*_f.*

$$p^*_{pf} = \frac{a(-2(1+b) + 2k_d^2 - 3k_d k_r + k_r^2)}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_d k_r + 2k_r^2}$$

$$p^*_{rf} = -\frac{a(2 + 2b - 2k_d^2 + k_d k_r)}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_d k_r + 2k_r^2}$$

$$t^*_f = -\frac{a(1+b)k_r}{2(-1+b)(1+b-k_d^2) + 2(-1+b)k_d k_r + k_r^2}$$

Based on Proposition 5, one can obtain similar impacts to the showrooming effect with those under the royalty contract in Corollary 3.

Corollary 3. *Under the buyout contract, the showrooming effect coefficient k_d has a positive influence on the optimal online sales price p_{pf}^* and negative impacts on the optimal offline sales price p_{rf}^* and the retailer's service effort level t_f^*.*

Moreover, the difference between the optimal offline selling price p_{rf}^* and the optimal online selling price p_{pf}^* is in the following.

$$p_{rf}^* - p_{pf}^* = \frac{a(k_r - 2k_d)k_r}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_d k_r + 2k_r^2} \tag{12}$$

Based on Assumption 2, $k_d \leq \frac{1}{2}k_r$. Hence, Corollary 4 is obvious to obtain.

Corollary 4. *Under the centralized decision-making with the buyout contract, the optimal online selling price will also be close to the optimal offline selling price when the growth coefficient of offline demand resulting from the offline retailer's service effort tends to be equal to that of the online demand benefitting from showrooming effect.*

4.2.3. Contract Coordination with the Buyout Contract

As stated in Section 4.1.3, some contracts can be developed so as to lead DSC members to execute centralized decisions for Pareto optimality. Hence, this subsection also proposes a cost-sharing contract for the channel coordination. That is, the publisher will share $(1-h)$ $(0 \leq h \leq 1)$ of the retailer's service effort cost under the buyout contract. Thus, the retailer's profit is

$$M_{r4} = (p_{r4} - w_4) \times d_{r4} - \frac{h}{2}{t_4}^2,$$

and the profit of the publisher is

$$M_{p4} = w_4 - c_0 * d_{r4} + p_{p4} - c_0 \times d_{p4} - n - \frac{(1-h)}{2}{t_4}^2$$

It then provides the publisher with a reasonable range for the wholesale price for the retailer below.

Proposition 6. *For a given h, the cost-sharing contract can make DSC members reach Pareto optimality under the buyout contract if the wholesale price w_4 is subject to the condition of $w_4^d(h) < w_4 < w_4^u(h)$.*

5. Numerical Analysis

5.1. Feasibility Analysis

5.1.1. Optimal Solutions and Profits for the DSC Members under the Royalty Contract

Referring to some data from [6], it is assumed that $k_r = 1, k_d = 0.3, a = 200$, $b = 0.2, c_0 = 10$, $y = 20$. According to Propositions 1–3, the optimal solutions and optimal profits of each member and the supply chain are obtained under decentralized decision-making, centralized decision-making and contract coordination, respectively (Table 3). Furthermore, based on Proposition 3, there exists the relationship where:

$$125.4 - 96.3h < w_2 < 180.9 - 96.3h \tag{13}$$

Table 3. Optimal solutions/profits of DSC members under the royalty contract (h = 0.6).

Decentralized Decision-Making	w_1^*	p_{p1}^*	p_{r1}^*	t_1^*	M_{p1}^*	M_{r1}^*	M_1^*
	123.6	**151.3**	**194.2**	**49.5**	**19,030.3**	**3768.8**	**22,799.1**
Centralized decision-making	w^*	p_{pc}^*	p_{rc}^*	t_c^*	M_{pc}^*	M_{rc}^*	M_c^*
	-	178.5	206.6	168.2	-	-	28,608.4
Cost-sharing contract coordination	w_2	p_{pc}^*	p_{rc}^*	t_c^*	M_{p2}	M_{r2}	M_c^*
	90	178.5	206.6	168.2	19,973.7	8634.7	28,608.4
	105	178.5	206.6	168.2	22,176.5	6431.9	28,608.4
	120	178.5	206.6	168.2	24,379.3	4229.1	28,608.4

When the publisher shares 40% of the retailer's service effort cost ($h = 0.6$), the wholesale price locates within the range (67.6, 123.1) based on Inequality (13). In this case, Table 3 suggests that the cost-sharing contract can lead to the 25.5% growth of the total profit with respect to that observed under decentralized decision-making, and well-coordinate the publisher and the retailer to achieve Pareto optimality.

Similarly, Tables 4 and 5 provide the optimal solutions and profits of the book DSC members under the royalty contract for the cases of $h = 0.5$ and $h = 0.4$, respectively. According to Inequality (13), the wholesale price falls within the range (77.3, 132.8) for the case of $h = 0.5$, and within the range (86.9, 142.4) for the case of $h = 0.4$. Tables 4 and 5 show that the cost-sharing contract can also help the publisher and the retailer to arrive at the win–win status.

Table 4. Optimal solutions/profits of DSC members under royalty contract (h = 0.5).

Decentralized Decision-Making	w_1^*	p_{p1}^*	p_{r1}^*	t_1^*	M_{p1}^*	M_{r1}^*	M_1^*
	123.6	**151.3**	**194.2**	**49.5**	**19,030.3**	**3768.8**	**22,799.1**
Centralized decision-making	w^*	p_{pc}^*	p_{rc}^*	t_c^*	M_{pc}^*	M_{rc}^*	M_c^*
	-	178.5	206.6	168.1	-	-	28,608.4
Cost-sharing contract coordination	w_2	p_{pc}^*	p_{rc}^*	t_c^*	M_{p2}	M_{r2}	M_c^*
	100	178.5	206.6	168.1	20,028.5	8579.9	28,608.4
	110	178.5	206.6	168.1	21,497	7111.4	28,608.4
	120	178.5	206.6	168.1	22,965.5	5642.9	2,8608.4

Table 5. Optimal solutions/profits of DSC members under royalty contract (h = 0.4).

Decentralized Decision-Making	w_1^*	p_{p1}^*	p_{r1}^*	t_1^*	M_{p1}^*	M_{r1}^*	M_1^*
	123.6	**151.3**	**194.2**	**49.5**	**19,030.3**	**3768.8**	**22,799.1**
Centralized decision-making	w^*	p_{pc}^*	p_{rc}^*	t_c^*	M_{pc}^*	M_{rc}^*	M_c^*
	-	178.5	206.6	168.2	-	-	28,608.4
Cost-sharing contract coordination	w_2	p_{pc}^*	p_{rc}^*	t_c^*	M_{p2}	M_{r2}	M_c^*
	110	178.5	206.6	168.2	20,083.2	8525.2	28,608.4
	125	178.5	206.6	168.2	22,286	6322.4	28,608.4
	140	178.5	206.6	168.2	24,488.8	4119.6	28,608.4

Based on Tables 3–5, it can be seen that the cost-sharing contract can lead the publisher and the retailer to keep their total profit at a global optimum as well as under different cost-sharing ratios. Furthermore, with the increase of the cost-sharing ratio, to keep Pareto optimality, the feasible range of the wholesale price moves upward. Hence, there are many

possible choices for their cooperation. The final choice may depend on the bargaining power between the publisher and the retailer.

Moreover, the total demand includes the online demand and the offline demand. In this case, the total demand is 260 books. Thus, the author can earn 260 × 20 = USD 5200 under the royalty contract.

5.1.2. Optimal Solutions and Performance of Book DSC under the Buyout Contract

Under the buyout contract, it assumes that $k_r = 1, k_d = 0.3, a = 200, b = 0.2$, $c_0 = 10, n = 5000$. Based on Propositions 4–6, Table 6 provides the optimal solutions and optimal profit for each member and the supply chain under decentralized decision-making, centralized decision-making and contract coordination, respectively.

Similarly, based on Proposition 6, there exists the relationship where

$$67.8 - 11h < w_4 < 163.1 - 11h \tag{14}$$

Table 6. Optimal solutions/profits of DSC members under the buyout contract (h = 0.6).

Decentralized Decision-Making	w_3^*	p_{p3}^*	p_{r3}^*	t_3^*	M_{p3}^*	M_{r3}^*	M_3^*
	112.1	**142.4**	**189.2**	**54.0**	**17,647.6**	**4485.2**	**22,132.8**
Centralized decision-making	w^*	p_{pf}^*	p_{rf}^*	t_f^*	M_{pf}^*	M_{rf}^*	M_f^*
	-	172.0	202.6	183.4	-	-	29,046.4
Cost-sharing contract coordination	w_4	p_{pf}^*	p_{rf}^*	t_f^*	M_{p4}	M_{r4}	M_f^*
	70	172.0	202.6	183.4	17,896.6	11,149.8	29,046.4
	90	172.0	202.6	183.4	21,100.6	7945.8	29,046.4
	110	172.0	202.6	183.4	24,304.7	4741.7	29,046.4

When the publisher undertakes 40% of the service effort cost of the retailer ($h = 0.6$) under the buyout contract, the corresponding range of the wholesale price is (61.2, 157.6), based on Inequality (14). In this case, Table 6 demonstrates that the cost-sharing contract can help DSC members to raise the profit growth of 31.2% under the buyout contract with respect to that of the decentralized decision-making and achieve Pareto optimality for many possible choices.

Similarly, Tables 7 and 8 show the optimal solutions and profits of the book DSC members under the buyout contract for the cases of $h = 0.5$ and $h = 0.4$, respectively. According to Inequality (14), the wholesale price locates within the range (62.3, 157.6) for the case of $h = 0.5$, and within the range (63.4, 157.6) for the case of $h = 0.4$. Tables 7 and 8 demonstrate that the cost-sharing contract can also lead the book DSC members to achieve Pareto optimality.

Table 7. Optimal solutions/profits of DSC members under the buyout contract (h = 0.5).

Decentralized Decision-Making	w_3^*	p_{p3}^*	p_{r3}^*	t_3^*	M_{p3}^*	M_{r3}^*	M_3^*
	112.1	**142.4**	**189.2**	**54.0**	**17,647.6**	**4485.2**	**22,132.8**
Centralized decision-making	w^*	p_{pf}^*	p_{rf}^*	t_f^*	M_{pf}^*	M_{rf}^*	M_f^*
	-	172.0	202.6	183.4	-	-	29,046.4
Cost-sharing contract coordination	w_4	p_{pf}^*	p_{rf}^*	t_f^*	M_{p4}	M_{r4}	M_f^*
	80	172.0	202.6	183.4	17,816.1	11,230.3	29,046.4
	100	172.0	202.6	183.4	21,020.2	8026.2	29,046.4
	120	172.0	202.6	183.4	24,224.2	4822.2	29,046.4

Table 8. Optimal solutions/profits of DSC members under the buyout contract (h = 0.4).

Decentralized Decision-Making	w_3^*	p_{p3}^*	p_{r3}^*	t_3^*	M_{p3}^*	M_{r3}^*	M_3^*
	112.1	**142.4**	**189.2**	**54.0**	**17,647.6**	**4485.2**	**22,132.8**
Centralized decision-making	w^*	p_{pf}^*	p_{rf}^*	t_f^*	M_{pf}^*	M_{rf}^*	M_f^*
	-	172.0	202.6	183.4	-	-	29,046.4
Cost-sharing contract coordination	w_4	p_{pf}^*	p_{rf}^*	t_f^*	M_{p4}	M_{r4}	M_f^*
	90	172.0	202.6	183.4	17,735.6	11,310.8	29,046.4
	105	172.0	202.6	183.4	20,138.7	8907.7	29,046.4
	120	172.0	202.6	183.4	22,541.7	6504.7	29,046.4

Based on Tables 6–8, it can be concluded that, for each different cost-sharing ratio, there are corresponding impacts on their own profits, but their total profit can stay the same as the global optimum. Furthermore, the feasible range of the wholesale price is not sensitive to the cost-sharing ratio. However, the final solution for the cooperation still depends on the bargaining power between the publisher and the retailer.

In addition, in contrast to the royalty contract, the buyout contract can bring more benefits to the publisher and the retailer. From the view of the author, in this case, the author earns USD 5200 under the royalty contract, which is more than the USD 5000 he would earn under the buyout contract. In general, the author can find the break-even point (BEP) between the royalty contract and the buyout contract, and his choice may depend on the demand forecasting for the book. He would likely choose the buyout contract if the forecasting is not more than the BEP.

5.2. Sensitivity Analysis

In the following, the study will test the impacts of the showrooming effect on the optimal solutions and the optimal profits of each member and the supply chain under two contracts, respectively.

5.2.1. Sensitivity Analysis of the Optimal Solutions and Profits under Royalty Contract

Under the royalty contract, it is assumed that $k_r = 1, a = 200, b = 0.2, c_0 = 10$, $h = 0.6, y = 20$. In the following, it tests the impact of the growth coefficient of the online demand from the showrooming effect (k_d) on the optimal profits of each member and the supply chain under decentralized and centralized decision-makings, as well as the optimal service effort level and the optimal pricing decisions.

Based on Figure 1, the total profit of the publisher and the retailer under the decentralized decision mechanism is less than that observed under the centralized decision mechanism for any given showrooming effect. Furthermore, each profit will reduce with the rise of the showrooming effect coefficient.

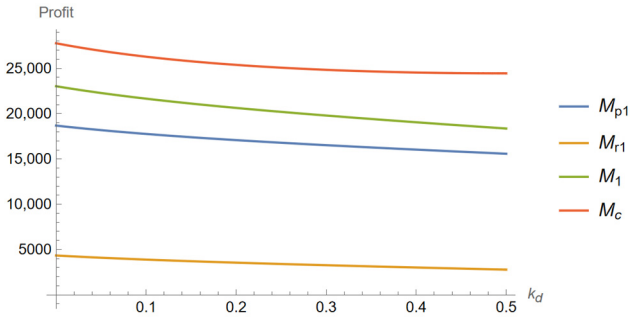

Figure 1. Impact of k_d on the optimal profits of the book DSC members.

With reference to Figure 2, the retailer's service effort level in the decentralized mechanism is much less than that observed in the centralized mechanism. Moreover, its service effort level is significantly affected by the showrooming effect under both decision-makings, which is partially supported by Corollary 1.

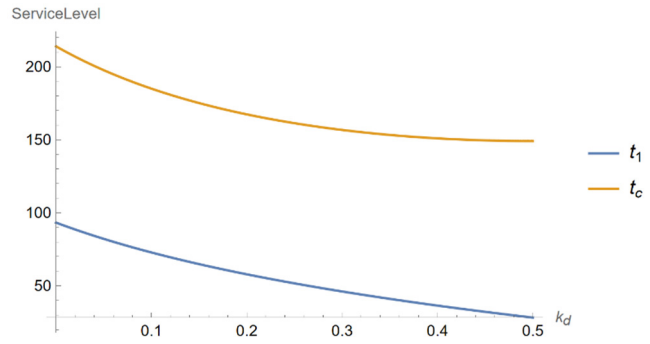

Figure 2. Impact of k_d on the retailer's service effort level under royalty contract.

Figure 3 shows that the optimal online sales price is less than the offline sales price in either the decentralized or the centralized decision mechanisms. With the encouragement of the showrooming effect, the optimal online selling price increases with the growth of the showrooming effect. In contrast, the optimal offline selling price has to go down, and tends to equal the optimal online selling price when there is a serious showrooming effect.

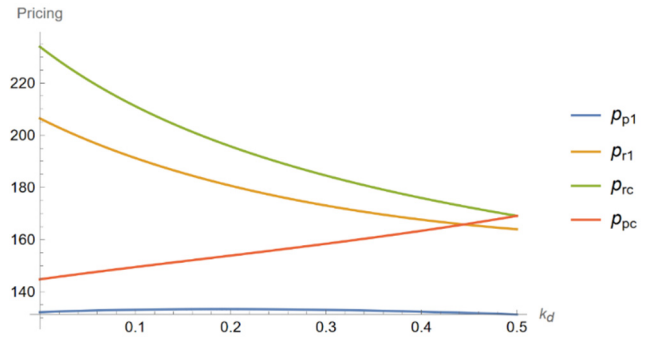

Figure 3. Impact of k_d on the optimal pricing decisions under the royalty contract.

5.2.2. Sensitivity Analysis of the Optimal Solutions and Profits under Buyout Contract

In this subsection, it assumes that $k_r = 1, a = 200, b = 0.2, c_0 = 10, h = 0.6, n = 5000$. Similarly, it tests the impact of the showroom effect (k_d) on the optimal profits of each member and the supply chain, the optimal service effort level of the retailer and the optimal online and offline sales prices under the buyout contract.

Figures 4–6 show the similar impacts of the showrooming effect on the optimal decisions and profits for the book DSC members. With respect to each profit under the royalty contract, those under the buyout contract are slightly higher; the retailer would like to provide a higher service level under the centralized decision-making with the buyout contract. In addition, the publisher would like to determine a higher online sales price in the centralized mechanism with the buyout contract.

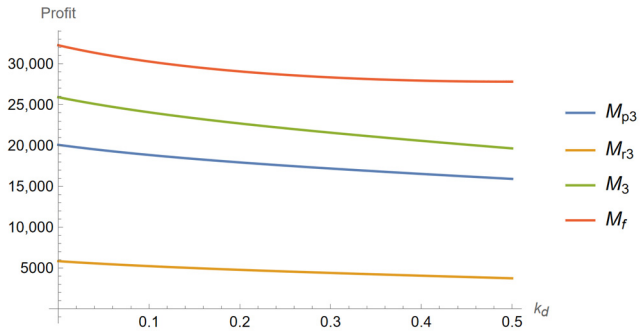

Figure 4. Impact of k_d on the optimal profits of DSC members under the buyout contract.

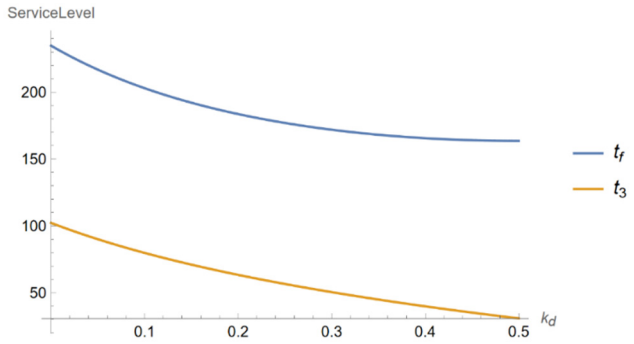

Figure 5. Impact of k_d on the retailer's service effort level under buyout contract.

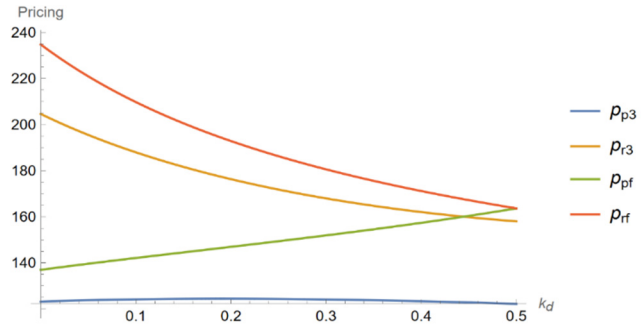

Figure 6. Impact of k_d on the optimal pricing decisions under buyout contract.

6. Conclusions and Future Research

6.1. Conclusions

This research focused on a book DSC, in which an author sells the copyright to the publisher with either the royalty contract or the buyout contract. Then, the publisher has to determine the online selling price to sell physical books directly to customers, set the wholesale price for the traditional retailer and distribute physical books to the retailer and, finally, the retailer has to make the decision on the offline selling price for the offline customers. Specifically, this work takes into account the showrooming effect in the book DSC. It used Stackelberg game theory to study the optimal pricing decisions and the service effort level in decentralized and centralized decision mechanisms with either the royalty contract or the buyout contract. Then, it developed a cost-sharing contract to realize Pareto optimality for both the publisher and the retailer. Furthermore, this study investigated the influence of the showrooming effect on the optimal decisions and the profits of each member and the whole supply chain. Finally, it conducted a numerical analysis to provide a more intuitive explanation for the theoretical results and to find more interesting insights.

The main findings and the corresponding managerial implications are summarized as follows:

(1) The showrooming effect has a negative impact on the optimal offline selling price of the retailer. It also discourages the retailer from reducing his service effort level, whereas the showrooming effect stimulates the publisher to raise the optimal online selling price and the wholesale price for the offline channel, which is harmful to the offline retailer. Hence, it is critical to introduce contracts that encourage the offline retailer to cooperate with the publisher and achieve a win–win situation.
(2) The cost-sharing contract introduced in this study can realize the channel coordination for the book DSC members. It provides many possible cooperation choices for the publisher and the retailer to achieve a win–win situation. In real business, the final best possible combination of cost-sharing ratio and wholesale price mainly depends on the bargaining power between the publisher and the retailer. In addition, besides cost-sharing contracts, DSC members can seek other contract coordination, such as revenue-sharing contracts, and wholesale price contracts.
(3) In general, the showrooming phenomenon of experiencing offline and buying online mainly results from the cheaper online selling price. This study suggests that there will be little difference between the optimal online and offline pricings if the growth coefficient of the offline demand (resulting from the offline retailer's service effort) tends to be equal to that of the online demand, benefitting from the showrooming effect.
(4) From the view of the author, there are two options (royalty or buyout contract) for him to choose. The author is suggested to analyze the break-even point between the royalty contract and the buyout contract and make his choice according to the demand forecasting for the book. The buyout contract would be better if the demand forecasting is no more than the break-even point. Otherwise, the royalty contract would be better.

6.2. Future Research

There also exist some limitations in this study. First, it focuses on the three-echelon book dual-channel supply chain and analyzes the two cases under the royalty contract and the buyout contract, respectively. However, the author's decision is not considered. Second, the current research problem involves only four decision variables, and there is still some gap between the research and the reality. Third, there are two common customer behaviors along the dual-channel supply chain—cross-channel return and out-of-stock replacement—which will affect the decisions and profits of DSC members. Finally, there are some assumptions presented in this study which hold for most cases, but they cannot cover all the possible cases. All these issues can be taken into account in future research.

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Appendix A

Appendix A.1

Proof of Proposition 1 . Based on Stackelberg game theory, the backward induction is adopted to obtain the optimal decision for the retailer's offline sales price p_r and its own service effort level t.

In order to verify whether the optimal responses of the retailer's offline selling price p_r and its own service effort level t exist, the Hessian matrix of M_{r1} on p_r and t is constructed below.

$$\mathrm{H}(t_1, p_{r1}) \begin{bmatrix} \frac{\partial^2 M_{\mathrm{r1}}}{\partial (t_1)^2} & \frac{\partial^2 M_{\mathrm{r1}}}{\partial t_1 \partial p_{\mathrm{r1}}} \\ \frac{\partial^2 M_{\mathrm{r1}}}{\partial p_{\mathrm{r1}} \partial t_1} & \frac{\partial^2 M_{\mathrm{r1}}}{\partial (p_{\mathrm{r1}})^2} \end{bmatrix} \begin{bmatrix} -1 & -k_d + k_r \\ -k_d + k_r & -2 \end{bmatrix}$$

Since $\frac{\partial^2 M_{\mathrm{r1}}}{\partial (t_1)^2} = -1 < 0$, and the second-order principal of $\mathrm{H}(t_1, p_{r1})$ is $2 - (k_r - k_d)^2 > 0$, thus $\mathrm{H}(t_1, p_{r1})$ is negative definite, which implies that the retailer profit is a joint concave function of p_r and t. Hence, there exist optimal solutions for the retailer as follows.

$$p_{r1}^* = -\frac{-a - b p_{\mathrm{p1}} - w_1 + (-k_d + k_r)^2 w_1}{2 - (-k_d + k_r)^2} \tag{A1}$$

$$t_1^* = \frac{(k_d - k_r)(a + b p_{\mathrm{p1}} - w_1)}{-2 + k_d^2 - 2 k_d k_r + k_r^2} \tag{A2}$$

Based on Equations (A1) and (A2), the Hessian matrix of M_{p1} on p_{p1} and w_1 is obtained below.

$$H(w_1, p_{p1}) = \begin{bmatrix} \frac{\partial^2 M_{\mathrm{p1}}}{\partial (w_1)^2} & \frac{\partial^2 M_{p1}}{\partial w_1 \partial p_{p1}} \\ \frac{\partial^2 M_{p1}}{\partial p_{p1} \partial w_1} & \frac{\partial^2 M_{p1}}{\partial (p_{p1})^2} \end{bmatrix} = \begin{bmatrix} \frac{2}{-2 + (k_d - k_r)^2} & b + \frac{k_d(-k_d + k_r)}{-2 + (k_d - k_r)^2} \\ b + \frac{k_d(-k_d + k_r)}{-2 + (k_d - k_r)^2} & \frac{4 - 2b^2 + 2(k_d - k_r)((-1 + b)k_d + k_r)}{-2 + (k_d - k_r)^2} \end{bmatrix} \tag{A3}$$

The first-order principal of Matrix (A3) is $\frac{\partial^2 M_{p1}}{\partial (w_1)^2} < 0$, since $0 \le k_r \le 1, 0 \le k_d < 1$. The second-order principal of Matrix (A3) is

$$\left| H(w_1, p_{p1}) \right| = \frac{8 - 8b^2 - (k_d - k_r)^2 (4 - 4b^2 + ((-1 + b)k_d - b k_r)^2)}{\left(-2 + (k_d - k_r)^2\right)^2} \tag{A4}$$

According to Assumptions 2 and 3, it is easy to check whether Expression (A4) is positive. Hence, $H(w_1, p_{p1})$ is negative definite, implying that there exist optimal solutions for the publisher as follows.

$$\begin{aligned} p_{p1}^* = [&(-4(1 + b)(a + y - by) + (k_d - k_r)((-1 + b)^2 y k_d^3 + (-1 + (4 - 3b)b) y k_d^2 k_r \\ &- k_r \left(a(2 + b) + \left(2 + b - 3b^2\right) y + b^2 y k_r^2\right) + k_d (a(3 + b) + y + (2 \\ &- 3b) by + b(-2 + 3b) y k_r^2)))] \\ &/ [(8(-1 + b^2) + (k_d - k_r)^2 (4 - 4b^2 + ((-1 + b)k_d - b k_r)^2))] \end{aligned}$$

$$\begin{aligned} w_1^* = [&-((4(1 + b)(a + y - by) + (k_d - k_r)(-((ab(3 + b) + 4y + (-3 + b)b(1 \\ &+ b) y) k_d) + (-1 + b)(2a + (-1 + b) y) k_d^3 + (a(2 + b(4 + b)) + (-1 \\ &+ b)\left(-2 + b^2\right) y + \left(a(3 - 5b) - 2(-1 + b)^2 y\right) k_d^2) k_r + (a(-1 + 4b) \\ &+ y + (-3 + b) by) k_d k_r^2 + b(-a + y) k_r^3)))] \\ &/ [(8(-1 + b^2) + (k_d - k_r)^2 (4 - 4b^2 + ((-1 + b)k_d - b k_r)^2)))] \end{aligned}$$

Then the optimal solutions for the retailer are below.

$$p_{r1}^{*} = [(2(1+b)\big(a(-3+b)+\big(-1+b^2\big)y\big) - (k_d-k_r)((-1+b)(2a+(-1+b)y)k_d^3 + \Big(a(3-5b)-2(-1+b)^2y\Big)k_d^2k_r + k_r(a(2+3b)-\big(-2+b+b^2\big)y + b(-a+y)k_r^2) + k_d(-a(1+3b)+(-1+b)(3+b)y + (a(-1+4b)+y+(-3+b)by)k_r^2)))] / [(8(-1+b^2)+(k_d-k_r)^2(4-4b^2+((-1+b)k_d-bk_r)^2))))]$$

$$t_1^{*} = [(1+b)(a+(-1+b)y)(k_d-k_r)(2-2b+(k_d-k_r)((-1+b)k_d-bk_r))] / [(8(-1+b^2)+(k_d-k_r)^2(4-4b^2+((-1+b)k_d-bk_r)^2))))]$$

Hence, the optimal profits for the publisher and the retailer can be derived, respectively. □

Appendix A.2

Proof of Proposition 2. According to the backward induction, the Hessian matrix of M_c on p_{rc}, p_{pc} and t_c is as follows.

$$H(p_{\mathrm{rc}}, p_{\mathrm{pc}}, t_c) = \begin{bmatrix} \frac{\partial^2 M_c}{\partial (t_c)^2} & \frac{\partial^2 M_c}{\partial t_c \partial p_{\mathrm{pc}}} & \frac{\partial^2 M_c}{\partial t_c \partial p_{\mathrm{rc}}} \\ \frac{\partial^2 M_c}{\partial p_{\mathrm{pc}} \partial t_c} & \frac{\partial^2 M_c}{\partial \left(p_{\mathrm{pc}}\right)^2} & \frac{\partial^2 M_c}{\partial p_{\mathrm{pc}} \partial p_{\mathrm{rc}}} \\ \frac{\partial^2 M_c}{\partial p_{\mathrm{rc}} \partial t_c} & \frac{\partial^2 M_c}{\partial p_{\mathrm{rc}} \partial p_{\mathrm{pc}}} & \frac{\partial^2 M_c}{\partial (p_{\mathrm{rc}})^2} \end{bmatrix} = \begin{bmatrix} -1 & k_d & -k_d + k_r \\ k_d & -2 & 2b \\ -k_d + k_r & 2b & -2 \end{bmatrix}$$

It is obvious that its first-order principal $\frac{\partial^2 M_c}{\partial (t_c)^2} = -1 < 0$, its second-order principal $2 - k_d^2 > 0$ and its third-order principal, $\left|\mathrm{H}(p_{\mathrm{rc}}, p_{\mathrm{pc}}, t_c)\right| = 2(-2 + 2b^2 + 2k_d^2 - 2bk_d^2 - 2k_dk_r + 2bk_dk_r + k_r^2)$, is negative based on Assumption 3. Thus, $H(p_{\mathrm{rc}}, p_{\mathrm{pc}}, t_c)$ is negative definite, and their total profit is a joint concave function of p_{rc}, p_{pc} and t_c. Hence, the corresponding optimal solutions are derived below.

$$p_{pc}^{*} = \frac{-2(a+y-by)(1+b-k_d^2) - (3a+y-by)k_dk_r + (a+y+by)k_r^2}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_dk_r + 2k_r^2} \tag{A5}$$

$$p_{rc}^{*} = \frac{-2(a+y-by)(1+b-k_d^2) - (a-3(-1+b)y)k_dk_r + 2yk_r^2}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_dk_r + 2k_r^2} \tag{A6}$$

$$t_c^{*} = -\frac{(1+b)(a+(-1+b)y)k_r}{2(-1+b)(1+b-k_d^2) + 2(-1+b)k_dk_r + k_r^2} \tag{A7}$$

Finally, their maximum total profit can be obtained. □

Appendix A.3

Proof of Corollary 1. According to Expressions (A1)–(A3), their first-order derivates can be computed with respect to the showrooming effect coefficient. Based on Assumptions 2 and 3, it is not difficult to verify that $\frac{\partial p_{pc}^{*}}{\partial k_d} > 0$, $\frac{\partial p_{rc}^{*}}{\partial k_d} < 0$, and $\frac{\partial t_c^{*}}{\partial k_d} < 0$. □

Appendix A.4

Proof of Proposition 3. Under the cost-sharing contract with a given h, the publisher and the retailer should execute the optimal solutions under the centralized decision-making so as to achieve the global optimum. Thus, the profit of the retailer is

$$\boldsymbol{M_{r2} = (p^*_{rc} - w_2) \times d_{rc} - \frac{h}{2} t^{*2}_c.} \tag{A8}$$

The profit of the publisher is

$$M_{p2} = (w_2 - c_0 - y) \times d_{rc} + (p^*_{pc} - c_0 - y) \times d_{pc} - (1 - h) \times \frac{1}{2} t^{*2}_c \tag{A9}$$

To arrive Pareto optimality, the profits of the two members under the cost-sharing contract should be superior to those under the decentralized decision-making. It implies that the following inequation group (A10) should hold.

$$\begin{cases} M_{r1}(p^*_{pc},\ p^*_{rc},\ t^*_c) < M_{r2} \\ M_{p1}(p^*_{pc},\ p^*_{rc},\ t^*_c) < M_{p2} \\ w_2 > c_0 \end{cases} \tag{A10}$$

According to Inequation Group (A10), the wholesale price w_2 can obtain its lower bound, $w^d_2(h)$, and its upper bound, $w^u_2(h)$. □

Appendix A.5

Proof of Proposition 4. The proof is similar to that of Proposition 1. Hence, the optimal solutions of each member can be derived under the decentralized mechanism below.

$$P^*_{p3} = \left[a\left(-4(1+b) + (3+b)k_d^2 - (5+2b)k_d k_r + (2+b)k_r^2\right)\right] / [8(-1+b^2) + (k_d - k_r)^2(4 - 4b^2 + ((-1+b)k_d - bk_r)^2)]$$

$$w^*_3 = [(a(-4(1+b) + (k_d - k_r)(b(3+b)k_d - 2(-1+b)k_d^3 - \left(2 + b(4+b) + (-5b)k_d^2\right)k_r + (1-4b)k_d k_r^2 + bk_r^3)))] / [8\left(-1+b^2\right) + (k_d - k_r)^2(4 - 4b^2 + ((-1+b)k_d - bk_r)^2)]$$

$$P^*_{r3} = [(a(2(-3+b)(1+b) - (k_d - k_r)(2(-1+b)k_d^3 + (3-5b)k_d^2 k_r + k_r(2+3b - bk_r^2) + k_d\left(-1 - 3b + (-1+4b)k_r^2\right))))] / [8\left(-1+b^2\right) + (k_d - k_r)^2\left(4 - 4b^2 + ((-1+b)k_d - bk_r)^2\right)]$$

$$t^*_3 = [a(k_d - k_r)(2 - 2b^2 + (1+b)(k_d - k_r)((-1+b)k_d - bk_r))] / [8(-1+b^2) + (k_d - k_r)^2(4 - 4b^2 + ((-1+b)k_d - bk_r)^2)]$$

□

Appendix A.6

Proof of Proposition 5. The proof is similar to that of Proposition 2. Hence, it is not difficult to obtain the optimal solutions of each member under the centralized decision-making below.

$$\boldsymbol{p^*_{pf} = \frac{a(-2(1+b) + 2k_d^2 - 3k_d k_r + k_r^2)}{4(-1+b)(1+b-k_d^2) + 4(-1+b)k_d k_r + 2k_r^2}} \tag{A11}$$

$$p_{rf}^{*} = -\frac{a(2+2b-2k_d^2+k_dk_r)}{4(-1+b)(1+b-k_d^2)+4(-1+b)k_dk_r+2k_r^2} \tag{A12}$$

$$t_f^{*} = -\frac{a(1+b)k_r}{2(-1+b)(1+b-k_d^2)+2(-1+b)k_dk_r+k_r^2} \tag{A13}$$

Thus, the total profit including the publisher and the retailer can be acquired. □

Appendix A.7

Proof of Corollary 3. According to Equations (A11)–(A13), their first-order derivates can be computed with respect to the showrooming effect coefficient. Based on Assumptions 2 and 3, it is not difficult to verify that $\frac{\partial p_{pf}^{*}}{\partial k_d} > 0$, $\frac{\partial p_{rf}^{*}}{\partial k_d} < 0$, and $\frac{\partial t_f^{*}}{\partial k_d} < 0$. □

Appendix A.8

Proof of Proposition 6. Under the cost-sharing contract with a given h, the publisher and the retailer should execute the optimal solutions under the centralized decision-making so as to achieve the global optimum. Thus, the profit of the retailer is

$$\boldsymbol{M_{r4}} = (\boldsymbol{p_{rf}^{*}} - \boldsymbol{w_4}) \times \boldsymbol{d_{rf}} - \frac{\boldsymbol{h}}{\boldsymbol{2}}\boldsymbol{t_f^{*2}}. \tag{A14}$$

The profit of the publisher is

$$M_{p4} = w_4 - c_0 \times d_{rf} + p_{pf}^{*} - c_0 \times d_{pf} - n - \frac{(1-h)}{2}t_f^{*2} \tag{A15}$$

To arrive Pareto optimality, the profits of the supply chain members under the cost-sharing contract should be superior to those under the decentralized mechanism. It implies that the following inequation group (A16) should hold.

$$\begin{cases} M_{r3}(p_{pf}^{*}, p_{rf}^{*}, t_f^{*}) < M_{r4} \\ M_{p3}(p_{pf}^{*}, p_{rf}^{*}, t_f^{*}) < M_{p4} \\ w_4 > c_0 \end{cases} \tag{A16}$$

According to Inequation Group (A16), the wholesale price w_4 can obtain its lower bound, $w_4^{d}(h)$, and its upper bound, $w_4^{u}(h)$. □

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