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Brand-Owners' Exclusive Channel Strategies in Multitier Supply Chains: Effect of Contract Unobservability

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Abstract: In multitier supply chains, brand-owners often form exclusive deals with downstream retailers or upstream suppliers. Therefore, the selection of exclusive channel strategies becomes a critical decision for brand owners, resulting in three typical structures: a flexible structure, an exclusive retailing-channel structure, and an exclusive purchasing-channel structure. This paper contributes to the literature by formulating these three representative channel structures in a three-tier supply chain. Both observable and unobservable contracts are considered in each structure. We build game-theoretical models and derive the equilibrium outcomes under observable and unobservable contracts. We find that the exclusive retailing channel is more beneficial for brand-owners, regardless of whether the contracts are observable or unobservable. Additionally, the exclusive retailing channel benefits the entire supply chain more than the exclusive purchasing channel when the level of channel substitutability is low (high) under contract observability (unobservability). With regard to the effect of contract unobservability, we find that it can benefit brand-owners when the level of channel substitutability is low, but it can harm them when the level of channel substitutability is high. Furthermore, we explore the effects of channel substitutability and demonstrate that brand-owners' performance can be positively and negatively affected by the channel substitutability under contract unobservability. Our findings provide operational strategies for brand-owners to form exclusive channels in a multitier supply chain.

Keywords: contract unobservability; multitier supply chain; exclusive channels; channel competition; wholesale price

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1. Introduction

In practice, exclusive channel strategies are commonly observed in a variety of goods and service markets. In the vaccine market, some overseas vaccine suppliers select exclusive retailers [1]. For instance, Sanofi Pasteur received exclusive worldwide marketing rights for infectious disease vaccines from Translate Bio [2]. In the mobile phone market, some brand-owners' mobile phones were sold only through exclusive telecom service providers when their mobile phones were first launched [3]. For instance, Apple and AT&T originally signed a 5 year exclusive deal for iPhone when the iPhone was first launched in 2007 [4]. In addition, it is common knowledge that some film and television programs are available through exclusive channels in the TV market. Similarly, numerous books were only released through exclusive reading platforms in the e-book market.

In a multitier supply chain, brand-owners may form exclusive deals with downstream retailers or upstream suppliers, resulting in two typical exclusive channel strategies: exclusive retailing-channel and exclusive purchasing-channel strategies. The exclusive retailing-channel strategy involves brand-owners forming exclusive deals with downstream retailers to distribute goods or services. For instance, in 2018, OnePlus, a mobile phone brand-owner, signed a contract with e-retailer JD.com to exclusively sell its products in

China [5]. On the other hand, the exclusive purchasing-channel strategy entails brand-owners forming exclusive deals with upstream suppliers to procure goods or services. For example, IKEA, a renowned furniture brand-owner, signed an exclusive agreement with Caesarstone, a leading manufacturer of high-quality engineered quartz surfaces, in 2013 [6]. Obviously, the exclusive retailing channel can help brand-owners enhance pricing power, thus increasing efficiency and competitiveness [7]. In contrast, the exclusive purchasing channel may reduce supply resilience, but it helps brand-owners control the quality of supply and improve the competitiveness of goods or services. Therefore, a crucial question arises: which strategy is more beneficial to brand-owners when forming exclusive deals, the exclusive retailing channel or exclusive purchasing channel?

Most previous studies on contract agreement in the supply chain, regardless of whether competition is downstream or upstream, have made the general assumption that the contract terms are common knowledge for all competitors. For example, suppliers make a public commitment to the contracts offered to all the competing retailers, which means that the contract terms between a supplier and an individual retailer are known to other retailers. However, this assumption may not reflect all realistic situations. In practice, contract terms may be private information or only partially observable among particular competing members [8–10]. A supplier may opportunistically adjust the original contract and privately negotiate particular terms with each individual retailer, even after the public announcement of contracts to all retailers [8]. For instance, Chinese leading domestic appliance brands Gree and Midea unilaterally adjusted prices on major retail platforms (such as JD.com and Gome) without disclosing the contract to rivals [10]. Clearly, the unobservability of contracts has a direct impact on supply chain members' pricing strategies and performance. Therefore, another critical question our study addresses is: how does contract unobservability affect brand-owners' exclusive channel strategies?

To address the aforementioned issues, we consider a three-tier supply chain system consisting of two suppliers, two brand-owners and two retailers. The brand-owners purchase goods from the upstream suppliers and sell them through the retailers. To investigate the brand-owners' exclusive channel strategies, we propose three distinct structures: (1) flexible structure, in which each supplier can sell products to both brand-owners, and each brand-owner can sell products through both retailers; (2) exclusive retailing-channel structure, in which the brand-owners form exclusive deals with the retailers, and each brand-owner sells products exclusively through its allied retailer; (3) exclusive purchasing-channel structure, in which the brand-owners form exclusive deals with the suppliers, and each brand-owner procures products exclusively from its allied supplier. We consider two contrasting scenarios where contract terms are either observable or unobservable in the supply chain. We focus on examining the preferences of brand-owners for exclusive retailing-channel and purchasing-channel strategies and investigate the impact of contract unobservability on the performance of the supply chain participants.

Our study contributes to the existing literature in several ways. First, most existing studies consider a two-tier supply chain consisting of upstream suppliers and downstream retailers, and then investigate the incentives of the suppliers and retailers to form exclusive deals (e.g., [3,7]). We depart from the existing literature by comparing the upstream and downstream exclusive channel strategies of brand-owners in a three-tier supply chain, which are commonly observed in practice. Second, most existing studies on supply-chain contracting assume that contract terms are observed by all members (e.g., [11,12]), while contract unobservability is also essential in practice. The distinguishing feature of our work is that both contract observability and unobservability in the supply chain are considered. We explore the impact of contract unobservability on the exclusive channel strategies of brand-owners. Third, we provide managerial implications for the brand-owners to optimize their exclusive channel decisions. For example, the exclusive retailing channel is more beneficial for the brand-owners, regardless of whether the contracts are observable or unobservable. We identify two effects of a low wholesale price on the equilibrium:

(1) a demand-increase effect in the brand-owners' own channel, and (2) a demand-decrease effect in the competing channel, to illustrate the driving forces.

Our findings have implications for achieving and maintaining supply-chain sustainability. By examining the effect of contract unobservability on the selection of exclusive channel strategies, our analysis provides insights into how brand-owners can make more sustainable decisions in their supply chains. To be specific, our study suggests that brand-owners should avoid unobservable contracts when the level of channel substitutability is high, as contract unobservability can harm brand-owners' performance when implementing exclusive channels. To promote sustainability and responsible business practices, brand-owners should prioritize the use of observable contracts, which can increase transparency and accountability in their supply chains. Moreover, our analysis highlights the importance of selecting the most effective exclusive channel strategy. When the level of channel substitutability is low (high) under contract observability (unobservability), the exclusive retailing channel benefits the entire supply chain more than the exclusive purchasing channel. This suggests that brand-owners can create more sustainable and efficient supply chains by prioritizing the implementation of exclusive retailing channels.

The remainder of our study is organized as follows: we review the most related studies in Section 2; the model settings, including channel structure and contract unobservability, are presented in Section 3; in Section 4, we study the exclusive channel strategies and the effect of contract unobservability; in Section 5, the effect of channel substitutability is investigated; Section 6 presents conclusions and future research directions.

2. Literature Review

Our study is related to three primary streams of research: (1) channel distribution in supply chains, (2) exclusive channel strategies, and (3) contract unobservability. These three research streams are all related to the management of supply-chain relationships. Channel distribution in supply chains focuses on the different ways that products are distributed through the supply chain, such as direct sales, through brand-owners, or through retailers. Exclusive channel strategies, on the other hand, involve the use of exclusive agreements with certain channel partners, such as exclusive distribution or exclusive supply agreements. Contract unobservability refers to the situation where it is difficult or impossible for a channel partner to observe its rival's contract terms. We concisely review the related studies below.

2.1. Channel Distribution in Supply Chains

The first and most related stream is the literature on channel distribution, which has been extensively studied in recent years. Cattani et al. [13] and Tsay and Agrawal [14] provided a comprehensive and insightful discussion on channel distribution in supply chains. Most existing studies on channel distribution focused on a two-tier supply chain. Among them, some studies investigated channel distribution from the perspective of an upstream manufacturer. They studied a manufacturer's choice of direct and indirect sales channels, such as He et al. [11], Wang et al. [15], Chen et al. [16], Pun et al. [17], and Zhang et al. [18]. On the contrary, some studies investigated channel distribution from the perspective of a downstream retailer. They mainly focused on the retailer's choice of agency selling and reselling channel strategy (e.g., Abhishek et al. [19] and Zhang and Zhang [20]), and the retailer's choice of an online-and-offline channel strategy (e.g., Zhang et al. [21] and Nie et al. [22]) by modeling different channel structures. The abovementioned studies all built several different channel structures, in order to investigate which channel structure (channel strategy) is more beneficial. Unlike them, we mainly focus on the perspective of brand-owners, specifically, the brand-owners' exclusive channel strategies in a three-tier supply chain. Table 1 presents relations between the existing literature on channel distribution and our study.

Table 1. Summary of existing studies on channel distribution in supply chains.

Papers	Three-Tier Supply Chain	Channel Structures	Perspective of Research Subjects	Theme
He et al. [11], Wang et al. [15]	×	Dual-channel supply chains	Manufacturer	A manufacturer's choice of direct and indirect sales channels
Chen et al. [16], Pun et al. [17], Zhang et al. [18]	×	Single-channel supply chain; dual-channel supply chain	Manufacturer	A manufacturer's choice of direct and indirect sales channels
Abhishek et al. [19]	×	Dual-channel supply chains	Retailer	A retailer's choice of agency selling and reselling channel strategy
Zhang and Zhang [20]	×	Single-channel supply chains; dual-channel supply chains	Retailer	A retailer's choice of agency selling and reselling channel strategy
Zhang et al. [21]	×	Single-channel supply chains; dual-channel supply chain	Retailer	A retailer's choice of online-and-offline channel strategy
Nie et al. [22]	×	Dual-channel supply chains	Retailer	A retailer's choice of online-and-offline channel strategy
Giri et al. [23]	√	Single-channel supply chain	Supply chain coordination	Channel coordination/Pareto improvement
Islam et al. [24]	√	Multi-channel supply chain (a supplier, a manufacturer, and multiple retailers)	Manufacturer	A manufacturer-managed consignment policy
Lan et al. [25]	√	Dual-channel supply chain (a manufacturer, two distributors, and a retailer)	Supply chain coordination	Competition between two distributors; coordination/Pareto improvement
Li and Chen [26]	√	Dual-channel supply chain (two suppliers, one manufacturer, and two retailers)	Supply chain coordination	A manufacturer's vertical integration strategies
This paper	√	Multichannel supply chains (two suppliers, two brand-owners and two retailers)	Brand-owners	Brand-owners' exclusive channel strategies; contract unobservability

Unlike the above literature on channel distribution in a two-tier supply chain, some previous studies investigated channel distribution in a three-tier supply chain, such as Giri et al. [23], Islam et al. [24], Lan et al. [25], and Li and Chen [26]. However, Giri et al. [23] focused on a single-channel supply chain to study the channel coordination/Pareto improvement. They did not investigate the horizontal competition, such as competition among retailers. Furthermore, Islam et al. [24] considered the competition among multiple retailers to investigate a manufacturer managed consignment policy in a three-tier supply chain involving a single supplier, a single manufacturer, and multiple retailers. Both Lan et al. [25] and Li and Chen [26] modeled a three-tier dual-channel supply channel from the perspective of supply-chain coordination. On the basis of these studies, we consider three kinds of multichannel supply chains consisting of two suppliers, two brand-owners, and two retailers, to investigate the brand-owners' exclusive channel strategies.

In summary, the above studies on channel distribution in a two-tier supply chain are relevant to us; we also build several different channel structures in order to investigate different channel strategies. However, we model these structures in a three-tier supply chain. This allows us to study the brand-owners' exclusive retailing-channel and exclusive purchasing-channel strategies. Different from previous studies investigating channel distribution in a three-tier supply chain, we consider a three-tier supply chain with two suppliers, two brand-owners, and two retailers, which is prevalent in practice. In addition, we compare three channel structures, namely, flexible structure, exclusive retailing-channel structure, and exclusive purchasing-channel structure, to study the upstream and downstream channel distribution strategies of the brand-owners.

2.2. Exclusive Channel Strategies

Numerous studies have focused on exclusive channel strategies in supply chains. Among them, some studies investigated the impact of product substitutability in a dual-exclusive-channel system. For example, McGuire and Staelin [27] investigated the impact of product substitutability on Nash equilibrium distribution structures. Zhang et al. [28] and Li et al. [29] investigated the effect of product substitutability and relative channel status on pricing decisions. However, we investigate the effect of channel substitutability in three typical channel systems, including two exclusive channel structures. The above-mentioned studies did not compare different exclusive channel structures (strategies) or analyzed which channel structure (strategy) is better. However, several studies mainly focused on the comparison of different exclusive strategies. For example, Niu et al. [1] built game-theoretical models to compare exclusive retailing and competitive retailing in vaccine supply chains and found that the overseas vaccine supplier would prefer competitive retailing when the overseas vaccine and the local vaccine are deeply substitutable. Cai et al. [3] investigated the efficacy of a combination of exclusive channels and revenue sharing by modeling a hybrid multichannel supply chain in a bilateral duopoly setting with complementary goods. Our study is more relevant to that of Cai et al. [3], in which four different exclusive channel structures in a two-tier supply chain were investigated. Unlike them, we consider three typical channel structures in a three-tier supply chain to investigate the brand-owners' exclusive retailing-channel and exclusive purchasing-channel strategies. Furthermore, we investigate the brand-owners' exclusive channel strategies under contract observability and unobservability.

2.3. Contract Unobservability

Most existing studies assumed that contract terms between suppliers and retailers are common knowledge (e.g., [30]). However, unobservable contracts can better reflect channel competition in business-to-business transactions. Our work is related to the study of unobservable contracts between suppliers and retailers, which generally assumes that contract terms are unobservable to the rivals. Most previous studies with unobservable contracts considered the following supply chain structures: (1) supply chains with one upstream supplier and multiple downstream retailers (e.g., [9,31,32]), (2) supply chains with multiple upstream suppliers and one downstream retailer (e.g., [10]), and (3) supply chains with chain-to-chain competition (e.g., [7,33,34]). Our study contributes to the existing literature by modeling chain-to-chain competition in a three-tier supply chain system with contract unobservability. These studies with contract unobservability mainly focused on the impact of contract unobservability on vertical integration and supply-chain contracting. For example, O'Brien and Shaffer [31] showed that nonlinear contracts fail to obtain the vertically integrated outcome when retailers cannot observe their rivals' contracts. Our study is more relevant to the study of the impact of contract unobservability on supply-chain contracting. Typical studies include Li and Liu [9] and Liu et al. [10]. Both studies compared wholesale-price contract and two-part contract under contract unobservability. The former considered a supply chain consisting of one manufacturer and two retailers, while the latter considered a supply chain consisting of two manufacturers and one retailer. Consistent with these two studies, our study also considers wholesale-price contract and adopts passive beliefs as an equilibrium refinement criterion to analyze the models. Unlike them, our study mainly focuses on the effect of contract unobservability on the decision making and performance of supply-chain members under different channel structures. Similarly, Zhuo et al. [7] also modeled three typical channel structures, with the consideration of contract unobservability, to study brand-owners' vertical and horizontal alliance strategies. However, our study mainly focuses on brand-owners' exclusive channel strategies in a three-tier supply chain.

We follow the above studies by considering unobservable contracts in a three-tier supply chain consisting of two suppliers, two brand-owners, and two retailers. Thus, contact terms between suppliers and brand-owners, as well as between brand-owners and retailers, are unobservable. We focus on the impact of contract unobservability on the brand-owners' exclusive retailing-channel and purchasing-channel strategies.

We summarize the differences between our study and the related literature below to highlight our academic contributions. First, we complement the existing studies by investigating exclusive channels in a three-tier supply chain. Second, we compare two typical strategies of brand-owners on exclusive channels, namely, exclusive retailing-channel and purchasing-channel strategies. Third, the effect of contract unobservability in a three-tier supply chain with different channel structures is investigated.

3. Model

We consider a three-tier supply chain system consisting of two suppliers, indexed by supplier $i \in \{1,2\}$, two brand-owners, indexed by BO $j \in \{a,b\}$, and two retailers, indexed by retailer $k \in \{x,y\}$. The brand-owners purchase products from the suppliers and sell them through the retailers. Each supplier produces a single product (i.e., supplier i produces product i, $i \in \{1,2\}$) and supplies it to brand-owners at a price w_{ij}. The unit production cost is constant and normalized to zero without loss of generality. The retailers purchase products from the brand-owners at a price s_{ijk} and sell them to the consumers at a retail price p_{ijk}. All the notations are summarized in Table 2 for easy reference. Note that a bar () is add to i, j, and k to denote a rival and a tilde (˜) is added to the parameters to denote the conjectured results.

Table 2. Summary of notations.

Notation	Interpretation
	Indices
i, j and k	Indices $i \in \{1,2\}$, $j \in \{a,b\}$, and $k \in \{x,y\}$ represent supplier i, BO j and retailer k, respectively.
O and U	Superscripts O and U represent the observable and unobservable cases, respectively.
F, R and P	Superscripts F, R, and P represent structures F, R, and P, respectively.
	Parameters
τ	Level of channel substitutability.
N	The number of available channels.
α_{ijk}	The consumer′s preference for product i sold through channel ijk.
	Decision and calculated variables
w_{ij}	Supplier i's wholesale price sold to BO j.
s_{ijk}	BO j's wholesale price of product i sold to retailer k.
p_{ijk}	Retail price of channel ijk.
d_{ijk}	Product demand of channel ijk.
π_i, π_j and π_k	Profit of supplier i, BO j, and retailer k, respectively.
Π_S	Profit of supply-chain system.

3.1. Channel Structure

To explore the exclusive channel strategies, we develop three typical supply-chain structures: flexible structure (structure F), exclusive retailing-channel structure (structure R), and exclusive purchasing-channel structure (structure P). In the flexible structure, the brand-owners can purchase products from each supplier and distribute products to each retailer. In the exclusive retailing-channel structure, the brand-owners form exclusive deals with the downstream retailers, creating a chain-to-chain competition in the downstream market. In the upstream market, the brand-owners can purchase products from each supplier. In the exclusive purchasing-channel structure, the brand-owners form exclusive deals with the upstream suppliers, creating a chain-to-chain competition in the upstream market, while still being able to distribute products to each retailer in the downstream market. The three structures are presented in Figure 1 for easy reference.

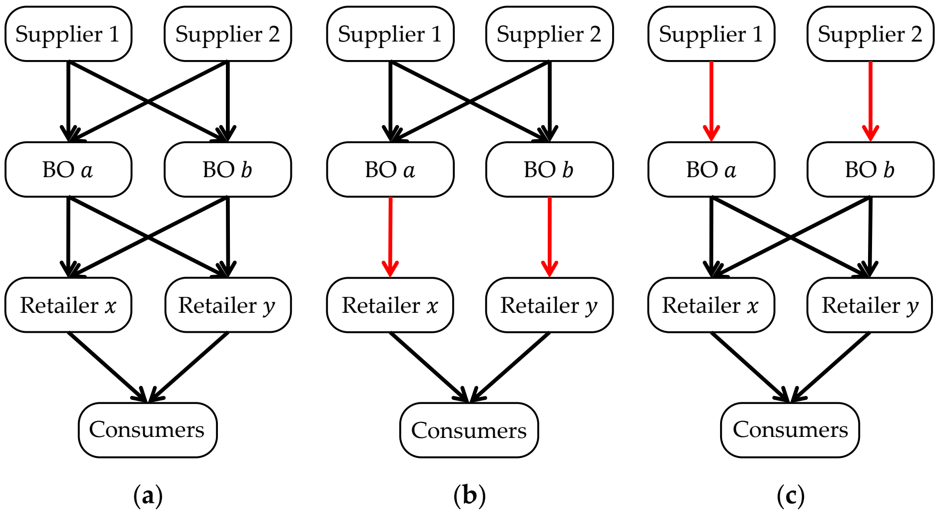

Figure 1. Three typical channel structures: (**a**) Flexible structure; (**b**) Exclusive retailing-channel structure; (**c**) Exclusive purchasing-channel structure.

We denote the demand for channel ijk as d_{ijk}, $i \in \{1,2\}$, $j \in \{a,b\}$, and $k \in \{x,y\}$. To obtain demand functions for the different channel structures, we adopt the framework established by Ingene and Parry [35] and employ a utility function of a representative consumer from the perspective of aggregate demand as follows:

$$U = \sum_{ijk}\left(\alpha_{ijk}d_{ijk} - \frac{d_{ijk}^2}{2}\right) - \tau\sum_{lmn\neq ijk}\frac{d_{ijk}d_{lmn}}{2} - \sum_{ijk}p_{ijk}d_{ijk}, \quad (1)$$

where τ $(0 \leq \tau < 1)$ denotes the level of channel substitutability. Note that the channels are completely monopolistic if $\tau = 0$; as τ approaches 1, the channels converge toward being completely substitutable. The term α_{ijk} reflects the consumer's preference for product i sold through channel ijk and can be considered as a measure of how much the representative consumer initially values channel ijk's product. We assume a symmetric setting and $\sum\alpha_{ijk} = 1$.

On the basis of the existing literature (e.g., Cai et al. [3], Zhang et al. [28], Xu et al. [36], Guan et al. [37]), the demand for the available channels can be expressed as follows:

$$d_{ijk} = A_{ijk} - \beta p_{ijk} + \theta\sum_{lmn\neq ijk}p_{lmn}, \quad (2)$$

where

$$A_{ijk} = \frac{(1+(N-2)\tau)\alpha_{ijk} - \tau\sum_{lmn\neq ijk}\alpha_{lmn}}{(1-\tau)(1+(N-1)\tau)}, \quad (3)$$

$$\beta = \frac{1+(N-2)\tau}{(1-\tau)(1+(N-1)\tau)}, \quad (4)$$

$$\theta = \frac{\tau}{(1-\tau)(1+(N-1)\tau)}, \quad (5)$$

where N is the number of available channels.

3.2. Contract Unobservability

In this model, the suppliers first make wholesale-price contract offers to the brand-owners, who in turn make wholesale-price contract offers to the retailers. Generally, contract types are common knowledge for all supply-chain members, while the contract terms are private information and become unobservable in the realistic business environments. For instance, brand-owners cannot observe each other's prices from suppliers; similarly, retailers cannot observe each other's prices from brand-owners. Hence, we consider two contrasting cases, namely, the observable and unobservable contracts, taking into account that contract unobservability better reflects the competitive nature of channels in realistic business-to-business transactions. Next, we take the flexible structure as an example to illustrate the event sequence, the profit function, and the equilibrium outcome under contract observability and unobservability, respectively.

In the flexible structure with observable contracts, supplier i offers a wholesale-price contract to BO j with a wholesale price w_{ij} to maximize its gross profit, which is given as follows:

$$\pi_i^F = \sum\nolimits_{j\in\{a,b\}} \sum\nolimits_{k\in\{x,y\}} w_{ij} d_{ijk}. \tag{6}$$

After accepting the contract from suppliers, BO j offers a wholesale-price contract to retailer k with a wholesale price s_{ijk} to maximize its gross profit, which is given as follows:

$$\pi_j^F = \sum\nolimits_{i\in\{1,2\}} \sum\nolimits_{k\in\{x,y\}} \left(s_{ijk} - w_{ij}\right) d_{ijk}. \tag{7}$$

After accepting the contract from brand-owners, retailer k is involved in the price competition and determines the retail price p_{ijk} to maximize its gross profit, which is given as follows:

$$\pi_k^F = \sum\nolimits_{i\in\{1,2\}} \sum\nolimits_{j\in\{a,b\}} \left(p_{ijk} - s_{ijk}\right) d_{ijk}. \tag{8}$$

Lastly, consumers make purchases and profits are realized. We solve the equilibrium outcome in each structure, which is summarized in Lemma 1. Please refer to Appendix A for the detailed derivation.

Lemma 1. *Under contract observability, the equilibrium outcome in each structure is summarized as follows:*

(a) *in structure F,* $p_{ijk}^{FO} = \frac{(-1+\tau)(-28+\tau(-363+\tau(-1670+\tau(-3180+\tau(-2070+\tau(-57+200\tau))))))}{16(1+\tau)(-2+(-7+\tau)\tau)(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))}$,
$s_{ijk}^{FO} = \frac{(-1+\tau)(1+3\tau)(-12+\tau(-105+\tau(-239+\tau(-55+27\tau))))}{8(-2+(-7+\tau)\tau)(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))}$, $w_{ij}^{FO} = \frac{(-1+\tau)(1+3\tau)(1+\tau(5+2\tau))}{2(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))}$,
$\pi_i^{FO} = -\frac{(1+3\tau)^2(1+\tau(5+2\tau))^2(4+\tau(33+\tau(50+\tau(-68+19(-2+\tau)\tau))))}{8(1+\tau)(1+7\tau)(-2+(-7+\tau)\tau)(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))^2}$,
$\pi_j^{FO} = -\frac{(-1+\tau)(1+\tau(5+2\tau))(4+\tau(49+\tau(198+\tau(280+19(2-3\tau)\tau))))^2}{32(1+\tau)(1+7\tau)(-2+(-7+\tau)\tau)^2(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))^2}$,
and $\pi_k^{FO} = -\frac{(-1+\tau)(1+3\tau)(1+\tau(5+2\tau))^2(-4+\tau(-37+\tau(-87+19(-1+\tau)\tau)))^2}{64(1+\tau)^2(1+7\tau)(-2+(-7+\tau)\tau)^2(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))^2}$.

(b) *in structure R,* $p_{ijk}^{RO} = \frac{-28+\tau(-107+\tau(-9+\tau(248+\tau(18+\tau(-171+(51-2\tau)\tau)))))}{8(-2+3(-1+\tau)\tau)(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))}$,
$s_{ijk}^{RO} = \frac{(-1+\tau)(12+\tau(57+\tau(60+\tau(-41+16(-3+\tau)\tau))))}{4(-2+3(-1+\tau)\tau)(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))}$, $w_{ij}^{RO} = \frac{(-1+\tau)(1+\tau)(-1+(-2+\tau)\tau)}{8+3(-1+\tau)\tau(1+\tau)(-7+2\tau)}$,
$\pi_i^{RO} = \frac{(-1+\tau)(1+\tau)^2(-1+(-2+\tau)\tau)^2(4+\tau(13+\tau(2+\tau(-13+2\tau))))}{4(1+3\tau)(-2+3(-1+\tau)\tau)(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2}$,
$\pi_j^{RO} = \frac{(-1+\tau)(1+\tau)(1+2\tau)(-1+(-2+\tau)\tau)(4+\tau(13+\tau(2+\tau(-13+2\tau))))^2}{16(1+3\tau)(2-3(-1+\tau)\tau)^2(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2}$,
and $\pi_k^{RO} = -\frac{(-1+(-2+\tau)\tau)^2\left(-1+\tau^2\right)(4+\tau(13+\tau(2+\tau(-13+2\tau))))^2}{32(1+3\tau)(2-3(-1+\tau)\tau)^2(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2}$.

(c) *in structure P,* $p_{ijk}^{PO} = -\frac{(-1+\tau)(-112+\tau(-456+\tau(-402+\tau(201+\tau(229+(-37+\tau)\tau)))))}{8(-4+3(-1+\tau)\tau)(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))}$,
$s_{ijk}^{PO} = \frac{2(-1+\tau)(1+\tau)(6+\tau(18+\tau(3+(-12+\tau)\tau)))}{(-4+3(-1+\tau)\tau)(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))}$, $w_{ij}^{PO} = \frac{(-1+\tau)(1+\tau)(-4+(-9+\tau)\tau)}{32+6(-1+\tau)\tau(-14+(-11+\tau)\tau)}$,
$\pi_i^{PO} = \frac{(-1+\tau)(1+\tau)^2(-4+(-9+\tau)\tau)(-2+(-3+\tau)\tau)\left(8+\tau\left(24+\tau-18\tau^2+\tau^3\right)\right)}{8(1+3\tau)(-4+3(-1+\tau)\tau)(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))^2}$, $\pi_j^{PO} = \frac{(1+\tau)^2\left(2+\tau-4\tau^2+\tau^3\right)\left(8+\tau\left(24+\tau-18\tau^2+\tau^3\right)\right)^2}{8(1+3\tau)(4-3(-1+\tau)\tau)^2(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))^2}$,
and $\pi_k^{PO} = -\frac{(-2+(-3+\tau)\tau)^2\left(-1+\tau^2\right)\left(8+\tau\left(24+\tau-18\tau^2+\tau^3\right)\right)^2}{32(1+3\tau)(4-3(-1+\tau)\tau)^2(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))^2}$.

Under contract unobservability, the game becomes an incomplete information game, and we need to solve the game according to the concept of refined Bayesian equilibrium solution. We follow the existing studies to assume passive beliefs in our model [9]. Taking the downstream structure of the supply chain as an example, the passive beliefs imply that, when a retailer encounters an unexpected quotation provided by the brand-owners, it will not change its beliefs in another retailer and will not urge the brand-owners to change the terms of the contract with another retailer. To be specific, suppose $\widetilde{p}_{ij\bar{k}}$ is the retailer k's belief of the retailer $\bar{k}$'s retail price $p_{ij\bar{k}}$, and $\widetilde{C}_{\bar{k}}$ is retailer k's belief of the contract between the BO j and retailer $\bar{k}$. We have $\widetilde{p}_{ij\bar{k}} = p_{ij\bar{k}}(\widetilde{C}_{\bar{k}})$, where $p_{ij\bar{k}}(\cdot)$ is retailer $\bar{k}$'s strategy profile. Under the assumption of passive beliefs, even if the retailer k receives an unexpected contract quotation, namely, $C_k \neq C_k^*$, it will not change its belief in $C_{\bar{k}}$ (see [38]).

Under contract unobservability, the suppliers' decisions are identical to those under contract observability. However, the problems of the brand-owners and the retailers should be solved on basis of the passive beliefs. When BO j accepts the contracts from the suppliers, it chooses the values of s_{ijk} to maximize its conjectured profit, which is specified as follows:

$$\widetilde{\pi}_j^F = \sum_{i\in\{1,2\}} \sum_{k\in\{x,y\}} \left(s_{ijk} - w_{ij}\right)\widetilde{d}_{ijk}, \tag{9}$$

where $\widetilde{d}_{ijk}$ denotes the conjectured demand affected by the conjectured wholesale price of BO $\bar{j}$. After accepting the contracts from the brand-owners, retailer k chooses the values of p_{ijk} to maximize its conjectured profit, which is specified as follows:

$$\widetilde{\pi}_k^F = \sum_{i\in\{1,2\}} \sum_{j\in\{a,b\}} \left(p_{ijk} - s_{ijk}\right)\widetilde{d}_{ijk}. \tag{10}$$

According to the demand function $d_{ijk} = A_{ijk} - \beta p_{ijk} + \theta \sum_{lmn\neq ijk} p_{lmn}$, we can easily derive the retailer k's conjectured demand $\widetilde{d}_{ijk} = A_{ijk} - \beta p_{ijk} + \theta(\sum_{lm\neq ij} p_{lmk} + \sum \widetilde{p}_{lm\bar{k}})$, where $l \in \{1,2\}$, $m \in \{a,b\}$, and $\widetilde{p}_{lm\bar{k}}$ is the retailer k's belief of the retailer $\bar{k}$'s price $p_{lm\bar{k}}$. We have $p_{lm\bar{k}} = \widetilde{p}_{lm\bar{k}}$ on basis of the passive beliefs. Therefore, we solve the equilibrium outcome and summarize the results in Lemma 2. Please refer to Appendix B for the detailed derivation.

Lemma 2. *Under contract unobservability, the equilibrium outcome in each structure is summarized as follows:*

(a) *in structure F,* $p_{ijk}^{FU} = \frac{(-1+\tau)(14+\tau(175+\tau(714+953\tau)))}{32(-4+\tau(-49+\tau(-191+7\tau(-31+11\tau))))}$, $s_{ijk}^{FU} = \frac{(-1+\tau)(1+3\tau)(6+\tau(55+123\tau))}{16(-4+\tau(-49+\tau(-191+7\tau(-31+11\tau))))}$, $w_{ij}^{FU} = \frac{(-1+\tau)(1+3\tau)(1+4\tau)(1+5\tau)}{4(-4+\tau(-49+\tau(-191+7\tau(-31+11\tau))))}$, $\pi_i^{FU} = \frac{(1-\tau)(1+3\tau)^2(1+4\tau)(1+5\tau)^2(2+\tau(19+43\tau))}{32(1+7\tau)(4+\tau(49+\tau(191+7(31-11\tau)\tau)))^2}$, $\pi_j^{FU} = \frac{(1-\tau)(1+3\tau)^2(1+5\tau)(2+\tau(19+43\tau))^2}{128(1+7\tau)(4+\tau(49+\tau(191+7(31-11\tau)\tau)))^2}$, *and* $\pi_k^{FU} = \frac{(1-\tau)(1+3\tau)(1+5\tau)^2(2+\tau(19+43\tau))^2}{256(1+7\tau)(4+\tau(49+\tau(191+7(31-11\tau)\tau)))^2}$.

(b) *in structure R,* $p_{ijk}^{RU} = \frac{(-1+\tau)(7+10\tau)}{8(-4+\tau(-3+4\tau))}$, $s_{ijk}^{RU} = \frac{3+\tau-4\tau^2}{4(4+(3-4\tau)\tau)}$, $w_{ij}^{RU} = \frac{-1+\tau^2}{-8-6\tau+8\tau^2}$, $\pi_i^{RU} = \frac{(1-\tau)(1+\tau)^2(1+2\tau)}{8(1+3\tau)(4+(3-4\tau)\tau)^2}$, $\pi_j^{RU} = \frac{(1+2\tau)^2\left(1-\tau^2\right)}{16(1+3\tau)(4+(3-4\tau)\tau)^2}$, *and* $\pi_k^{RU} = \frac{(1+2\tau)^2\left(1-\tau^2\right)}{32(1+3\tau)(4+(3-4\tau)\tau)^2}$.

(c) *in structure P,* $p_{ijk}^{PU} = \frac{(-1+\tau)(14+\tau(72+\tau(115+58\tau)))}{8(-8+\tau(-36+\tau(-39+2\tau(5+11\tau))))}$, $s_{ijk}^{PU} = \frac{(-1+\tau)(1+\tau)(3+\tau(12+11\tau))}{-16+2\tau(-36+\tau(-39+2\tau(5+11\tau)))}$, $w_{ij}^{PU} = \frac{(-1+\tau)(1+\tau)(2+3\tau)(2+5\tau)}{4(-8+\tau(-36+\tau(-39+2\tau(5+11\tau))))}$, $\pi_i^{PU} = \frac{(1-\tau)(1+\tau)^2(1+2\tau)(2+3\tau)(2+5\tau)(2+\tau(8+7\tau))}{16(1+3\tau)(8+\tau(36+\tau(39-2\tau(5+11\tau))))^2}$, $\pi_j^{PU} = \frac{(1-\tau)(1+\tau)^2(1+2\tau)(2+\tau(8+7\tau))^2}{16(1+3\tau)(8+\tau(36+\tau(39-2\tau(5+11\tau))))^2}$, *and* $\pi_k^{PU} = \frac{(1+2\tau)^2\left(1-\tau^2\right)(2+\tau(8+7\tau))^2}{32(1+3\tau)(8+\tau(36+\tau(39-2\tau(5+11\tau))))^2}$.

4. Exclusive Channel Strategies

In this section, we compare the equilibrium outcomes of the three channel structures to investigate the brand-owners' exclusive channel strategies under contract observability and unobservability. We try to make clear which strategy, the exclusive retailing channel or the exclusive purchasing channel, is more beneficial to brand-owners. In addition, we examine incentives for suppliers and retailers to establish exclusive channels with brand-owners.

4.1. Exclusive Channel Strategies under Contract Observability

Under contract observability, the contract terms are common knowledge. For example, retailer k knows the contract terms between brand-owners and retailer $\bar{k}$, and BO j knows the contract terms between suppliers and BO $\bar{j}$. We compare the equilibrium prices of different structures, and the results are summarized in Proposition 1.

Proposition 1. *Comparing the equilibrium prices across the structures under contract observability yields*

(a) $w_{1a}^{FO} < w_{1a}^{RO} \leq w_{1a}^{PO}$,

(b) $s_{1ax}^{FO} < s_{1ax}^{RO} \leq s_{1ax}^{PO}$,

(c) $p_{1ax}^{FO} < p_{1ax}^{RO} \leq p_{1ax}^{PO}$.

Proposition 1 states that the equilibrium prices in the flexible structure are lower than in the exclusive retailing-channel and exclusive purchasing-channel structures. This is because the flexible structure has more available channels, resulting in more intense competition and lower prices across every tier of the supply chain.

Interestingly, the exclusive purchasing channel results in higher prices in every tier of the supply chain than the exclusive retailing channel, namely, $w_{1a}^{RO} \leq w_{1a}^{PO}$, $s_{1ax}^{RO} \leq s_{1ax}^{PO}$, and $p_{1ax}^{RO} \leq p_{1ax}^{PO}$. Possible reasons are as follows: in the upstream market, the suppliers offer wholesale-price contracts and the brand-owners are the wholesale price takers. However, in the downstream market, the brand-owners are the wholesale price makers who offer wholesale-price contracts to the retailers. As a result, in the exclusive purchasing-channel structure, the suppliers offer higher wholesale prices due to more intense competition caused by more available channels between the suppliers and the brand-owners. However, in the downstream market, the available channels between the brand-owners and the retailers are identical; hence, an exclusive retailing channel does not lead to weaker channel competition downstream. As a result, an exclusive purchasing channel leads to higher wholesale prices in the upstream market, which increases the brand-owners' purchase cost. Consequently, the brand-owners will offer contracts with higher wholesale prices to the retailers downstream, resulting in $s_{1ax}^{RO} \leq s_{1ax}^{PO}$.

Next, we compare the supply-chain members' profits of different structures, and the results are summarized in Proposition 2.

Proposition 2. *Comparing the supply chain members' profits across the structures under contract observability yields*

(a) $\pi_i^{FO} < \pi_i^{RO} \leq \pi_i^{PO}$,

(b) $\pi_j^{FO} < \pi_j^{PO} \leq \pi_j^{RO}$,

(c) $\pi_k^{FO} < \pi_k^{PO} \leq \pi_k^{RO}$.

Proposition 2 suggests that both the exclusive purchasing channel and the exclusive retailing channel lead to improved performance for all members of the supply chain. This is consistent with the findings by Cai et al. [3], which consider a supply chain system consisting of two suppliers and two retailers. This is because fewer available channels create a more monopolistic market, which benefits suppliers, brand-owners, and retailers. This may explain why Apple and AT&T originally signed a 5 year exclusive deal for iPhone when the iPhone was first launched in 2007 [4]. In a similar case, Sanofi Pasteur received exclusive worldwide marketing rights for infectious disease vaccines from Translate Bio [2]. To be specific, Proposition 2(a) suggests that suppliers prefer to establish exclusive channels with brand-owners, a result supported by Proposition 1(a), which implies that suppliers benefit from a more monopolistic market by charging higher wholesale prices. In contrast, Propositions 2(b) and (c) indicate that brand-owners and retailers prefer the exclusive retailing-channel. The driving forces are as follows: an exclusive purchasing channel reduces the available channels in the upstream market and brings monopolistic advantages to the suppliers. This drives the suppliers to quote high wholesale prices, which increases the purchase costs of the brand-owners and the retailers. However, an exclusive retailing channel can reduce the purchase costs of the brand-owners and the retailers. In addition, the exclusive retailing channel also helps to weaken competition between brand-owners, making it the preferred strategy over the exclusive purchasing channel. This indicates that the incentives of the brand-owner and the retailer to make an exclusive retailing deal can be aligned. This result extends the findings by Cai et al. [3], which showed that forming exclusive deals without revenue sharing cannot be an equilibrium. This may explain why the OnePlus, a mobile phone brand-owner, signed a contract with the downstream e-retailer JD.com to sell its products exclusively in China [5].

We further compare the profits of the entire supply-chain system across the structures, and the results are summarized in Proposition 3.

Proposition 3. *Comparing the supply chain's profits across the structures under contract observability yields the following:*

(a) $\Pi_S^{FO} < \Pi_S^{RO}$; $\Pi_S^{FO} < \Pi_S^{PO}$,

(b) $\Pi_S^{RO} \geq \Pi_S^{PO}$ *if* $0 \leq \tau \leq \tau_1$; *otherwise,* $\Pi_S^{RO} < \Pi_S^{PO}$, *where* $\tau_1 = 0.76$.

Proposition 3(a) suggests that exclusive channels can always lead to a higher profit for the supply-chain system, regardless of whether it is an exclusive retailing channel or exclusive purchasing channel. As stated in Proposition 2, both exclusive channel structures can result in higher profits for suppliers, brand-owners, and retailers, benefiting the entire supply-chain system.

One interesting question is which exclusive channel structure leads to a higher profit for the supply-chain system? As shown in Proposition 3(b), the answer depends on the level of channel substitutability. We find that an exclusive retailing channel (purchasing channel) leads to a higher profit for the supply-chain system when the level of channel substitutability is relatively low (high). The driving force behind this is as follows: Proposition 1 shows that the exclusive purchasing channel leads to higher prices at each tier of the supply chain than the exclusive retailing channel. When the level of channel substitutability is relatively low ($0 \leq \tau \leq \tau_1$), the channel competition is weak, and the supply-chain members have incentives to set high prices. In this case, the higher price of the exclusive purchasing channel at each tier cannot benefit the supply-chain members. Hence, the exclusive retailing channel leads to a higher profit of the supply-chain system. In contrast, when the level of channel substitutability is relatively high ($\tau > \tau_1$), the channel competition is intense, and the supply-chain members have incentives to set low prices. In such cases, an exclusive purchasing channel can help each supply-chain member to set high prices, thus leading to higher profits for the supply-chain system.

4.2. Exclusive Channel Strategies under Contract Unobservability

When contracts are unobservable, the terms of the contract are not observed by the competitors. For example, the purchase prices of brand-owners from suppliers are not disclosed to each other. We use superscript U to represent the unobservable case. We compare the equilibrium prices across the structures under contract unobservability, and summarize the results in Proposition 4.

Proposition 4. *Comparing the equilibrium prices across the structures under contract unobservability yields*

(a) $w_{1a}^{FU} < w_{1a}^{RU} \leq w_{1a}^{PU}$,

(b) $s_{1ax}^{FU} < s_{1ax}^{PU} \leq s_{1ax}^{RU}$,

(c) $p_{1ax}^{FU} < p_{1ax}^{PU} \leq p_{1ax}^{RU}$.

Similar to the case under contract observability, Proposition 4 shows that exclusive channels can lead to higher prices of the supply-chain members. However, in contrast to the observable case, an exclusive retailing channel results in higher prices of the brand-owners and the retailers than an exclusive purchasing channel, namely, $s_{1ax}^{PU} \leq s_{1ax}^{RU}$ and $p_{1ax}^{PU} \leq p_{1ax}^{RU}$. The rationale behind this finding is as follows: under exclusive purchasing-channel, the brand-owners have incentives to set low wholesale prices. This is because a low wholesale price has two effects on the equilibrium: (1) a demand-increase effect in the brand-owners' own channel, and (2) a demand-decrease effect in the competing channel. The demand-decrease effect arises because, as a wholesale price decreases, the competing channel expects a competitive disadvantage and responds by undercutting procurement. However, under an exclusive purchasing channel, the brand-owners' incentives to set a low wholesale price are weakened, because the demand-decrease effect in the competing channels becomes weaker. Obviously, a brand-owner's profit is from both competing retailers. Hence, a brand-owner setting a low wholesale price will bring a significant demand-decrease effect, which will hurt not only the rival's profit but also the brand-owner's profit from the other channel. Consequently, the exclusive retailing channel results in a higher wholesale price for the brand-owners compared to the exclusive purchasing channel, resulting in a higher retail price under the exclusive retailing-channel.

Next, we compare the supply-chain members' profits across the structures under contract unobservability, and the results are summarized in Proposition 5.

Proposition 5. *Comparing the supply-chain members' profits across the structures under contract unobservability yields*

(a) $\pi_i^{FU} < \pi_i^{RU} \leq \pi_i^{PU}$,

(b) $\pi_j^{FU} < \pi_j^{PU} \leq \pi_j^{RU}$,

(c) $\pi_k^{FU} < \pi_k^{RU} \leq \pi_k^{PU}$.

Proposition 5(a) shows that the exclusive channel leads to a higher profit for suppliers, consistent with the results under contract observability. According to Proposition 4, an exclusive retailing channel results in higher prices of brand-owners and retailers than exclusive purchasing-channel. However, Propositions 5(b) and (c) show that the brand-owners benefit from setting higher wholesale prices, while the retailers are hurt by the higher retail prices. Downstream competition is weakened by an exclusive retailing channel; thus, brand-owners can benefit more from the weak competition as they have the power to set the wholesale prices to seize profits from retailers. Hence, the brand-owners prefer an exclusive retailing channel. However, the retailers have to set high retail prices because of contract unobservability according to Proposition 4, which reduces the demand quantity. In addition, we find that the retailer's marginal profit (i.e., $p_{ijk} - s_{ijk}$) is higher under an exclusive purchasing channel. Consequently, the retailers prefer an exclusive purchasing channel. The results indicate that forming exclusive retailing deals between brand-owners and retailers under unobservable contracts is a weakly dominant strategy for both retailers; however, it is a dominated strategy for both brand-owners. The results are in line with the main finding by Cai et al. [3], which investigate exclusive channels in a two-tier supply chain.

We further compare the profits of the entire supply-chain system across the structures under contract unobservability, and the results are summarized in Proposition 6.

Proposition 6. *Comparing the supply chain's profits across the structures under contract unobservability yields*

(a) $\Pi_S^{FU} < \Pi_S^{RU}$; $\Pi_S^{FU} < \Pi_S^{PU}$,

(b) $\Pi_S^{PU} > \Pi_S^{RU}$ *if* $0 \le \tau < \tau_2$; *otherwise*, $\Pi_S^{PU} \le \Pi_S^{RU}$, *where* $\tau_2 = 0.70$.

Proposition 6(a) shows that an exclusive channel can lead to a higher profit of the supply-chain system under contract unobservability, regardless of an exclusive retailing channel or exclusive purchasing channel. The driving forces are similar to those under contract observability. Forming exclusive deals will benefit suppliers, brand-owners, and retailers. As a result, the entire supply chain is better off.

Unlike that under contract observability, Proposition 6(b) shows that an exclusive retailing channel (purchasing channel) leads to a higher profit of the supply-chain system when the level of channel substitutability is relatively high (low). The essential reason is that contract unobservability results in an exclusive retailing channel leading to a higher price at each tier of the supply chain than an exclusive purchasing channel (see Proposition 4). When the level of channel substitutability is relatively low ($0 \le \tau < \tau_2$), the channel competition is weak, and the supply-chain members have incentives to set high prices. In this situation, the exclusive retailing channel brings higher prices at each tier, which cannot benefit the supply-chain members. Hence, an exclusive purchasing channel leads to a higher profit of the supply-chain system. On the other hand, when the level of channel substitutability is relatively high ($\tau \ge \tau_2$), the channel competition is intense, and the supply-chain members have incentives to set low prices. In such a situation, an exclusive retailing channel can help each supply-chain member to set high prices, consequently leading to higher profits of the supply-chain system.

4.3. Effects of Contract Unobservability

In this section, we focus on how contract unobservability affects the equilibrium decisions and performances of the supply-chain members under different channel structures. The analytical results are summarized in Proposition 7.

Proposition 7. *Comparing the equilibrium between observable and unobservable contracts yields (we have* $I \in \{F, R, P\}$; τ_3^I, τ_4^I, *and* τ_5^I *are shown in Figure 2)*

(a) $w_{1a}^{IO} \ge w_{1a}^{IU}$, $s_{1ax}^{IO} \ge s_{1ax}^{IU}$ *and* $p_{1ax}^{IO} \ge p_{1ax}^{IU}$,

(b) $\pi_i^{IO} \le \pi_i^{IU}$ *if* $\tau \le \tau_3^I$; *otherwise*, $\pi_i^{IO} > \pi_i^{IU}$,

(c) $\pi_j^{IO} \le \pi_j^{IU}$ *if* $\tau \le \tau_4^I$; *otherwise*, $\pi_j^{IO} > \pi_j^{IU}$,

(d) $\pi_k^{IO} \le \pi_k^{IU}$,

(e) $\Pi_S^{IO} \le \Pi_S^{IU}$ *if* $\tau \le \tau_5^I$, *otherwise* $\Pi_S^{IO} > \Pi_S^{IU}$.

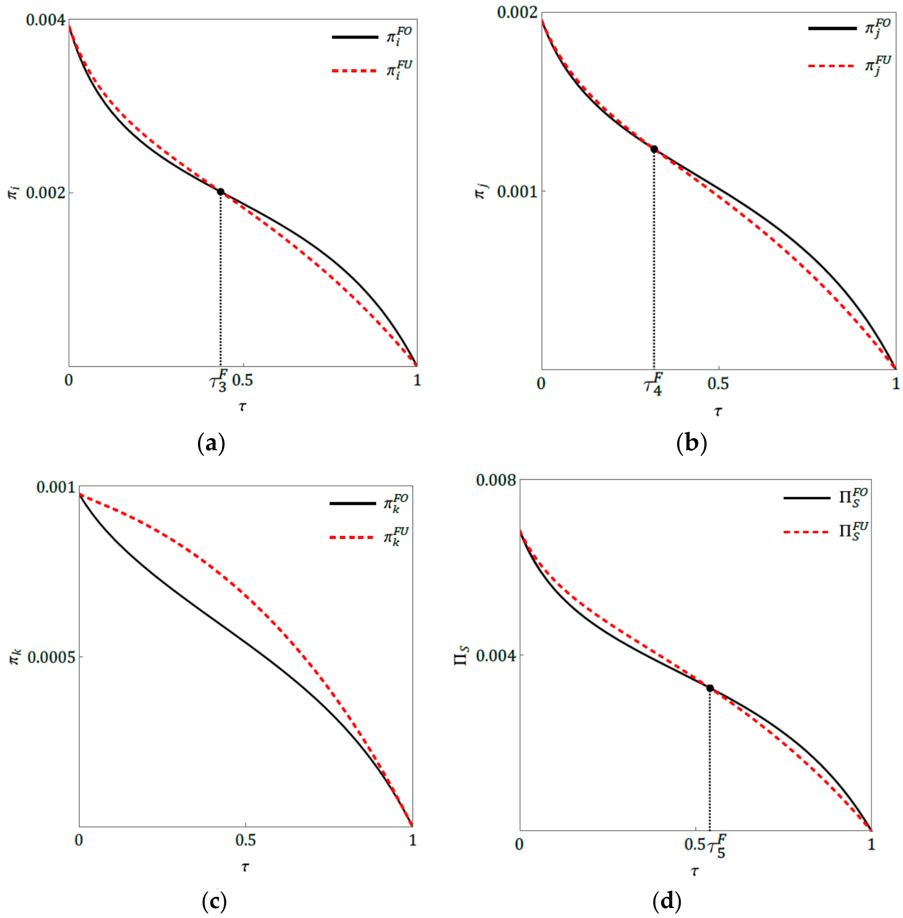

Figure 2. Profits of the supply-chain members and the entire supply chains in a flexible structure. (**a**) Suppliers' profit; (**b**) Brand-owners' profit; (**c**) Retailers' profit; (**d**) Supply chains' profit.

Proposition 7(a) shows that, when contracts are unobservable, equilibrium prices at every tier of the supply chain decrease. As we previously mentioned, when contracts are observable, a low wholesale price has two effects on the equilibrium: (1) a demand-increase effect in the channel of the wholesale price, and (2) a demand-decrease effect in the competing channels. However, the latter effect disappears when contracts are unobservable. Consequently, suppliers and brand owners are motivated to establish low wholesale prices to stimulate demand, which ultimately leads to lower equilibrium prices at each tier of the supply chain under contract unobservability.

Propositions 7(b–d) show the profit comparison between contract observability and unobservability, which are depicted in Figure 2. As shown in Propositions 7(b) and (c), contract unobservability leads to a higher (lower) profit of the suppliers and the brand-owners when the level of channel substitutability is relatively low (high). This finding builds upon the results in Li and Liu [9], which demonstrated that a monopolist manufacturer's profit under contract unobservability is always lower than under contract observability. The driving forces behind these findings are as follows: we know that the channel competition is weak when the level of channel substitutability is relatively low. When the level of channel substitutability is relatively low, channel competition is weak. In this situation, suppliers and brand owners have less incentive to set low wholesale prices to stimulate demand. Therefore, they benefit from higher wholesale prices and become better off under contract unobservability. In contrast, when the channel competition is fierce, the suppliers and the brand-owners have to set low wholesale prices. The demand-decrease effect in the competing channels disappears, which makes the wholesale price become lower. Consequently, the suppliers and the brand-owners are hurt by the decreased wholesale prices and become worse off under contract unobservability.

Proposition 7(d) shows that contract unobservability leads to a higher profit of the retailers. As illustrated in Proposition 7(a), when rivaling contract terms are not observed, the suppliers and the brand-owners always have an incentive to cut wholesale prices. On one hand, a lower wholesale price increases the retailers' profit margin. On the other hand, a lower retail price can stimulate the demand volume. Consequently, the retailers under contract unobservability are better off. This result extends the finding by Liu et al. [10], who studied a supply-chain system with a retail platform and two upstream manufacturers. Under the channel structure in Liu et al. [10], observable contracts were more beneficial for the retailer than unobservable contracts.

Consequently, as stated in Proposition 7(e), the entire supply chain's profit under contract unobservability is higher than under contract observability when the level of channel substitutability is relatively low, and vice versa.

5. Effects of Channel Substitutability

Since the competition between supply chains becomes increasingly popular with the development of economic globalization [39], we explore the effect of channel substitutability on the equilibrium prices and performance of the supply-chain members in this section. First, we explore the effect of channel substitutability on the equilibrium prices, which is summarized in the following proposition:

Proposition 8. *The equilibrium prices decrease in the level of channel substitutability under both observable and unobservable contracts.*

Proposition 8 indicates that the supply-chain members, including suppliers, brand-owners, and retailers, will lower their prices as competition among supply chains becomes more intense. This is significantly different from previous studies (e.g., [9]), in which the competition between retailers was considered and the wholesale prices were constant. The result in Proposition 8 is intuitive; as the channel competition (i.e., competition between supply chains) becomes fiercer, the members in the supply chains will reduce their prices to attract more consumers under price competition.

Next, we investigate the effect of channel substitutability on the performance of the supply-chain members under contract observability and unobservability. We find that, in structures F and P, the brand-owners' profit decreases in the level of channel substitutability. This result is intuitive; as channel competition intensifies, the brand-owners will reduce their prices to attract more consumers, thereby hurting their profitability. The difference is that the brand-owners' profit can be positively and negatively affected by the level of channel substitutability. To be specific, when the level of channel substitutability is moderate (i.e., $0.331 < \tau < 0.572$), the brand-owners' profit increases as the channel competition intensifies (see Figure 3 with the observable case as an example). The possible reasons for this are as follows: note that, under an exclusive retailing channel, the brand-owners form exclusive deals with the downstream retailers, while forming flexible deals with the upstream suppliers. This means that the competition between the two suppliers is fiercer than that between the two brand-owners, which results in a slight change in the brand-owners' profit margin (i.e., $s^{RO} - w^{RO}$) when the level of channel substitutability is moderate. Meanwhile, due to the decrease in supply-chain members' prices, the demand increases significantly as the level of channel substitutability increases. Therefore, the brand-owners' profit increases as the channel competition intensifies when the level of channel substitutability is moderate, due to a slight change of profit margin and a significant increase in demand. This finding is in contrast to conventional wisdom and can be insightful. It indicates that a fiercer channel competition due to an exclusive retailing channel might be beneficial for the brand-owners when channel competition is moderate.

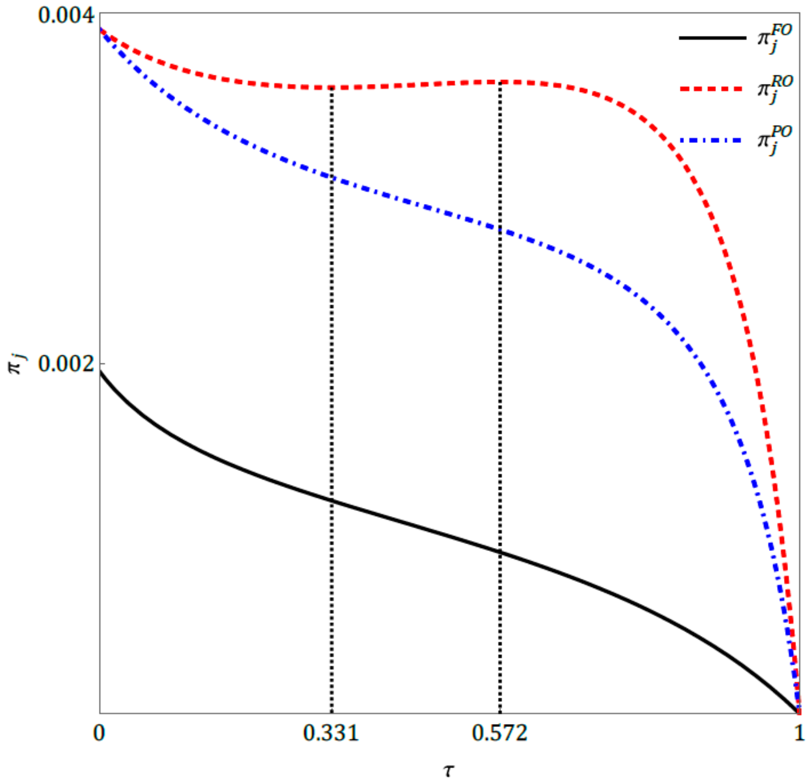

Figure 3. Effect of channel subsitutabilty on the brand-owners' profits.

6. Conclusions

It is common practice for brand-owners in supply chains to establish exclusive deals with upstream suppliers or downstream retailers. However, previous research on supply chain contracts largely assumed that contract terms are observable by all parties in the channel. In reality, such terms may not be observed by parties other than the signatories. To address this issue, we proposed a three-tier supply chain framework comparing three representative structures, namely, the flexible structure, the exclusive retailing-channel structure, and the exclusive purchasing-channel structure. We focused on investigating the incentives for brand-owners to form either an exclusive retailing channel or an exclusive purchasing channel, taking into account the unobservability of contract terms. Our analysis yielded several interesting findings.

Firstly, we found that the exclusive purchasing-channel structure resulted in the highest monopolistic wholesaling market in the three structures under contract observability. Under contract unobservability, the exclusive retailing-channel structure led to higher prices for brand-owners and retailers than the exclusive purchasing-channel structure, which is the opposite of what occurred under contract observability. Under contract observability, the exclusive purchasing-channel structure benefited upstream suppliers more, while the exclusive retailing-channel structure benefited brand-owners and downstream retailers more. This misalignment of incentives suggests that suppliers may have different goals to brand-owners and retailers when forming exclusive channels. It is worth noting that, under contract unobservability, the incentives of the suppliers and retailers to choose exclusive channel strategies can be aligned. In terms of the entire supply chain's profits, both the exclusive retailing-channel and the purchasing-channel structures dominate the flexible structure due to channel reduction. Interestingly, the effects of the two exclusive channel strategies on the entire supply chain depend on the level of channel substitutability. When the level of channel substitutability is low, the exclusive retailing-channel structure benefits the entire supply chain more than the exclusive purchasing-channel structure. Otherwise, the converse is true. Contrary to the observable case, our analysis showed that, when the level of channel substitutability is low, the exclusive purchasing-channel structure is more beneficial for the entire supply chain than the exclusive retailing-channel structure.

Secondly, we investigated the impact of contract unobservability and showed that contract unobservability results in lower prices for supply-chain members. Additionally, we found that, when the level of channel substitutability is relatively low, the profits of suppliers and brand-owners are higher under contract unobservability than under contract observability, whereas the opposite holds when substitutability is high. This result expands the finding by Li and Liu [9] that a monopolist manufacturer's profit is always lower under contract unobservability, without accounting for the level of channel substitutability. In contrast, we found that the retailers' profit is lower under contract observability than contract unobservability, regardless of the level of channel substitutability. This result extends the finding by Liu et al. [10] that a monopolist retailer's profit is higher under contract observability than contract unobservability in a supply-chain system consisting of two manufacturers and a monopolist retailer. Interestingly, our results also indicate that the entire supply chain can benefit from contract unobservability when the level of channel substitutability is low.

Lastly, we explored the effect of channel substitutability, and found that the equilibrium prices decrease in the level of channel substitutability under both contract observability and unobservability in all structures. Interestingly, we showed that the brand-owners' profits can be positively and negatively affected by the level of channel substitutability under contract unobservability. More specifically, as channel competition intensifies, the brand-owners' profit increases due to a slight change of profit margin and a significant increase in demand, when the level of channel substitutability is moderate. This implies that, when the channel competition is moderate, more intense channel competition with an exclusive retailing channel might be beneficial for the brand-owners.

The results have potential managerial implications. First, the brand-owners are suggested to implement an exclusive channel, regardless of whether it is an exclusive retailing or purchasing channel. This is because an exclusive channel can lead to a more monopolistic market, which benefits all supply-chain parties. Second, our analysis suggested that brand-owners should prioritize implementing an exclusive retailing channel over an exclusive purchasing channel, regardless of contract observability. Third, brand-owners should avoid adopting unobservable contracts when the level of channel substitutability is high. In this situation, contract unobservability will hurt the brand-owners when implementing exclusive channels.

We raise several issues and avenues for future research. First, various contract forms can be considered. Wholesale price contacts are considered in our model. However, there are other contract forms in the supply chain, such as a two-part tariff contract [9] and buyback contract [32], which can also be considered in the future studies. Second, other supply-chain structures can be investigated. For example, as presented in Cai et al. [3], a hybrid channel structure with only one brand-owner to establish exclusive channel while the other brand-owner can form flexible channels can also be studied.

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Appendix A Derivation of Equilibrium under Contract Observability

We use the flexible structure as the example to illustrate how to solve the generalized Nash bargaining game. We adopt standard backward induction to solve the problem.

First, retailer $k \in \{x, y\}$ maximizes its gross profits $\pi_k^F = \sum_{i\in\{1,2\}} \sum_{j\in\{a,b\}} \left(p_{ijk} - s_{ijk}\right) d_{ijk}$ by choosing the retail prices p_{1ak}, p_{1bk}, p_{2ak}, and p_{2bk}. This leads to the following first-order conditions (FOC) $\frac{\partial \pi_k^F}{\partial p_{ijk}} = A_{ijk} - 2\beta p_{ijk} + \beta s_{ijk} + \theta(2\sum_{lm\neq ij} p_{lmk} + \sum p_{lm\bar{k}} - \sum_{lm\neq ij} s_{lmk}) = 0$, where $l \in \{1,2\}$, $m \in \{a,b\}$, and $n \in \{x,y\}$. From the second-order conditions $\frac{\partial^2 \pi_k^F}{\partial p_{ijk}^2} = -2\beta < 0$, we can see that each retailer's objective function is concave in its own decision variable. Then, we solve the eight equations and have $p_{ijk} = \frac{(2\beta(A_{ijk}+\beta s_{ijk})-2\theta A_{ijk}+(\sum s_{lm\bar{k}}-12 s_{ijk})\beta\theta+(12 s_{ijk}+2\sum_{lm\neq ij} s_{lmk}-3\sum s_{lm\bar{k}})\theta^2)}{4(\beta-5\theta)(\beta-\theta)}$.

Second, BO $j \in \{a, b\}$ maximizes its gross profits $\pi_j^F = \sum_{i\in\{1,2\}} \sum_{k\in\{x,y\}} \left(s_{ijk} - w_{ij}\right) d_{ijk}$ by choosing the wholesale prices s_{1jx}, s_{1jy}, s_{2jx}, and s_{2jy}. According to the symmetric setting of α_{ijk}, and substituting p_{ijk} into π_j^F, we derive the following second-order condition: $\frac{\partial^2 \pi_j^F}{\partial s_{ijk}^2} = \frac{1+\tau(12+\tau(40+27\tau))}{(-1+\tau)(1+\tau)(1+5\tau)(1+7\tau)} < 0$. Therefore, each brand-owner's objective function is concave in its own decision variable. From the FOCs, we have $s_{ijk} = -\frac{1}{8\left(-4-40\tau-107\tau^2-50\tau^3+9\tau^4\right)}(2 + (17 + 12\sum_{l\in\{1,2\}} w_{l\bar{j}})\tau + (29 + 18 w_{\bar{i}j} + 80\sum_{l\in\{1,2\}} w_{l\bar{j}})\tau^2 + (-21 + 60 w_{\bar{i}j} + 124\sum_{l\in\{1,2\}} w_{l\bar{j}})\tau^3 + (-27 + 50 w_{\bar{i}j} + 40\sum_{l\in\{1,2\}} w_{l\bar{j}})\tau^4 + 2w_{ij}\left(8 + 80\tau + 223\tau^2 + 130\tau^3 + 7\tau^4\right))$.

Third, supplier $i \in \{1,2\}$ maximizes its gross profits $\pi_i^F = \sum_{j\in\{a,b\}} \sum_{k\in\{x,y\}} w_{ij} d_{ijk}$ by choosing the wholesale prices w_{ix} and w_{iy}. Substituting s_{ijk} into π_i^F, we can derive the following second-order condition: $\frac{\partial^2 \pi_i^F}{\partial w_{ij}^2} = \frac{1}{18}\left(\frac{12}{-1+\tau} - \frac{1}{1+\tau} - \frac{2}{1+7\tau} + \frac{3+9\tau}{-2+(-7+\tau)\tau} + \frac{-3-9\tau}{2+\tau(13+9\tau)}\right) < 0$. Therefore, each supplier's objective function is concave in its own decision variable. Following the FOCs, the suppliers' optimal wholesale price is $w_{ij} = \frac{(-1+\tau)(1+3\tau)(1+\tau(5+2\tau))}{2(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))}$.

Similarly, the exclusive retailing- or purchasing-channel structures under contract observability can be solved based on this framework, and all the optimal solutions are presented in Lemma 1.

Appendix B Derivation of Equilibrium under Contract Unobservability

We use the flexible structure as the example to illustrate how to obtain the equilibrium outcomes under contract unobservability. We employ standard backward induction to solve the problem.

First, let $\widetilde{p}_{ij\bar{k}}$ be retailer k's belief of retailer $\bar{k}$'s retail price $p_{ij\bar{k}}$, which, according to passive beliefs, is not a function of s_{ijk}. As such, the problem facing retailer k is to choose values for p_{ijk} that maximize its conjectured profit $\widetilde{\pi}_k^F = \sum_{i\in\{1,2\}} \sum_{j\in\{a,b\}} \left(p_{ijk} - s_{ijk}\right) \widetilde{d}_{ijk}$. We can easily derive retailer k's conjectured demand $\widetilde{d}_{ijk} = A_{ijk} - \beta p_{ijk} + \theta(\sum_{lm\neq ij} p_{lmk} + \sum \widetilde{p}_{lm\bar{k}})$, where $l \in \{1,2\}$, $m \in \{a,b\}$, and $\widetilde{p}_{lm\bar{k}}$ is the retailer k's belief of the retailer $\bar{k}$'s price $p_{lm\bar{k}}$. This leads to the following first-order condition (FOC) $\frac{\partial \widetilde{\pi}_k^F}{\partial p_{ijk}} = A_{ijk} - 2\beta p_{ijk} + \beta s_{ijk} + \theta(2\sum_{lm\neq ij} p_{lmk} + \sum \widetilde{p}_{lm\bar{k}} - \sum_{lm\neq ij} s_{lmk})$. From the second-order condition $\frac{\partial^2 \widetilde{\pi}_k^F}{\partial p_{ijk}^2} = -2\beta < 0$, we can see that each retailer's objective function is concave in its own decision variable. Then, we solve the equations and have $p_{ijk} = \frac{A_{ijk}+(\beta-3\theta)s_{ijk}+\theta\sum\tilde{p}_{l\bar{m}k}}{2(\beta-3\theta)}$.

Second, let $\tilde{s}_{i\bar{j}k}$ be BO j's belief of BO $\bar{j}$'s wholesale price $s_{i\bar{j}k}$. Similar to the above proof, the BO j chooses the values of s_{ijk} to maximize its conjectured profit $\tilde{\pi}_j^F = \sum_{i\in\{1,2\}}\sum_{k\in\{x,y\}}\left(s_{ijk}-w_{ij}\right)\tilde{d}_{ijk}$, where $\tilde{d}_{ijk}$ is BO j's conjecture of demand. Substituting p_{ijk} into $\tilde{d}_{ijk}$, we have $\tilde{d}_{ijk} = \frac{1}{2}(A_{ijk} - \beta s_{ijk} + \theta(s_{i\bar{j}k} + \sum\tilde{p}_{l\bar{m}k} + \sum\tilde{s}_{l\bar{j}k}))$, where $l \in \{1,2\}$, $m \in \{a,b\}$ and $\tilde{s}_{l\bar{j}k}$ is the BO j's belief of the BO $\bar{j}$'s price $s_{l\bar{j}k}$. From the second-order conditions $\frac{\partial^2\tilde{\pi}_j^F}{\partial s_{ijk}^2} = -\beta < 0$, we can see each brand-owner's objective function is concave in its own decision variable. Then, we solve the FOC equations and have $s_{ijk} = \frac{1}{4\beta(\beta-2\theta)}(2\beta(A_{ijk}+\beta w_{ij}) + (2\sum\tilde{p}_{l\bar{m}k} - 4w_{ij} + w_{1\bar{j}} + w_{2\bar{j}})\beta\theta + (w_{1j} + w_{2j} - w_{1\bar{j}} - w_{2\bar{j}})\theta^2)$.

Third, supplier $i \in \{1,2\}$ maximizes its gross profits $\pi_i^F = \sum_{j\in\{a,b\}}\sum_{k\in\{x,y\}} w_{ij}\tilde{d}_{ijk}$ by choosing the wholesale prices w_{ix} and w_{iy}. Substituting s_{ijk} into π_i^F, we can derive the following second-order condition: $\frac{\partial^2\pi_i^F}{\partial w_{ij}^2} = \frac{2+\tau(32+\tau(167+283\tau))}{2(-1+\tau)(1+4\tau)(1+6\tau)(1+7\tau)} < 0$. Therefore, each supplier's objective function is concave in its own decision variable. Following the FOCs, the suppliers' optimal wholesale price is $w_{ij} = \frac{(1+5\tau)\left(1+\left(-1+4\sum\tilde{p}_{lmn}\right)\tau\right)}{4(4+\tau(35+73\tau))}$.

It follows that $p_{ijk} = \frac{1}{32(1+3\tau)(1+4\tau)(4+\tau(35+73\tau))}(14+\tau(161+104\sum\tilde{p}_{l\bar{m}k}+ 8(\tilde{p}_{1bk}+\tilde{p}_{2ak}+\tilde{p}_{2bk})+539\tau+8\tilde{p}_{1ak}(1+3\tau)(1+5\tau)^2+\tau(104(\tilde{p}_{1bk}+\tilde{p}_{2ak}+\tilde{p}_{2bk})+ 1296(\tilde{p}_{1\bar{b}k}+\tilde{p}_{2\bar{a}k}+\tilde{p}_{2\bar{b}k})+239\tau+\tau(5272(\tilde{p}_{1\bar{b}k}+\tilde{p}_{2\bar{a}k}+\tilde{p}_{2\bar{b}k})+440\left(\tilde{p}_{1bk}+\tilde{p}_{2ak}+\tilde{p}_{2bk}\right) -953\tau+(600\sum_{lm\neq ij}\tilde{p}_{lmk}+7024(\tilde{p}_{1\bar{b}k}+\tilde{p}_{2\bar{a}k}+\tilde{p}_{2\bar{b}k}))\tau)+8\tilde{p}_{1\bar{a}k}(162+\tau(659+878\tau)))))$. The retailers' beliefs must be correct along the equilibrium path, i.e., $\tilde{p}_{ijk} = p_{ijk}$. Solving for p_{ijk}, we get $p_{ijk} = \frac{(-1+\tau)(14+\tau(175+\tau(714+953\tau)))}{32(-4+\tau(-49+\tau(-191+7\tau(-31+11\tau))))}$. It follows that $s_{ijk} = \frac{(-1+\tau)(1+3\tau)(6+\tau(55+123\tau))}{16(-4+\tau(-49+\tau(-191+7\tau(-31+11\tau))))}$ and $w_{ij} = \frac{(-1+\tau)(1+3\tau)(1+4\tau)(1+5\tau)}{4(-4+\tau(-49+\tau(-191+7\tau(-31+11\tau))))}$.

Similarly, the exclusive retailing- or purchasing-channel structures under contract unobservability can be solved on the basis of this framework; all the optimal solutions are presented in Lemma 2.

Appendix C Proofs

Proof of Proposition 1. First, we take the comparison of w_{1a}^{FO}, w_{1a}^{RO}, and w_{1a}^{PO} as an example to illustrate how to prove the results in Proposition 1.

According to the equilibrium outcome in Lemma 1, we have $w_{1a}^{FO} - w_{1a}^{RO} = \frac{1}{2}(-1+\tau)(F_1+F_2)$, where $F_1 = -\frac{2(1+\tau)(-1+(-2+\tau)\tau)}{8+3(-1+\tau)\tau(1+\tau)(-7+2\tau)}$ and $F_2 = \frac{(1+3\tau)(1+\tau(5+2\tau))}{-8+\tau(-65+\tau(-123+\tau(25+43\tau)))}$. With $\tau \in [0,1)$, we derive that $\frac{\partial F_1}{\partial\tau} = \frac{6+2\tau(28+3\tau(26+\tau(20+\tau(-9+2(-2+\tau)\tau))))}{(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2} > 0$ and $F_{1min} = F_{1\tau=0} = \frac{1}{4}$.

Since $\frac{\partial^2 F_2}{\partial\tau^2} = \frac{338+2\tau(2121+\tau(11352+\tau(38693+\tau(109680+\tau(243297+\tau(323668+129\tau(1851+43\tau(17+2\tau))))))))}{(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))^3} < 0$, F_2 is concave in τ. It is easy to obtain that $F_{2min} > F_{2\tau=1} = -\frac{1}{4}$. Hence, $w_{1a}^{FO} - w_{1a}^{RO} = \frac{1}{2}(-1+\tau)(F_1+F_2) < 0$.

From Lemma 1, we get $w_{1a}^{RO} - w_{1a}^{PO} = (-1+\tau)(1+\tau)F_3$, where $F_3 = \frac{-1+(-2+\tau)\tau}{8+3(-1+\tau)\tau(1+\tau)(-7+2\tau)} + \frac{4-(-9+\tau)\tau}{32+6(-1+\tau)\tau(-14+(-11+\tau)\tau)}$. We derive $\frac{\partial F_3}{\partial\tau} = \frac{F_4}{2(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))^2}$, where $F_4 = 1024+3\tau(3328+\tau(11056+\tau(13808+3\tau(1761+\tau(1252+\tau(-4559+\tau(-13518+$

$\tau(2993 + 3\tau(3184 + \tau(-1091 + 2\tau(-41 + 9\tau))))))))))$. Solving FOC $\frac{\partial F_4}{\partial \tau} = 0$, we have $\tau = 0.853$. Therefore, $F_{4min} = \min\{F_{4\tau=0}, F_{4\tau=1}, F_{4\tau=0.853}\} = 1024 > 0$ and $\frac{\partial F_3}{\partial \tau} > 0$. Hence, $F_3 \geq F_{3\tau=0} = 0$ and $w_{1a}^{RO} - w_{1a}^{PO} = (-1+\tau)(1+\tau)F_3 \leq 0$. Proof of Proposition 1(a) is established. Similarly, the results in Propositions 1(b) and (c) can be derived by simple arithmetic manipulation. □

Proof of Proposition 2. First, we take the comparison between π_i^{FO} and π_i^{RO} as an example to illustrate how to prove the results in Proposition 2.

According to the equilibrium outcome in Lemma 1, we have $\pi_i^{FO} - \pi_i^{RO} = -\frac{(-1+\tau)(1+\tau)^2(-1+(-2+\tau)\tau)^2(4+\tau(13+\tau(2+\tau(-13+2\tau))))}{4(1+3\tau)(-2+3(-1+\tau)\tau)(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2} - \frac{(1+3\tau)^2(1+\tau(5+2\tau))^2(4+\tau(33+\tau(50+\tau(-68+19(-2+\tau)\tau))))}{8(1+\tau)(1+7\tau)(-2+(-7+\tau)\tau)(-8+\tau(-65+\tau(-123+\tau(25+43\tau))))^2}$. It is easy to find that the function of $\pi_i^{FO} - \pi_i^{RO}$ is continuous over its domain (i.e., $0 \leq \tau < 1$). Now, we can solve for the extreme points of the function as follows: $\tau = 0.283$, $\tau = 0.454$, and $\tau = 0.642$. Comparing the extreme and boundary values of the function, we derive that $\pi_i^{FO} - \pi_i^{RO} < \left(\pi_i^{FO} - \pi_i^{RO}\right)_{max} = \left(\pi_i^{FO} - \pi_i^{RO}\right)_{\tau=1} = 0$. Similarly, the results in Proposition 2 can be derived by simple arithmetic manipulation. □

Proof of Proposition 3. Similar to the proof of Proposition 2, the results in Proposition 3(a) can be derived by simple arithmetic manipulation. □

Now, we compare Π_S^{RO} and Π_S^{PO}. From Lemma 1, we obtain the total profit for the entire supply chain in exclusive retailing- and purchasing-channel structures as follows:

$$\Pi_S^{RO} = \pi_1^{RO} + \pi_a^{RO} + \pi_x^{RO} = -\frac{(-1+\tau)(1+\tau)(-1+(-2+\tau)\tau)(4+\tau(13+\tau(2+\tau(-13+2\tau))))(-28+\tau(-135+\tau(-144+\tau(104+\tau(122+\tau(-49+2\tau))))))}{32(1+3\tau)(2-3(-1+\tau)\tau)^2(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2},$$

$$\Pi_S^{PO} = \pi_1^{PO} + \pi_a^{PO} + \pi_x^{PO} = -\frac{(-1+\tau)(1+\tau)(-2+(-3+\tau)\tau)\left(8+\tau\left(24+\tau-18\tau^2+\tau^3\right)\right)(-112+\tau(-456+\tau(-402+\tau(201+\tau(229+(-37+\tau)\tau)))))}{32(1+3\tau)(4-3(-1+\tau)\tau)^2(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))^2}.$$

We then visualize the proof in Figure A1. We define τ_1 as the intersection point between $\Pi_S^{RO} - \Pi_S^{PO}$ and τ-axis. Therefore, solving the single crossing point between $\left(\Pi_S^{RO} - \Pi_S^{PO}\right)$ and the τ-axis by setting $\Pi_S^{RO} - \Pi_S^{PO} = 0$ yields $\tau_1 = 0.76$. We then observe that $\Pi_S^{RO} \geq \Pi_S^{PO}$ when $0 \leq \tau \leq \tau_1$, and $\Pi_S^{RO} < \Pi_S^{PO}$ when $\tau_1 < \tau < 1$.

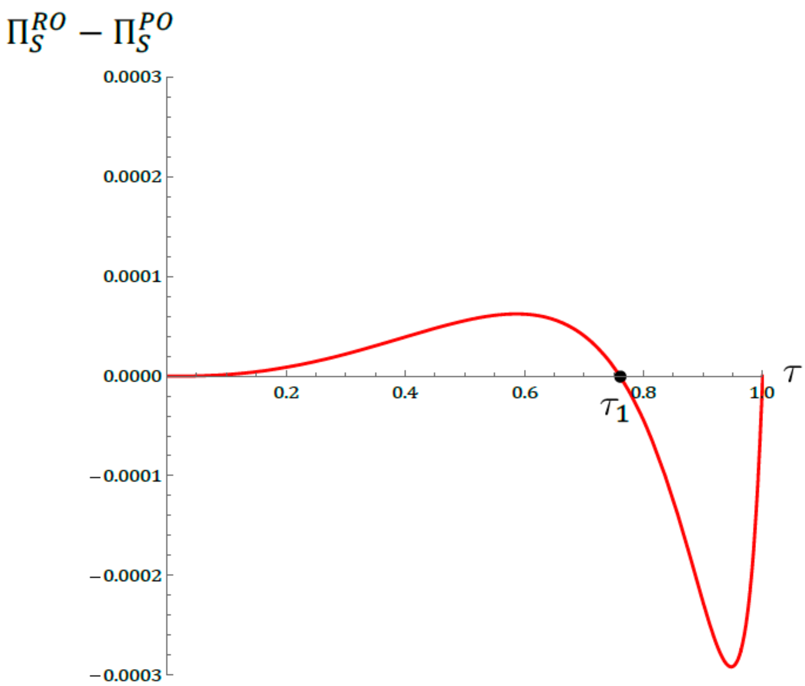

Figure A1. Curve of $\Pi_S^{RO} - \Pi_S^{PO}$.

Proof of Proposition 4. Similar to the proof of Proposition 1. □

Proof of Proposition 5. Similar to the proof of Proposition 2. □

Proof of Proposition 6. Similar to the proof of Proposition 3. □

Proof of Proposition 7. Similar to the proof of Proposition 1, the results in Proposition 7(a) can be derived by simple arithmetic manipulation. Now, we take the flexible structure as an example to show the proof of Propositions 7(b)–(e). We visualize the proof of Propositions 7(b)–(e) in Figure 2. First, solving the crossing points between π_i^{FO} and π_i^{FU} by setting $\pi_i^{FO} = \pi_i^{FU}$ yields $\tau = 0$ and $\tau = \tau_3^F = 0.436$. We then observe that $\pi_i^{FO} \leq \pi_i^{FU}$ when $0 \leq \tau \leq \tau_3^F$; otherwise, $\pi_i^{FO} > \pi_i^{FU}$. Secondly, solving the crossing points between π_j^{FO} and π_j^{FU} by setting $\pi_j^{FO} = \pi_j^{FU}$ yields $\tau = 0$ and $\tau = \tau_4^F = 0.319$. We then observe that $\pi_j^{FO} \leq \pi_j^{FU}$ when $0 \leq \tau \leq \tau_4^F$; otherwise, $\pi_j^{FO} > \pi_j^{FU}$. Third, solving the single crossing point between π_k^{FO} and π_k^{FU} by setting $\pi_k^{FO} = \pi_k^{FU}$ yields $\tau = 0$. We then observe that $\pi_k^{FO} \leq \pi_k^{FU}$ for $0 \leq \tau < 1$. Lastly, solving the crossing points between Π_S^{FO} and Π_S^{FU} by setting $\Pi_S^{FO} = \Pi_S^{FU}$ yields $\tau = 0$ and $\tau = \tau_5^F = 0.540$. We then observe that $\Pi_S^{FO} \leq \Pi_S^{FU}$ when $0 \leq \tau \leq \tau_5^F$; otherwise, $\Pi_S^{FO} > \Pi_S^{FU}$. □

Similarly, the results in exclusive retailing-channel and exclusive purchasing-channel structures can also be derived.

Proof of Proposition 8. First, we take the suppliers' prices in the three structures as an example to show the result in Proposition 8. Taking the first-order derivative of w_i^{FO}, w_i^{RO}, and w_i^{PO} with respect to τ, we have

$$\frac{\partial w_i^{FO}}{\partial \tau} = -\frac{(3+\tau(10+19\tau))(3+\tau(24+\tau(56+\tau(28+17\tau))))}{2(8+\tau(65+\tau(123-\tau(25+43\tau))))^2} < 0,$$

$$\frac{\partial w_i^{RO}}{\partial \tau} = -\frac{5+\tau(20+\tau(15+\tau(-8+3(-1+\tau)\tau(-1+3\tau))))}{(8+3(-1+\tau)\tau(1+\tau)(-7+2\tau))^2} < 0,$$

$$\frac{\partial w_i^{PO}}{\partial \tau} = -\frac{(3+\tau(2+3\tau))(8+\tau(24+\tau(19+3(-2+\tau)\tau)))}{2(16+3(-1+\tau)\tau(-14+(-11+\tau)\tau))^2} < 0.$$

Taking the first-order derivative of w_i^{FU}, w_i^{RU}, and w_i^{PU} with respect to τ, we have

$$\frac{\partial w_i^{FU}}{\partial \tau} = -\frac{5+\tau(102+\tau(881+\tau(4152+\tau(11391+\tau(17530+12019\tau)))))}{4(4+\tau(49+\tau(191+7(31-11\tau)\tau)))^2} < 0,$$

$$\frac{\partial w_i^{RU}}{\partial \tau} = -\frac{3(1+\tau^2)}{2(4+(3-4\tau)\tau)^2} < 0,$$

$$\frac{\partial w_i^{PU}}{\partial \tau} = -\frac{8+\tau(68+\tau(246+\tau(480+\tau(539+\tau(343+101\tau)))))}{2(8+\tau(36+\tau(39-2\tau(5+11\tau))))^2} < 0.$$

It is easy to obtain that the suppliers' prices decrease in the level of channel substitutability under both contract observability and unobservability. Similarly, it is easy to derive that the brand-owners' and the retailers' prices decrease in the level of channel substitutability. For brevity, the proof is omitted here. □

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