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Coordinated Supply Contracts for a Two-Echelon Supply Chain under Given Bargaining Powers

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Abstract: This paper addresses the supply contracts within a decentralized supply chain comprising an upstream component supplier and a downstream manufacturer. With the need to invest in production capacity before the sales season, suppliers often make conservative capacity decisions due to uncertain demand, which gives rise to the double marginalization problem. The distribution of supply chain profits is typically determined based on each member's relative bargaining power, often exogenously provided in the market. While numerous studies have been conducted to design supply contracts for coordination in decentralized supply chains, most of them overlook the supplier's capacity constraints and the existing bargaining power structure. To bridge this gap, this study proposes a supply contract scheme that achieves coordination under any given bargaining power structure. The key finding of this paper is that two contract types, namely capacity cost-sharing (CCS) and surplus capacity compensation (SCC), can address the entire spectrum of bargaining powers. This study demonstrates how to identify a specific threshold for a given bargaining power structure, from which the appropriate contract type is selected. Through numerical illustrations, we present how to select coordinated contracts for different bargaining power structures and examine the influence of contract parameters on the profit of each supply chain member. The primary contribution is that this study provides actionable insights for practitioners to effectively implement coordinated contracts by presenting a straightforward and practical methodology.

Keywords: coordinated supply contract; capacity building; capacity cost sharing; revenue sharing; bargaining power

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Citation: Jung, S.-M.; Koh, S.-G.; Kim, Y.-J.; Koo, P.-H. Coordinated Supply Contracts for a Two-Echelon Supply Chain under Given Bargaining Powers. *Sustainability* **2023**, *15*, 13005. https://doi.org/10.3390/su151713005

Academic Editor: Arkadiusz Kawa

Received: 14 July 2023
Revised: 22 August 2023
Accepted: 27 August 2023
Published: 29 August 2023

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1. Introduction

In supplier–manufacturer supply chains (SC), the dynamics between downstream manufacturers and upstream suppliers shape the system's efficiency, resilience, and sustainability. As the downstream manufacturer ('he') relies on the upstream supplier ('she') for components crucial to the final product, challenges in procuring these components have grown in significance. The procurement issues have been even more critical recently due to the increasingly turbulent and uncertain SC environment. A vivid illustration of these challenges emerged in the global automotive industry's staggering $200 billion loss in 2021 caused by a semiconductor chip shortage, leading to an 11-million vehicle production deficit [1,2]. This stark reality highlights the vital role of efficient capacity planning and decision-making in today's SC landscape.

The introduction of new products necessitates substantial investments in production capacity from both manufacturers and suppliers [3]. These investments are inherently intricate due to the uncertainty in product demand at the time of decision-making. Historically, firms undertaking capacity investments have borne the associated risks [4]. The investment risks could be critical for the supplier, especially when a single downstream manufacturer exclusively uses the component, as an excessive capacity investment can result in permanent losses. The risks are further amplified by current market environments, characterized by short product lifecycles, frequent SC disruptions, and high demand volatility. Consequently, suppliers often make conservative capacity investment decisions. However, the conservative decisions on the capacity investment made by the supplier often undermine the system efficiency in terms of the entire supply chain, resulting in what is known as the double marginalization problem [5].

One potential solution to this problem is vertical integration, wherein a single firm assumes ownership across multiple SC stages, thereby eliminating the need for external suppliers [6,7]. While this approach alleviates information distortion and the double marginalization issue, it introduces its own challenges, including substantial capital commitments and sole exposure to demand variability risks. This backdrop leads many industries to adopt decentralized SC functions by outsourcing to external firms [8]. Nevertheless, the double marginalization predicament endures in such decentralized supply chains, often impeding overall system efficiency [5]. Efficiency in the supply chain is crucial not only for enhancing a company's competitiveness, but also for promoting sustainability, managing energy consumption, and fostering a circular economy [9].

A contract is regarded as coordinated when it ensures that the individual decisions of the SC members in a decentralized environment align with the overall efficiency of the entire supply chain. In recent times, several supply contracts have been studied with the aim of achieving optimal coordination. Many coordinated contracts incorporate mechanisms by which the supplier assumes some of the retailer's risk of uncertain demand, allowing the retailer to increase the order quantities. Revenue-sharing, buy-back, and two-part tariff contracts are examples of such contracts [10–12]. The majority of earlier research has overlooked the critical aspect of integrating the supplier's production capacity in supply contracts, which is particularly significant in component supplier–manufacturer supply chains. A subset of studies explored contracts for capacity procurement involving the sharing of capacity investment risks between the supplier and the buyer (manufacturer in this study) [13–16]. Nevertheless, most existing supply contracts involving capacity decisions focus on how to maximize the overall channel profit rather than how to divide it among each supply chain member.

Profits within the supply chain are distributed among its members. The profit split is influenced by relative bargaining power, which refers to a party's ability to shape the terms and conditions of a contract in their favor [17]. Various factors, including asymmetric dependence, information asymmetry, reputation, and psychological behavior, impact relative bargaining power [18]. The higher the bargaining power, the more likely a party can secure favorable contract terms. For example, if upstream suppliers possess proprietary technology exclusive to them, their bargaining power could be stronger, leading them to claim a larger portion of the SC's profit. In real-life supply chains, the relative bargaining power among SC members is often externally determined in the market [18,19]. However, this aspect has not been adequately considered in the design of supply contracts. A limited number of studies have considered bargaining power in constructing channel-coordinated contracts. Tomlin [20] presented a nonlinear price-only contract coordinating the supplier–manufacturer supply chain under arbitrary bargaining power structures. Nonetheless, he acknowledged the practical challenges of implementing such contracts. Alternatively, he introduced a piecewise-linear contract with one or two breakpoints. While this contract offers simplicity in implementation, it does not guarantee channel coordination. Another study by Koo [21] proposed a coordinated supply contract addressing capacity investment and bargaining power. However, the contract only achieves channel coordination for a specific range of bargaining power, limiting its applicability to certain bargaining power structures.

This paper aims to bridge these gaps by presenting a coordinated supply contract scheme that embraces both bargaining power and capacity planning considerations. We propose a supply contract scheme that enables manufacturers to design and select supply contracts, facilitating channel coordination across all possible bargaining power structures.

The new contract scheme comprises two supply contracts: Capacity cost-sharing (CCS) and surplus capacity compensation (SCC). The CCS contract shares a portion of the supplier's capacity costs with the manufacturer, while the SCC contract compensates the supplier for investment in unused capacity. Both contracts employ the concept of revenue sharing among supply chain members. The two contracts encourage the supplier to invest in production capacity in alignment with the overall supply chain capacity under different bargaining power scenarios. In summary, this paper endeavors to address the following pivotal questions:

- How can a supply contract be designed to coordinate the supply chain, accounting for profit-split ratios influenced by market bargaining?
- What design principles should guide the supply contract's structure to align supplier and SC production capacities?
- Under the provided profit-split ratio, how should the parameters within the supply contracts be configured, and what interrelationships exist among these parameters?

The remainder of this paper is structured as follows. Section 2 reviews the existing literature on capacity planning and bargaining power in supply contracts. Section 3 introduces a basic model for determining production capacity in a supplier–manufacturer SC setting, accompanied by an elucidation of revenue sharing. Section 4 presents the supply contract scheme with CCS and SCC contracts to realize coordination across diverse bargaining power scenarios. Numerical case studies illustrating contract selection and parameter establishment are offered in Section 5. Section 6 presents numerical illustrations to demonstrate the selection of coordinated contracts for different bargaining power structures and investigate how the coordinated contract is selected and contract parameters are established to achieve channel coordination. The paper concludes in Section 6 with a synthesis of findings and suggestions for future research directions.

2. Literature Review

Traditionally, the literature on supply contracts has primarily focused on pricing mechanisms and quantity agreements within supplier–retailer supply chains operating in a make-to-order (MTO) environment. In this context, coordinated contracts generally involve mechanisms that allow the supplier to share some of the risks associated with uncertain demand, thereby enabling the retailer to increase their order quantity. These contract types encompass revenue-sharing [22,23], buyback [24,25], option [26,27], quantity-flexibility [28,29], and consignment contracts [30,31]. Comprehensive reviews of coordinated contracts have been conducted by Cachon [10], Shen et al. [11], and Gao et al. [12]. However, most earlier research has overlooked the critical aspect: The incorporation of the supplier's production capacity into supply contracts. This aspect is particularly significant in the context of component supplier–manufacturer supply chains. The present paper addresses a supply contract problem in which capacity planning and bargaining powers are considered. The literature review focuses on these topics.

2.1. Supply Contract with Capacity Planning

In contemporary supply chains, Original Equipment Manufacturers (OEMs) increasingly rely on outsourcing components, underscoring the growing significance of supplier capacity procurement. This trend has led to a surge in recent research efforts, highlighting the importance of investigating supplier production capacity as a crucial factor in designing efficient supply contracts. Cachon [13] introduced the capacity reservation (CR) contract within a supplier–manufacturer setting, wherein the supplier's capacity investment risk is shared with the manufacturer through reserving capacity in advance. The CR contract is a version of option contracts where the retailer pays an upfront reservation fee (option premium) for each unit of reserved capacity and pays the wholesale price (exercise price) for each ordered product when demand is realized. No capacity investment in the manufacturer is considered in the model. Erkoc and Wu [15] proposed a cost-sharing (CS) contract in which the buyer pays a portion of the supplier's capacity cost associated with her reservation. The CS contract allows the buyer either to receive a refund or to make an additional payment for the utilized capacity, depending on the actual demand. The authors showed that the CS contract could make the supplier build optimal channel capacity in make-to-order high-tech industries. They also introduced a variant of the CR contract, the deductible reservation (DR) contract, where the buyer pays an upfront fee for each unit of reserved capacity. The reservation fee is deductible from the purchasing price when the buyer places a firm order based on realized demand. The authors found that when only a portion of the reservation fee is deductible from the final payment, the supplier is willing to build the optimal channel capacity across a range of possible reservation fees. Jin and Wu [32] extended the DR contract to encompass excess capacity. In their contract, the supplier is the Stackelberg leader, setting both reservation and excess capacities that the buyer can purchase in a high-demand season. The authors proposed channel-coordinated DR contracts that enable the supplier and buyer to share the benefits of excess capacity while coordinating their actions to maximize profits.

Tomlin [14] examined the capacity procurement decision, wherein both the manufacturer and the supplier invest in capacity. The author introduced a novel mechanism for sharing the upside potential of high demand and showed that a nonlinear price-only contract can coordinate the supplier–manufacturer supply chain. As the nonlinear contract was challenging to implement in practice, he presented a piecewise-linear contract with some breakpoints for easy implementation. However, the user-friendly contract does not guarantee channel coordination. Taylor and Plambeck [33] investigated a contract scheme that allows the buyer to choose between price-only and price-and-quantity contracts. They identified the conditions under which the buyer prefers the former to the latter and demonstrated that buyers could enhance supply chain performance by providing information on their ordering decisions before the supplier's capacity investments. Gerchak and Wang [34] studied a supplier's capacity investment decisions in assembly systems where a single downstream assembler buys complementary components from multiple upstream suppliers. They introduced a component supply contract involving revenue sharing for sold products and buyback for unsold ones. The authors showed that this two-parameter contract could lead to channel coordination and increase the profits of all SC stakeholders. Fu et al. [35] also addressed a capacity procurement problem in an assembly system similar to Gerchak and Wang [34]. They considered a supplier–assembler SC where the assembler invested in the supplier's capacity and presented a procedure for determining the optimal investment levels and wholesale prices. The authors demonstrated that the assembler's investment could help the suppliers expand their capacity. However, they did not consider investment costs for the downstream assembler.

Li et al. [36] examined quantity flexibility (QF) contracts, in which the retailer commits to a minimum purchasing quantity, and the supplier commits to delivering no less than the agreed-upon quantity. They demonstrated that the QF contract could achieve channel coordination and presented approaches to establish contract parameters to coordinate the supply chain with an arbitrary profit split. Additionally, they discovered that retailers favor QF contracts over CR contracts because their profit split is higher under a coordinated supply chain environment. Yang et al. [37] investigated the role of retailers in a supplier's capacity investment strategies. They introduced two variations of CCS contracts, full CCS (FCCS) contract and partial CCS (PCCS) contract. In the FCCS contract, the retailer shares the capacity cost with the supplier for all production capacity, while in the PCCS contract, the retailer shares the capacity cost with the manufacturer for the capacity level exceeding a specific threshold. The authors compared and analyzed the effects of these two supply contracts on the profit of each member across various market conditions. However, their study did not explore the relationship between the proposed contracts and channel coordination.

2.2. Bargaining Power in Supply Contracts

Bargaining power plays a crucial role in determining the distribution of profits among supply chain stakeholders. Several factors are identified as important components of the bargaining power of negotiating parties, including dependence on others, organizational hierarchy, information asymmetry, psychological strategy, and reputation [38,39]. In real-world supply chains, the bargaining power among members is often externally determined within the market [18,19]. The industrial implications of bargaining power have been rigorously explored [40–43]. Nevertheless, there has been limited research on coordinated supply contract design considering bargaining power.

Morton [18] examined the video rental industry and analyzed the role of bargaining power in determining the vertical structure of the supply chain. The author discussed how varying levels of bargaining power influence the contractual arrangements between suppliers and retailers. The author discussed how varying levels of bargaining power influence the contractual arrangements between suppliers and retailers. Iyer and Villas-Boas [44] examined the impact of bargaining power on channel coordination under a wholesale contract in a manufacturer–retailer system. The authors found conditions under which the presence of a powerful retailer might be beneficial to all channel members. Production capacity is not considered in their model. Baron and Berman [42] investigated the influence of bargaining power on supply chain efficiency in competing supply chain settings. The authors demonstrated the selection procedure of bargaining power that maximizes overall supply chain profit.

Qing et al. [45] addressed a capacity allocation problem in a supplier–manufacturer supply chain where the supplier can participate in the downstream market and compete with the manufacturer. A dual channel is assumed where the capacity is allocated to either an internal channel (vertical integration), an external channel with an outside manufacturer, or both. They showed that the firm's bargaining powers have critical impacts on the optimal capacity allocation and the profits: The supplier's shared capacity increases with her higher bargaining power, but the manufacturer's shared capacity decreases with his bargaining power. Yang et al. [46] explored the impact of a supplier encroachment on the profit of the supply chain where a single supplier can sell a product either through the retailer, her direct channel, or both. They investigated how supplier encroachment is affected by bargaining power. Prasad et al. [38] examined the impact of some determining factors on bargaining power. They derived a theoretical model for the optimal SC split. Huang et al. [47] examined the impact of remanufacturing on channel coordination by examining the firm's preferred contractual form. Problems regarding a larger pie or a larger slice are addressed with two-part tariff and wholesale price contracts. Palit [48] emphasized that the selection of the appropriate contract type should be made based on the bargaining powers of SC members.

Shanthia et al. [49] addressed a contract problem related to investing in technology improvement in a supply chain under a wholesale contract. They investigated how bargaining power affects the efficiency of SC coordination mechanisms and found an inverse U-shape relationship between buyers' bargaining power and technology improvement investment. Koo [21] examined the effect of bargaining power in setting the contract parameters in a CCS contract in a supplier–manufacturer supply chain environment. The author showed that channel-coordinated CCS contracts are feasible only within a specific range of bargaining power when capacity investment is required for both the supplier and the manufacturer. This study builds upon the existing research [21] to explore approaches for designing supply contracts under all possible bargaining power scenarios.

2.3. Research Gap Analysis

Existing supply contract literature primarily focuses on maximizing the channel profit through channel coordination rather than on addressing the distribution of the profit based on bargaining power. This study addresses a research gap highlighted by Prasad et al. [38], who emphasized the importance of investigating how supply chain profits are distributed, taking into account the bargaining power of supply chain members. We present a contract scheme designed to achieve channel coordination regardless of the bargaining power distribution within supplier–manufacturer supply chains. Furthermore, this work incorporates considerations for capacity investment in the supplier within the contract-building process. Table 1 provides a comparative overview of the current work in relation to existing literature.

Table 1. The literature on supply contracts with capacity building and bargaining power.

Studies	Characteristics of Studies				
	Upstream Capacity	**Downstream Capacity**	**Bargaining Power**	**Coordination**	**Supply Chain Structure**
[22–31]	X	X	X	O	Supplier-Retailer
[13,15,32]	O	X	X	O	Supplier-Manufacturer
[14]	O	O	X	O	Supplier-Manufacturer
[34,35]	O	Δ	X	O	Supplier-Assembler
[36]	O	X	Δ	O	Manufacturer-Retailer
[37]	O	X	X	X	Manufacturer-Retailer
[42,44]	X	X	O	O	Manufacturer-Retailer
[45]	O	X	O	O	Supplier-Manufacturer
[49]	O	X	O	O	Supplier-Buyer
[39,46,48]	X	X	O	O	Supplier-Buyer
[47]	X	Δ	O	O	Supplier-Manufacturer
[21]	O	O	Δ	O	Supplier-Manufacturer
This work	O	O	O	O	Supplier-Manufacturer

O: Addressed. X: Not addressed. Δ: Partially addressed.

3. The Basic Model

This study considers a supply chain with one supplier and one manufacturer for a single sales season. The supplier is responsible for producing and delivering components to the manufacturer, who then completes the final products. Both SC stakeholders are required to establish their production capacities well in advance of the sales season. As demand becomes evident at the commencement of the sales season, the manufacturer's order quantity is constrained to match the realized demand, recognizing that unsold products at the end of the season hold no value. Surplus capacity goes to waste if demand falls short of capacity, while excess demand beyond capacity results in lost sales. It is assumed that the sale price of the final products is given in the market, and information about product price, production and capacity costs, and demand distribution is mutually shared between the SC members. There is a time lag between capacity investment and the sales season. The time difference raises the problem of the time value of money. However, this study does not explicitly delve into the time value of money because this issue is beyond the scope of our study. This paper resolves this problem by assuming that the time value of money is already incorporated in the cost factors. The stochastic demand for the final product, denoted as X, follows a probability density function $f(x)$ and a cumulative distribution function $F(x)$. The notations specified in Table 2 will be consistently used throughout the paper.

Table 2. Notation and descriptions.

Notations	Descriptions
K_s, K_m, K_{sc}	capacity of supplier, manufacturer, and supply chain, respectively.
c_s, c_m, c_{sc}	per-unit production cost of supplier, manufacturer, and SC, respectively.
k_s, k_m, k_{sc}	per-unit capacity cost of supplier, manufacturer, and SC, respectively.
p	per-unit retail price (revenue)
α	profit-split ratio for the supplier
$\varnothing$	supplier's revenue-sharing fraction
θ	fraction of supplier's capacity cost for which the supplier is responsible.
γ	compensation fraction for surplus capacity paid by manufacturer to supplier
X	market demand of the final product (random variable)
Q	expected sales (or production) volume
EP_s, EP_m, EP_{sc}	expected profit of supplier, manufacturer, and supply chain, respectively.

This section presents a basic model for determining production capacity in a supply chain involving a supplier and a manufacturer. Initially, we examine a centralized supply chain, where both the supplier and the manufacturer are under the ownership of a single firm. In this centralized system, the optimal capacity is determined to maximize the expected supply chain profit. Following this, we introduce the concept of the pure revenue-sharing contract, which serves as a foundational element of our contract framework presented in the subsequent section.

3.1. The Centralized System

In the centralized system, a decision maker aims to maximize the expected system-wide profit. (Refer to [21] for a more detailed description). When there is a realized demand x, the sales amount can be expressed as min(x, K_{sc}). The expected profit of the supply chain can be calculated as follows:

$$EP_{sc} = (p - c_s - c_m)\text{Q} \; - (k_s + k_m)K_{sc} \tag{1}$$

where Q is the expected sales amount and can be obtained as follows:

$$Q = E\min(x,\ K_{sc}) = K_{sc} - \int_0^{K_{sc}} F(x)dx \tag{2}$$

The first term on the right-hand side of the expression (1) represents the expected SC revenue from the sale, and the second term signifies the investment cost for the SC's capacity. The first-order derivative of Q with respect to K_{sc} provides: $\frac{dQ}{dK_{sc}} = 1 - F(K_{sc})$. It is clear that $\frac{dEP_{sc}}{dK_{sc}}$ decreases in K_{sc}, and EP_{sc} is concave in terms of K_{sc}. Therefore, the optimal capacity ${K_{sc}}^*$ for the centralized system can be found using the first-order condition of expression (1) as follows:

$${K_{sc}}^* = F^{-1}\left(1 - \frac{k_s + k_m}{p - c_s - c_m}\right) \tag{3}$$

The expected maximum profit, ${EP_{sc}}^*$, can be realized with capacity ${K_{sc}}^*$ for the entire supply chain. Let ρ_{sc} be the SC's marginal revenue, $\rho_{sc} = p - c_s - c_m$. Expression (3) demonstrates that the optimal capacity depends on the capacity-building cost, $k_s + k_m$ and SC marginal revenue: The optimal capacity decreases as the capacity-building cost increases, while it increases as the SC's marginal revenue increases.

3.2. Decentralized System: Pure Revenue Sharing (PRS) Contract

In a decentralized system with two independent SC members, each member makes decisions to maximize their profit. The sequence of events in the decentralized system is as follows: (1) The manufacturer sets a target SC capacity and designs a supply contract with some contract parameters, which he offers to the supplier. (2) The supplier then decides on the optimal capacity level to invest in and whether to sign the supply contract. (3) Both parties build the capacity if the contract is accepted. (4) When the sales season arrives, the manufacturer places a firm order with the supplier based on realized demand. (5) The supplier produces and delivers the components to the manufacturer. (6) The manufacturer uses the components to make finished products and sells them on the market.

For the base case contract scheme in the decentralized system, a PRS contract is used in which a fraction of the SC revenue is shared among the SC parties (refer to [22] for a more detailed description.) Out of the per-unit sales revenue p, $\text{Ø}p$ goes to the supplier while $(1 - \text{Ø})p$ goes to the manufacturer. It is assumed that no capacity cost is shared in this contract, and the supplier bears all the cost of her capacity. The expected profit of the supplier is given by:

$$EP_{prs.s} = (\text{Ø}p - c_s)Q - k_sK_s \tag{4}$$

From the manufacturer's perspective, he would set the optimal SC capacity obtained in expression (3) as a target SC capacity, i.e., $K_m = K_{sc}{}^*$. Note that the supply chain capacity is determined by the SC member with the lowest capacity. When the manufacturer's capacity K_m is known, the supplier will not have more capacity than the manufacturer's capacity because the order amount from the manufacturer should not be more than K_m. Therefore, $K_s \leq K_m$. Then, $K_{sc} = \min(K_s, K_m) = K_s$. The supplier would decide on her capacity to maximize her expected profit. Expression (4) is concave in terms of K_s, so the first-order condition gives the optimal supplier's capacity as follows:

$$K_{prs.s}{}^* = F^{-1}\left(1 - \frac{k_s}{\varnothing p - c_s}\right) \tag{5}$$

As Cachon [10] asserts, a contract coordinates the supply chain if the supplier's capacity investment level remains consistent with the capacity investment level of the centralized supply chain, i.e., $K_{prs.s}{}^* = K_{sc}{}^*$. Then, from expressions (3) and (5), the relationship between contract parameters must be satisfied for the SC coordination:

$$\varnothing_{prs}{}^* = \frac{(p - c_m)k_s + c_s k_m}{p(k_s + k_m)} \tag{6}$$

Note that the supply chain can be coordinated with a specific revenue-sharing fraction given in (6) in the decentralized supply chain under the PRS contract because all the parameters on the right side of the expression (6) are deterministic and known. Based on expression (6), we have $0 < \varnothing_{prs}{}^* < 1$. The expected profit of the manufacturer under the PRS contract is as follows:

$$EP_{prs.m} = ((1 - \varnothing)p - c_m)Q - k_m K_m \tag{7}$$

A supply contract would be acceptable by all the SC members only when every SC member makes a positive profit. Using expressions (4) and (7), $EP_{prs.s} = 0$ with $\varnothing = \frac{k_s K_s/Q + c_s}{p}$ and $EP_{prs.m} = 0$ with $\varnothing = \frac{p - k_m K_m/Q - c_m}{p}$, in the coordinated scenario. Then, the revenue-sharing fraction, $\varnothing$, must satisfy the following condition under the PRS contract:

$$\frac{k_s K_s/Q + c_s}{p} < \varnothing < \frac{p - k_m K_m/Q - c_m}{p} \tag{8}$$

As mentioned earlier, the profit-split fraction among the SC members is determined by relative bargaining power in the market. The problem is that the optimal revenue-sharing fraction obtained from (6) under the PRS contract usually does not satisfy the target bargaining power. In the next section, we introduce two contract schemes for SC coordination where bargaining power conditions are considered.

4. Coordinated Supply Contracts with Investment Risk Sharing

4.1. Capacity Cost Sharing (CCS) Contract with Revenue Sharing

In this contract, the manufacturer shares the investment risk of the supplier by paying a fraction of the supplier's capacity cost. The CCS contract model is adopted from [21]. The CCS contract contains two parameters, $\varnothing$ (the supplier's revenue share fraction) and θ (a fraction of the supplier's capacity cost for which the supplier is responsible). The manufacturer is responsible for $(1 - \theta)k_s$ among the per-unit capacity cost k_s of the supplier, while the supplier is responsible for θk_s. In the CCS contract, the expected profit of the supplier, $EP_{ccs.s}$, is given by:

$$EP_{ccs.s} = (\varnothing p - c_s)Q - \theta k_s K_s \tag{9}$$

The first term on the right-hand side of the expression represents the expected revenue obtained from the sale (revenue sharing), and the second part indicates the amount of the investment for the supplier's capacity that the supplier has to bear. Since $EP_{ccs.s}$ is concave in terms of K_s, the first-order condition gives the optimal supplier's capacity as:

$$K^*_{ccs.s} = F^{-1}\left(1 - \frac{\theta k_s}{\varnothing p - c_s}\right) \tag{10}$$

Now, to have a coordinated CCS contract, the supplier's capacity investment level should be equal to the optimal capacity investment level of the centralized supply chain, i.e., $K^*_{ccs.s} = K^*_{sc}$. Then, from expressions (3) and (10), the CCS contract satisfying the following expression coordinates the supply chain:

$$\frac{k_s + k_m}{p - c_s - c_m} = \frac{\theta k_s}{\varnothing p - c_s} \tag{11}$$

Given a specific value of Ø, the optimal capacity-sharing fraction, θ^*, can be obtained as follows:

$$\theta^* = \frac{(\varnothing p - c_s)(k_s + k_m)}{(p - c_s - c_m)k_s} \tag{12}$$

When $\theta = \theta^*$, the expected profit of the manufacturer is given by:

$$EP_{ccs.m} = [(1 - \varnothing)p - c_m]Q - (1 - \theta^*)k_s K_s - k_m K_m \tag{13}$$

We can see from expression (12) that θ and Ø are positively proportional to each other in the coordinated CCS contract, which is consistent with the common idea that the supplier would bear more capacity investment when she has a higher revenue sharing fraction. If the manufacturer is responsible for all the supplier's capacity investment (i.e., θ = 0), expression (12) gives the optimal revenue-sharing fraction as follows:

$$\varnothing^0 = \frac{c_s}{p} \tag{14}$$

Note that from expression (9), $EP_{ccs.s}$= 0 under θ = 0 and Ø= $\varnothing^0$, indicating that no supply chain profit is allocated to the supplier under the coordinated CCS contract. If the supplier bears all the cost of her capacity (i.e., θ = 1), the CCS contract is equivalent to the PRS contract, and the optimal revenue-sharing fraction $\varnothing^1$ is equal to expression (6):

$$\varnothing^1 = \varnothing_{prs}{}^* = \frac{(p - c_m)k_s + c_s k_m}{p(k_s + k_m)} \tag{15}$$

From expressions (14) and (15), it is clear that $\varnothing^0 > 0$ and $\varnothing^1 < 1$. Since the condition $0 \le \theta \le 1$ is a reasonable assumption, we have the following relationship in terms of Ø under coordinated CCS contracts:

$$\varnothing^0 \le \varnothing \le \varnothing^1. \tag{16}$$

Expression (16) reveals that the CCS contract coordinates the supply chain with a specific range of revenue fraction values determined by relative bargaining power. It should be noted that the supplier will not agree to any contract if Ø falls below $\varnothing^0$, as it would result in a negative expected profit. On the other hand, if Ø exceeds $\varnothing^1$, no coordinated CCS contract can exist with $\theta \le 1$. Under the coordinated CCS contract, the maximum profit of the manufacturer is realized with $\varnothing = \varnothing^0$ while the maximum profit of the supplier is achieved with $\varnothing = \varnothing^1$. In the next subsection, we propose a coordinated supply contract for the range of $\varnothing > \varnothing^1$.

4.2. Surplus Capacity Compensation (SCC) Contract with Revenue Sharing

In this contract, the manufacturer shares the investment risk with the supplier by compensating the supplier for a portion of the investment costs associated with unused capacity when the realized demand falls short of the supplier's capacity. The SCC contract has two key parameters: The revenue-sharing fraction (Ø) and the compensation fraction for the supplier's wasted capacity (γ). Under the terms of the contract, the supplier incurs an investment cost of $k_s K_s$ and is compensated with γk_s per unit of lost capacity. Note that the compensation is for the difference between the target capacity K^*_{sc} and the order amount. The expected profit of the supplier is as follows:

$$EP_{scc.s} = (\text{Ø}p - c_s)Q - k_s K_s + [K_{sc} - Q]\gamma k_s \tag{17}$$

Expression (17) is concave in terms of K_s, so the first-order condition gives the optimal supplier's capacity as:

$$K^*_{scc.s} = F^{-1}\left(1 - \frac{k_s}{\text{Ø}p - c_s - \gamma k_s}\right) \tag{18}$$

The optimal γ that leads to the coordinated supply chain is obtained by equalizing (3) and (18) as follows:

$$\gamma^* = \frac{\text{Ø}p - c_s}{k_s} - \frac{(p - c_s - c_m)}{k_s + k_m} \tag{19}$$

It is worth mentioning that γ and Ø are positively proportional to each other in the coordinated SCC contract: With higher Ø, we have higher γ, and vice versa. The positive correlation between γ and Ø seems to contradict the common belief that suppliers with a larger portion of the revenue should receive less compensation for excess capacity. We can explain this seemingly contradictory finding by the fact that the SCC contract is selected for higher supplier bargaining power, hence more profit should be granted to the supplier with a higher revenue-sharing ratio and compensation fraction. When $\gamma = \gamma^*$, the expected profit of the manufacturer is as follows:

$$EP_{scc.m} = [(1 - \text{Ø})p - c_m]Q - k_m K_m - [K_s - Q]\gamma^* k_s. \tag{20}$$

It is reasonable to assume that the compensation fraction γ must be greater than or equal to zero (with negative γ, the manufacturer receives compensation from the supplier when the supplier's capacity is wasted, which is not realistic in most industries). We can derive a condition in terms of Ø from expression (19), which is given by:

$$\text{Ø} > \frac{pk_s + c_s k_m - c_m k_s}{p(k_s + k_m)} \tag{21}$$

Note that the right-hand side of expression (21) is equal to Ø^1 in expression (15). As Ø increases, the expected profit of the manufacturer decreases. The manufacturer's expected profit must be greater than zero for the coordinated SCC contract to be viable. Therefore, the upper bound of Ø in the coordinated SCC contract, Ø^2, can be obtained from expressions (19) and (20) as follows:

$$\text{Ø}^2 = \frac{(p - c_m - c_s)Q - k_m K_m + c_s K_s + (K_s - Q)(p - c_m - c_s)k_s/(k_s + k_m)}{pK_s} \tag{22}$$

When $\text{Ø} = \text{Ø}^2$, no profit is expected for the manufacturer. Therefore, the coordinated SCC contracts exist for a range of revenue fractions, namely, $\text{Ø}^1 < \text{Ø} < \text{Ø}^2$.

4.3. Bargaining Power and Supply Contracts

We have investigated two supply contracts, CCS and SCC contracts. Both the CCS and SCC contracts employ the concept of revenue sharing among supply chain members. Note that the PRS contract is a special case of the CCS contract with $\theta = 1$ and the SSC contract with $\gamma = 0$. Each contract allocates SC profits differently between the supplier and manufacturer, with the profit-split ratio determined by the relative bargaining power of each SC member. Let α be the expected profit-split ratio for the supplier, i.e., $\alpha = EP_s/EP_{sc}$.

Then, α must be between 0 and 1 to ensure positive expected profits for both parties. In previous subsections, we found that the supply chain can be coordinated through the PRS contract for $\varnothing = \varnothing^1 = \varnothing_{prs}{}^*$. The $\varnothing^1$ value is as a break point where the CCS contract can lead to coordination for $\varnothing^0 < \varnothing < \varnothing^1$ and the SCC contract for $\varnothing^1 < \varnothing < \varnothing^2$. The coordinated contract with $\varnothing = \varnothing^0$ results in α = 0, which means that all the supply chain profits go to the manufacturer. Similarly, the coordinated contract with $\varnothing = \varnothing^2$ leads to α = 1, which means that all the supply chain profits go to the supplier. When the coordinated contract is built with $\varnothing^1$, we have $\alpha = \alpha^* = EP_{prs.s}{}^* / EP_{sc}{}^*$, which is the coordinated profit-split ratio in the PRS contract. $\varnothing^0$ corresponds to α = 0, $\varnothing^1$ to $\alpha = \alpha^*$, and $\varnothing^2$ to α = 1. Then, the supply chain can be coordinated through the PRS contract for $\alpha = \alpha^*$, the CCS contract for $0 < \alpha < \alpha^*$, and the SCC contract for $\alpha^* < \alpha < 1$. The α^* value serves as the threshold that distinguishes whether to employ the CCS contract or SCC contract for coordination.

Figure 1 illustrates a selection mechanism for coordinated supply contracts across various profit-split ratios. It is assumed that the target profit-split ratio, α^t, is provided in the market. The threshold profit-split ratio, α^*, is then calculated following the detailed procedure outlined in the preceding subsections. Subsequently, the appropriate contract type is chosen to achieve supply chain coordination based on the relationship between α^t and α^*. Specifically, the CCS contract is selected in the case of $\alpha^t < \alpha^*$, while the SCC contract is the coordinated choice for $\alpha^t > \alpha^*$. In cases where $\alpha^t = \alpha^*$, the PRS contract ensures supply chain coordination.

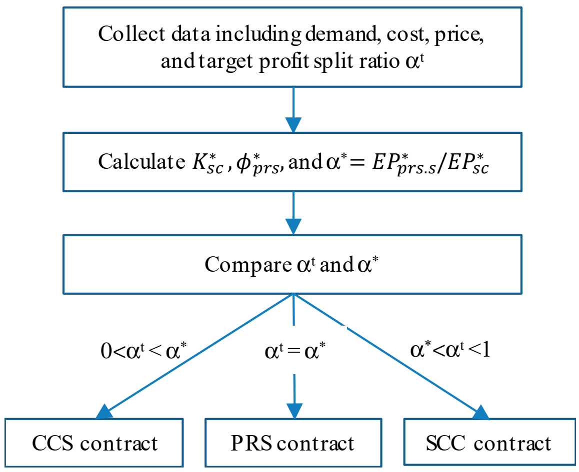


Figure 1. Coordinated contract scheme under different bargaining powers.

After selecting the appropriate supply contract, contract parameters must be determined under a given profit-split ratio, α^t. The key parameters for the CCS contract include $\varnothing$ and θ while the primary parameters for the CCS contract are $\varnothing$ and γ. The revenue sharing ratio, denoted as $\varnothing^t$, can be derived for the CCS contract using expressions (1), (9), and (12) as follows:

$$\varnothing^t = \frac{\alpha^t EP_{sc} - c_s(k_s + k_m)K_{sc}/(p - c_s - c_m)}{p[Q - (k_s + k_m)K_{sc}/(p - c_s - c_m)]} \tag{23}$$

In the case of the SCC contract, the compensation fraction γ can be obtained from expressions (1), (17), and (19) as follows:

$$\varnothing^t = \frac{\alpha^t EP_{sc} + (c_s + k_s)Q + (K_{sc} - Q)(p - c_s - c_m)k_s/(k_s + k_m)}{pK_{sc}} \tag{24}$$

The corresponding parameters, θ in the CCS contract and γ in the SCC contract, can be determined by using expressions (12) and (17), respectively.

5. Numerical Studies

In this section, we present an illustrative case that serves to validate the analytical findings and evaluate the impact of contract parameters on the profit of individual supply chain (SC) members. The scenario is adapted from Mathur [50] and Koo [21] with minor modifications, including the addition of certain parameters such as production and capacity costs at the manufacturer, as well as the substitution of the wholesale price with the revenue-sharing ratio. This illustrative case offers confirmation of our analytical results and a thorough examination of the influence of contract parameters on SC member profits. The demand for the product during the sales season is assumed to follow a uniform distribution X ~ Unif(20, 30), and the contract parameters are p = 40.0, c_s = 4.0, c_m = 5.0, k_s = 7.0, k_m = 3.0, and Ø = 0.4 (where Ø can be adjusted based on bargaining power). We deliberately opt for a straightforward parameter setup in this scenario for two primary reasons: (1) To facilitate practitioners' understanding through a clear solution approach and (2) to convey the overall significance even with the use of simple data. All numerical analyses are conducted using the MS Excel 2016 spreadsheet software on a desktop computer with an Intel Core i7-9700 CPU @ 3.00 GHz.

5.1. Centralized System

In the centralized system, a manager aims to maximize the overall SC profit. The optimal SC capacity, K_{sc}^*, is obtained from expression (3) as follows: $K_{sc}^* = F^{-1}\left(1 - \frac{k_s + k_m}{p - c_s - c_m}\right) = F^{-1}(0.677) = 26.8$. With the SC capacity determined, the expected production (sales) amount, Q, can be calculated from expression (2): $Q = K_{sc}^* - \int_0^{K_{sc}^*} F(x)dx = 24.5$. Subsequently, from expression (1), the expected profit of the supply chain is $EP_{sc} = (p - c_s - c_m)Q - (k_s + k_m)K_{sc}^* = 491.1$. This represents the maximum expected profit achievable by the entire supply chain. The optimal solution established within the centralized supply chain serves as a benchmark for achieving channel coordination in the subsequent decentralized SC scenarios.

5.2. Decentralized System with PRS Contract

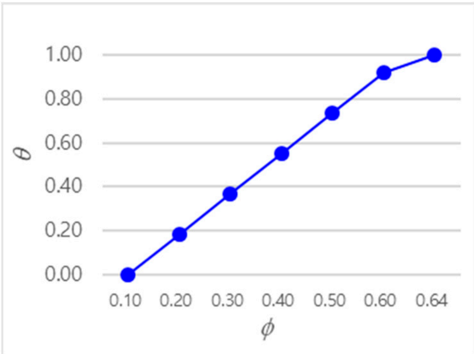
In the PRS contract, the supplier's profit is contingent on the revenue-sharing fraction Ø, determined by the relative bargaining powers of the SC members. Now, suppose Ø= 0.4 (i.e., 40% of the sale price goes to the supplier and 60% to the manufacturer). From expression (5), the supplier's capacity investment is $K_{prs.s}^* = F^{-1}\left(1 - \frac{k_s}{Øp - c_s}\right) = 24.2$. Consequently, the expected sales quantity is $Q = K_{prs.s}^* - \int_0^{K_{prs.s}^*} F(x)dx = 23.3$. The expected profits for the supplier and the manufacturer are: $EP_{prs.s} = (Øp - c_s)Q - K_s k_s = 110.4$, $P_{prs.m} = [(1 - Ø)p - c_m]Q - (1 - \theta)k_s K_s - k_m K_m = 370.2$, respectively. It is apparent that under the PRS contract, the total supply chain profit ($EP_{prs.sc} = EP_{prs.s} + P_{prs.m} = 480.6$) falls short of the centralized system by 10.5. This indicates that no coordinated PRS contract exists with Ø = 0.4. According to expression (6), the PRS contract can only coordinate the supply chain when the revenue-sharing fraction is $Ø_{prs}{}^* = \frac{(p - c_m)k_s + c_s k_m}{p(k_s + k_m)} = 0.6425$. In the coordinated PRS contract, the expected profits of the supplier and the manufacturer are 343.8 and 147.3, respectively. These findings suggest that channel coordination under the PRS contract is possible only when the supplier receives 70.0% of the total SC profit (i.e., $\alpha^* = 0.700$).

5.3. CCS Contract with Revenue Sharing

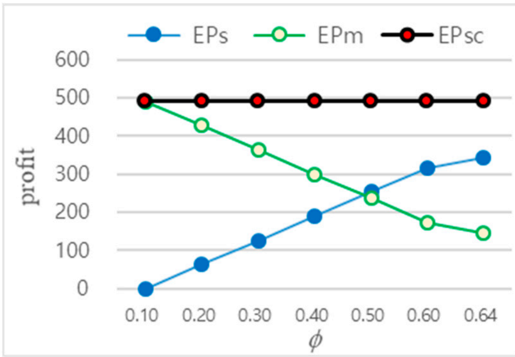
When the CCS contract is applied, the SC coordination is realized with the range of $Ø^0 \le Ø \le Ø^1 = Ø_{prs}{}^*$, i.e., $0.1 \le Ø \le 0.643$ in our case. Given $Ø = 0.4$, the optimal capacity cost-sharing fraction θ can be derived from expression (12): $\theta^* = 0.553$. From expression (10), the optimal supplier's capacity is $K_{ccs.s}^* = F^{-1}\left(1 - \frac{\theta k_s}{Øp - c_s}\right) = 26.8$, the same as in the centralized system. The expected profits for the supplier and the manufacturer, based on expressions (9) and (13), are $EP_{ccs.s} = (Øp - c_s)Q - \theta k_s K_s = 190.1$ and

$EP_{ccs.m} = [(1-Ø)p - c_m]Q - (1-\theta^*)k_sK_s - k_mK_m$ = 301.0, respectively. The total expected SC profit is $EP_{ccs.sc} = EP_{rs.s} + P_{rs.m} = 491.1$, mirroring the centralized system.

Figure 2 illustrates the relationship between Ø and θ under coordinated CCS contracts and the expected profit of each SC member under varying Ø values. Figure 2a demonstrates that as Ø increases, θ also increases within the coordinated CCS contract. From expression (12), the slope of the graph is $\frac{d\theta}{dØ} = \frac{(k_s+k_m)p}{(p-c_s-c_m)k_s} = 1.843$. Figure 2b shows that as Ø (and consequently θ) increases, the supplier's profit increases (the manufacturer's profit decreases). For example, the expected profit of the supplier is 190.1 at $Ø = 0.4$ and 316.9 at $Ø = 0.6$. It is also seen that in any value of Ø satisfying $Ø^0 \leq Ø \leq Ø^1$, the total profit of the supply chain remains the same at the optimal profit, 491.1, with the coordinated Ø and θ values. The results indicate that a coordinated CCS contract exists in the range of $Ø^0 \leq Ø \leq Ø^1$.



(**a**)



(**b**)

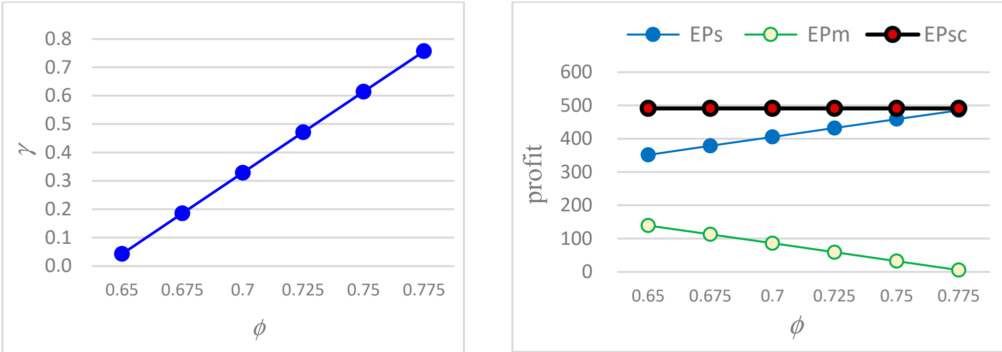
Figure 2. The coordinated set of (Ø,γ) and its impact on the profits under the SCC contract. (**a**) The coordinated set of (Ø, θ) (**b**) profit of SC members over different Ø*s*.

When Ø is greater than $Ø^1$ = 0.643, the θ value should be greater than 1.0. This implies that the supplier invests in her capacity, and at the same time, some of the capacity cost is paid to the manufacturer, which is unreasonable in real-world industries. The following SCC contract solves this problem.

5.4. SCC Contract with Revenue Sharing

For the range of $Ø^1 < Ø < Ø^2$, i.e., 0.643 $\leq Ø \leq$ 0.780 in our case, the SCC contract is applied. For instance, when $Ø = 0.7$, expression (19) yields the optimal per-unit compensation fraction γ under the SCC contract as follows: $\gamma^* = \frac{Øp-c_s}{k_s} - \frac{(p-c_s-c_m)}{k_s+k_m} = 0.329$. With this contract, the expected profits of the supplier and manufacturer are 405.4 and 85.8, respectively, which gives a total SC profit as 491.1, the same as in the centralized system.

Figure 3 illustrates the relationship between Ø and γ under coordinated SCC contracts and the expected profit of each SC member under varying Ø values. Figure 3a demonstrates that as Ø increases, γ also increases in the coordinated contract. The slope of the graph, derived from expression (19), is $\frac{d\gamma}{dØ} = \frac{p}{k_s} = 5.714$. Figure 3b shows that as (Ø, γ) increases, the manufacturer's profit decreases (the supplier's profit increases). The total SC profit remains constant at the optimal profit, 491.1, regardless of Ø values. When γ exceeds 0.780, the manufacturer's profit becomes negative. Therefore, the SC coordination is achieved through the SCC contract within the range of $Ø^1 \leq Ø \leq Ø^2$.



(**a**) (**b**)

Figure 3. The coordinated set of $(\varnothing, \gamma)$ and its impact on the profits under the SCC contract. (**a**) The coordinated set of $(\varnothing, \gamma)$; (**b**) profit of SC members over different $\varnothing s$.

5.5. Putting Supply Contracts Together

Table 3 presents the optimal parameter values of ϕ and θ in the coordinated CCS contract, as well as $\varnothing$ and γ in the coordinated SCC contract, across a range of profit-split ratios from zero to one. Notably, the ϕ range spans from $\varnothing^0$ $(= 0.1)$ to $\varnothing^2$ $(= 0.78)$, encompassing the entire spectrum of profit-split ratios under the coordinated contracts. When the profit-split ratio is 70% with $\alpha = 0.70$ (i.e., 70% of the SC profit goes to the supplier), the PRS contract leads to a coordinated contract with ϕ = 0.643. When the profit-split ratio falls below 70%, SC coordination can be achieved through the CCS contract, while when the profit-split ratio exceeds 70%, the SCC contract ensures SC coordination. It is evident that channel coordination is achieved either through the CCS or SCC contracts throughout the entire range of profit-split ratios, from $\alpha = 0$ to $\alpha = 1.0$. These results suggest that by taking into account the bargaining power of each member in the supply chain, it is feasible to establish a coordinated contract system among the CCS and SCC contracts (note that the PRS is a special case of CCS and SCC).

Table 3. Coordinated supply contract parameters over different profit-split ratios.

α	0.0	0.13	0.26	0.39	0.52	0.65	0.70	0.72	0.83	0.94	1.00
Φ *	0.1	0.2	0.3	0.4	0.5	0.6	0.643	0.65	0.7	0.75	0.780
θ *	0.000	0.184	0.368	0.553	0.737	0.922	1.000	—	—	—	—
γ *	—	—	—	—	—	—	0.000	0.043	0.329	0.614	0.786
EP_s	0.0	63.4	126.7	190.1	253.5	316.9	343.8	351.8	405.4	458.9	491.1
EP_m	491.1	427.8	364.4	301.0	237.6	174.3	147.3	139.3	85.8	32.2	0.0
EP_{sc}	491.1	491.1	491.1	491.1	491.1	491.1	491.1	491.1	491.1	491.1	491.1

* indicates the set of parameters under coordinated CCS and SCC contracts.

Figure 4 illustrates how the profits of each supply chain member vary with different profit-split ratios. When the supplier possesses greater bargaining power (with larger α), a coordinated SCC contract can be employed to achieve supply chain coordination. Conversely, a CCS contract can lead to supply chain coordination when the manufacturer wields more bargaining power. For instance, if the supplier has significant bargaining power with $\alpha = 0.83$ (i.e., the supplier receives 83% of the total supply chain profit), the manufacturer can adopt an SCC contract with $\varnothing$ = 0.7 and γ = 0.329 and offer the contract to the supplier. This contract ensures that the supplier receives the desired portion of the profit, and the supplier determines her capacity, $K^*_{ccs.s} = 26.8$. Consequently, the expected profits of the supplier and manufacturer are 405.4 and 85.8, respectively. Conversely, if the supplier has lower bargaining power with $\alpha = 0.26$, the manufacturer can opt for a CCS contract with $\varnothing$ = 0.3 and θ = 0.368 and offer the contract to the supplier. This contract results in expected profits of 126.7 and 364.4 for the supplier and manufacturer, respectively.

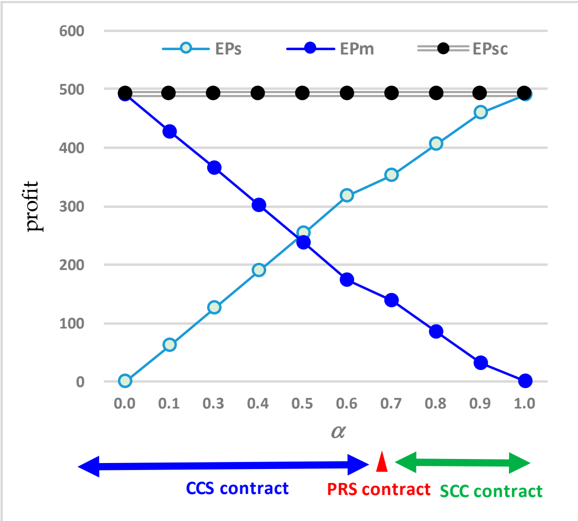


Figure 4. Coordinated contracts under different bargaining powers.

5.6. Additional Analysis

It is essential to pinpoint the critical threshold α^* that distinguishes the scenarios in which a CCS contract facilitates coordination from those in which an SCC contract achieves coordination. We conducted a sensitivity analysis on α^*, considering both production and capacity investment costs. The outcomes are presented in Figure 5. The values on the x-axis of the graph represent deviations from the benchmark's baseline value. The figure reveals that the decision threshold value, α^*, remains unaffected by production cost variations for suppliers and manufacturers. However, the production capacity costs of suppliers and manufacturers significantly influence the determination of the threshold value: Higher investment costs in suppliers lead to a proportional increase in the threshold value. Consequently, a CCS contract becomes viable for a wider range of bargaining power scenarios. Conversely, increased investment costs for manufacturers result in a reduced threshold value, indicating greater applicability of the SCC contract.

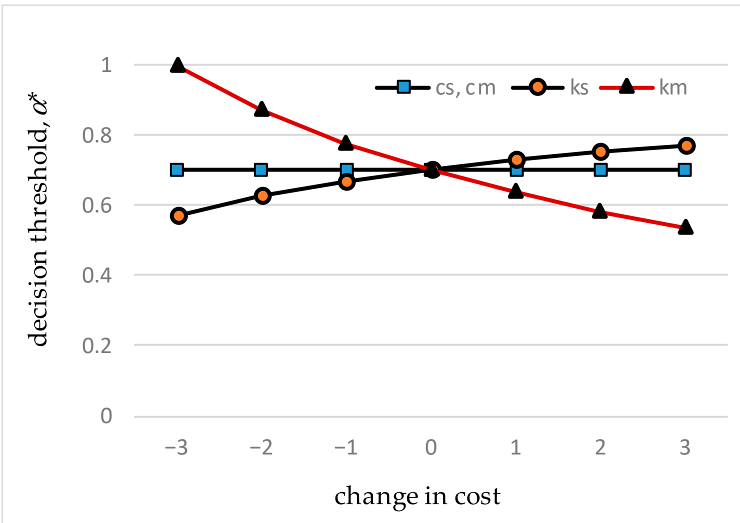


Figure 5. The effect of production and capacity costs on decision threshold, α^*.

Figure 6 illustrates how changes in the profit-sharing ratio impact the overall supply chain profit under two scenarios: One considering only revenue sharing and the other utilizing the contract scheme proposed in this study. The proposed contract scheme enables consistent optimal profit attainment regardless of the profit-sharing ratio. It is evident that relying solely on the PRS approach often falls short of achieving maximum profit. The performance of PRS is notably weaker when the supplier's bargaining power is low. In other words, the supply contract form proposed in this study is particularly effective when the supplier's bargaining power is limited.

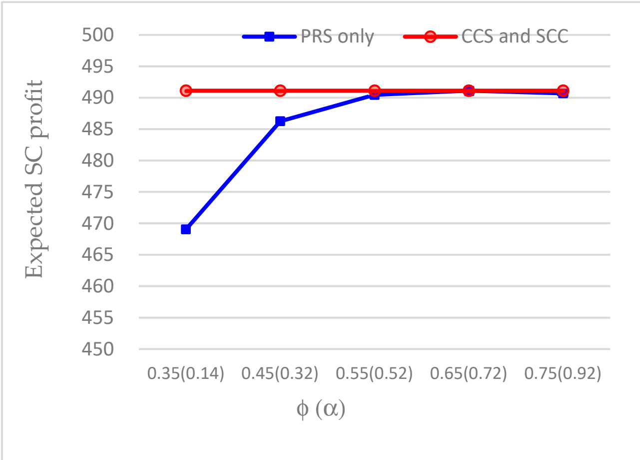


Figure 6. Performance of PRS only and the proposed contract scheme with CCS and SCC contracts.

6. Conclusions

In this paper, we propose a coordinated supply contract scheme where both bargaining power and capacity planning are considered within a supply chain featuring a single supplier and a single manufacturer. Our contract scheme is founded on two supply contracts, capacity cost-sharing (CCS) and surplus capacity compensation (SCC) contracts, both of which incorporate the concept of revenue sharing. The underlying idea behind the CCS and SCC contracts is that the manufacturer shares the cost of capacity investment with the supplier and so encourages the supplier to make more aggressive capacity investments. Our study demonstrates that channel coordination can be achieved through either of these contract policies across all ranges of bargaining powers. Specifically, the CCS contract can coordinate the supply chain under a lower supplier's bargaining power while SCC contracts can coordinate the supply chain under a higher supplier's bargaining power. We also investigate the relationship between the contract parameters, including the supplier's share of the supply chain revenue, capacity cost fraction taken by the supplier, and compensation fraction for surplus capacity paid by the manufacturer to the supplier. Our findings reveal that revenue-sharing and capacity cost-sharing fractions are positively proportional to each other in the coordinated CCS contract. An intriguing result is that the compensation rate for the surplus capacity increases as the capacity cost-sharing rate increases to achieve a coordinated SCC contract, which seems to contradict the common belief that the supplier with a larger share of the SC revenue should receive less compensation for unused capacity. This seemingly contradictory finding can be explained by the fact that since the SCC contract is selected for higher supplier bargaining power, more profit should be granted to the supplier with a higher revenue-sharing ratio and compensation fraction.

The primary contribution of this study lies in its provision of a pragmatic approach, empowering practitioners with tangible and actionable insights that facilitate the seamless implementation of coordinated contracts. This is especially valuable in market environments where the bargaining power among supply chain members is predetermined. Notably, the straightforward calculation of the critical threshold α^* and the simplified procedure for determining optimal contract parameters within CCS and SCC contracts (expressions (23) and (24)) further enhance the practicality of the proposed contract scheme. This streamlined approach empowers practitioners to readily adopt and operationalize the proposed contract scheme with minimal effort, translating theoretical insights into practical solutions for real-world supply chain management. The results presented in this article contribute to a deeper understanding of the impact of bargaining power on contract design for achieving coordination.

Our study has certain limitations that warrant further investigation.

- We assumed that the excess capacity is permanently lost, but in many cases, it may be sold in a spot market. Further research could investigate the impact of the spot market on contract designs.
- We assumed that all parameters except demand are deterministic, but in the fast-changing SC environment, it may be difficult to predict exact parameter values. For example, production costs might vary depending on the SC environment during the sales season. The learning curve may be an important issue in production cost. Our work could be extended to incorporate stochastic and variable factors.
- This study could be extended to the supply chain with multiple suppliers with various risk preferences. Multiple contract types may be designed to hedge supply chain risks using financial instruments such as forwards, options, and swaps.
- This article has studied numerical experiments to validate the model with a simplified scenario. While the results provide general implications of bargaining power on supply chain performance, further studies with some complex real-world cases are called for to enrich our findings.

Author Contributions: Conceptualization, S.-M.J. and P.-H.K.; methodology, S.-M.J. and P.-H.K.; software, Y.-J.K.; validation, S.-M.J., S.-G.K. and P.-H.K.; formal analysis, S.-M.J.; resources, P.-H.K.; data curation, S.-M.J. and Y.-J.K.; writing—original draft preparation, S.-M.J. and P.-H.K.; writing—review and editing, S.-M.J., Y.-J.K., S.-G.K. and P.-H.K.; supervision, P.-H.K.; funding acquisition, P.-H.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (no. 2019R1F1A1057585).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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