Print ISSN: 1738-3110 / Online ISSN 2093-7717
JDS website: http://www.jds.or.kr/
http://dx.doi.org/10.15722/jds.20.06.202206.125

Investigation of Impact of Revenue Sharing Contract on Performance of Two-Stage Supply Chain System

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Received: March 29, 2022. Revised: April 24, 2022. Accepted: June 05, 2022.

Abstract

Purpose: The revenue sharing contract has been used in various industries and it is expected to coordinate the individual companies' operations in a way to improve the whole supply chain performance. This study evaluates the performance of the revenue sharing contract to find out whether this contract achieves its original goal, the supply chain coordination. **Research design, data, and methodology**: The profit optimization models are developed to represent two stage supply chain system with a supplier and a buyer. By using the numerical examples of the proposed mathematical models, this study examines whether this supply chain contract coordinates the supply chain system. **Results**: The numerical examples show that the revenue sharing contract does not make the same supply chain profit as the centralized system does. With the proper combination of the wholesale price discount rate and revenue share ratio, both manufacturer and retailer can obtain increased profits from the revenue sharing contract. **Conclusions**: The outcomes of the numerical analysis imply that the revenue sharing certainly improves the supply chain performance but it does not fully coordinate the supply chain system. By controlling the wholesale price and revenue share ratio, every supply chain member can be beneficiaries of this supply chain contract.

Keywords : Revenue Sharing Contract, Supply Chain Management, Supply Chain Coordination, Optimization Model.

JEL Classification Code: M11, M19, M21, M29

1. Introduction

The supply chain system has the inherent limitation that prevents it from controlling its operations effectively and achieving the maximum overall performance, because its members tend to manage their operations for selfish ends. This phenomenon is called as 'double marginalization', and it is quite common in most industries. The double marginalization is perceived as the outcome from the failure of the supply chain coordination, and various supply chain contracts have been introduced to the industries to mitigate this problem (Kumar & Haider, 2011; Zhao & Zhu, 2017).

The revenue sharing contract has been widely used in various industries including DVD rental, fresh agricultural products, and semi-conductor, and it is well known to coordinate the individual companies' operations in the supply chain system and improve the whole supply chain performance (Khouja, Rajagopalan, & Sharer, 2010; Tang & Kouvelis, 2014; Yan, Wu, Ye, & Zhang, 2017). In two-stage supply chain system, as an example, the revenue sharing contract makes the buyer gives the predetermined portion of his revenue to the supplier. By forcing individual supply chain members to share the benefit from the supply chain operations, this contract is designed to prevent them from making selfish decisions on their operations and bring the active cooperation among them to achieve the improved

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outcomes in the perspective of the entire supply chain system.

This study investigates the impact of revenue sharing contract on the supply chain performance. In particular, this study focuses on the content of the revenue sharing contract and analyzes how this supply chain contract performs with different contents. Meanwhile, the numerous past studies already examine whether the revenue sharing contract coordinates the supply chain system, their outcomes are still inconclusive. By analyzing the performance of the revenue sharing contract with distinct contents, however, this study not only tests the supply chain coordination but also identifies its condition to be a feasible supply chain contract.

The mathematical models are developed to represent two stage supply chain system with the revenue sharing contract and its performance is analyzed in numerical examples. In the numerical analysis, this study compares the revenue sharing contract with the centralized system and examines whether the revenue sharing contract attains its original goal. Furthermore, by observing how the revenue sharing contract performs with different contents, this study pursues to find the specific conditions that make this supply chain contract outperforms the traditional supply chain system.

According to the numerical examples, the revenue sharing contract fails to makes the same amount of the supply chain profit as the centralized system does, and it still results in greater profit than the traditional system. When the revenue sharing contract maximizes the whole supply chain profit, the supplier has less profit than under the traditional system. The numerical analysis indicates that the revenue sharing contract makes greater profits for both supplier and buyer than the traditional system under the certain combination of revenue share ratio and wholesale price discount rate.

The outcomes from the numerical examples provide the valuable managerial implications. First, the revenue sharing contract may not bring the perfect supply chain coordination, but it still significantly improves the supply chain performance. Second, the revenue sharing contract should be carefully designed to be feasible, since it is acceptable by both buyer and supplier only under the particular combination of revenue share ratio and wholesale price discount rate.

2. Research Background

This study examines how the revenue sharing contract affects the supply chain performance. In particular, the key research objective of this study is to find out whether the revenue sharing contract attains the supply chain coordination.

2.1. Supply Chain Coordination

The concept of the supply chain coordination is initially introduced as the remedy for the double marginalization in the supply chain management. The double marginalization is the common phenomenon found in most industries and it represents the operational inefficiency caused by the selfish act of intendent supply chain member who pursues only his profit. The supply chain coordination is defined to be the supply chain system where all of its members manage their operations in a way to maximize the whole supply chain profit (Chopra & Meindl, 2010; Xiao & Jin, 2011). As an effective mechanism of the supply chain management, the supply chain coordination is expected to mitigate the double marginalization by aligning every member's operation to maximize the entire supply chain profit.

The revenue sharing contract has been applied to diverse industries and it has attracted heavy attentions from the academic researchers (Altug & van Ryzin, 2014; Bart, Chernonog, & Avinadav, 2020; Chen & Cheng, 2012; Hsiao, Chen, & Xiong, 2019; Wang & Shin, 2015). While numerous researchers examine the revenue sharing contract to confirm that it really coordinates the supply chain system, they choose quite different ways to perceive the supply chain coordination. Most of the past studies evaluates the resultant outcome from the revenue sharing contract to test the supply chain coordination (Hou, Wei, Li, Huang, & Ashley, 2017; Vafa Arani, Rabbani, & Rafiei, 2016; van der Veen & Venugopal, 2005). Xiao and Jin (2011), however, focus on the particular types of decision making and operations and they describe that the supply chain members integrate their operations to attain the mutual goal of the whole supply chain system under the supply chain coordination. In Altug and van Ryzin's study (2014), the supply chain coordination is represented as a form of contracts that bring the maximum supply chain profit and also improve every supply chain member's profit.

When the past studies test whether the revenue sharing contract coordinates the supply chain system, they use even diverse standards to make their judgements. A large group of past studies conclude that the revenue sharing contract coordinates the supply chain system when this contract results in the same amount of supply chain profit as the centralized or integrated system, where a single entity determines every operation of the entire supply chain system (Hu, Xu, & Meng, 2017; Li, Zhang, Zhao, & Liu, 2019; Yao, Xu, & Luan, 2016; Zhao, Xu, Chen, Liang, Yu, & Wang, 2020).

Another group of past studies focus on the individual supplier chain member's achievement as well as the entire supply chain performance (Alaei & Setak, 2015; Chakraborty, Mateen, Chatterjee, & Haldar, 2018; van der Rhee, Schmidt, A. van der Veen, & Venugopal, 2014; Yang,

Zhang, & Ji, 2017). They judge that the supply chain coordination is attained by making every supply chain member increase his profit with the revenue sharing contract.

In this study, the primary criterion for the supply chain coordination is whether the revenue sharing contract results in the same amount of the supply chain profit as the centralized system. Subsequently, this study conducts further analysis on both supplier's and buyer's profits with the revenue sharing contract and identifies that the supply chain coordination is fully realized under this contract.

2.2. Revenue Sharing Contract

Once the revenue sharing contract becomes known as the effective tool for coordinating the supply chain operations in diverse industries, this supply chain contract has attracted heavy attentions from the academic researchers (Zhao & Zhu, 2017). Since the main goal of the revenue sharing contract is to realize the supply chain coordination, most of past studies focus on the question whether the revenue sharing contract really coordinates the supply chain system. While numerous past studies conduct thorough analyses on the revenue sharing contract, but their conclusions are inconsistent.

A large group of past studies support that the revenue sharing contract successfully brings the supply chain coordination (Hsiao, Chen, & Xiong, 2019; Hu, Feng, & Chen, 2018; Hua, Zhang, & Xu, 2011; van der Veen & Venugopal, 2005; Wang & Shin, 2015; Wang, Fang, Gou, & Liang, 2017; Xue, Tang, & Zhang, 2016; Zhao & Zhu, 2017; Zhu, Kong, Xie, Li, & Cao, 2019). In other studies, however, this supply chain contract fails to coordinate the supply chain system (Krishnan & Winter, 2011; Xu, Chen, & Bai, 2016; Zhao, Xu, Chen, Liang, Yu, & Wang, 2020). In particular, a certain group of researchers show that the revenue sharing contract requires the additional features that enable this contract to realize the supply chain coordination (Bai, Xu, & Zhang, 2018; Cai, Hu, Tadikamalla, & Shang, 2017; Chakraborty, Mateen, Chatterjee, & Haldar, 2018; El Ouardighi, 2014; Peng, Pang, & Cong, 2018; Wang, Zhou, & Wang, 2010; Yan, Wu, Ye, & Zhang, 2017; Yao, Xu, & Luan, 2016; Zhang, Liu, Zhang, & Bai, 2015).

One possible reason of the inconsistent conclusion made by the past studies is that they employ quite different contents of the revenue sharing contract in their analyses. A group of past studies describe that the portion of revenue shared by each supply chain member is decided by either retailer (Cai, Hu, Tadikamalla, & Shang, 2017; Chen, Hu, & Wei, 2017; Zheng, Shu, Wang, Chen, Lai, & Gan, 2015; Zhu, Kong, Xie, Li, & Cao, 2019) or manufacturer (Hu, Xu, & Meng, 2017; Mafakheri & Nasiri, 2013; Palsule-Desai, 2013; Rasay & Mehrjerdi, 2017; Wang & Shin, 2015; Xue, Tang, & Zhang, 2016; Yang, Cao, Lu, & Zhang, 2017; Zhou, Zhao, Xue, & Gargeya, 2012). In other studies, the retailer or manufacturer agree on the amount of shared revenue (Bai, Xu, & Zhang, 2018; Chakraborty, Chauhan, & Vidyarthi, 2015; He & Zhao, 2016; Peng, Pang, & Cong, 2018).

A large number of studies assume that the revenue share ratio is simply given as an exogenous variable (Giovanni, 2014; Hou, Wei, Li, Huang, & Ashley, 2017; Liu, 2019; Qu, Zhou, Zhang, Wahab, Zhang, & Ye, 2019; Tang & Kouvelis, 2014; van der Rhee, Schmidt, A. van der Veen, & Venugopal, 2014; Wang & Liu, 2019; Wang, Fang, Gou, & Liang, 2017; Wang, Zhou, & Wang, 2010; Xu, Chen, & Bai, 2016; Yang, Miao, & Zhao, 2019). Meanwhile, others studies use the optimization algorithm and determine the revenue sharing ratio in a way to maximize the supply chain profit or to attain the supply chain coordination (Alaei & Setak, 2015; Cachon & Lariviere, 2005; Moon, Feng, & Ryu, 2015; Raza, 2018; Song & Gao, 2018).

This study examines whether the revenue sharing contract coordinates the supply chain system, as a huge number of past studies have done. While most researchers simply focus on the test of the supply chain coordination in their past studies on the revenue sharing contract, this study pursues to identify its condition of supply chain coordination. In particular, this study pays attention to the content of this supply chain contract, which results in the supply chain coordination or the best supply chain performance. By observing how the revenue sharing contracts perform with different combinations of the revenue share ratio and wholesale price discount rate, this study intends to figure out the proper content of this supply chain contract that leads to the improved outcomes for individual supply chain members as well as the entire supply chain system.

3. Supply Chain Models

On the purpose of finding out how the revenue sharing contract performs, this study analyzes the supply chain system by using mathematical modeling. The proposed mathematical model is developed to represent two stage supply chain system where one supplier trades with a buyer. The supplier manufactures a single product item and sells it to the buyer at the wholesale price. The buyer purchases the product from the supplier and sells it at the retail price to the retail market. The demand at the retail market is assumed to be solely determined by the retail price as described in Equation (1).

$$D = k - d \cdot R \tag{1}$$

This study tests whether the revenue sharing contract realizes the supply chain coordination by comparing this

contract with the centralized system. Two distinct mathematical models are formulated to indicate the supply chain system with the revenue sharing contract and centralized system. Table 1 shows the notations used in the proposed models.

Table 1: Notations in Mathematical Models

π_S	Supplier's profit	π_B	Buyer's profit
π_{SC}	Supply chain profit	D	Market demand
k	Potential demand size	d	Price sensitivity parameter
P	Wholesale price	R	Retail price
X	Production rate	Q	Order quantity
o_S	Setup cost	o_B	Ordering cost
h_S	Supplier's unit inventory holding cost	h_B	Buyer's unit inventory holding cost
v	Unit production cost	τ	Unit transportation cost
μ	Wholesale price discount rate	λ	Revenue share ratio

In the proposed mathematical models, the supply chain profit as well as supplier's and buyer's profits are evaluated as the key performance measurements. As the endogenous variables, the wholesale price (P), production rate (X), retail price (R), and order quantity (Q) are the decision variables. The other notations in Table 1 are exogenous variables. The potential demand size (k) and price sensitivity parameter (d) indicate the demand size (D) resulted by the retail price (R). The basic context of the supply chain system is described by using the parameters including the setup cost (o_S), ordering cost (o_B), unit inventory holding costs (h_S and h_B), unit production cost (v), and unit transportation cost (τ). The wholesale price discount rate (μ) and revenue share ratio (λ) represent the content of the revenue sharing contract. The demand size, production rate, and order quantity are measured in the number of products. All the profits and cost items in Table 1 are represented as the monetary value. Meanwhile, the wholesale price discount rate and revenue share ratio denote the proportions.

3.1. System with Revenue Sharing Contract

Under the revenue sharing contract, the buyer shares the predetermined portion of his revenue with the supplier, and in return, he purchases the product at the discounted price (Gui-xia, Yi-pin, Jian-guo, & Yue-hong, 2013; Hou, Wei, Li, Huang, & Ashley, 2017; Qin, 2008). Equation (2) shows the supplier's profit under the revenue sharing contract, and it indicates the revenue and costs including the setup cost, inventory holding cost, production cost, and transportation cost. In particular, the supplier's revenue contains the revenue from the sale to the buyer with the discounted wholesale price and the shared portion of buyer's revenue according to the revenue sharing contract. The joint economic lot size is applied to the inventory control system in the proposed model (Banerjee, 1986).

$$\pi_S = \mu \cdot P \cdot D + (1-\lambda) \cdot R \cdot D - \frac{o_S \cdot D}{Q} - \frac{h_S \cdot Q \cdot D}{2 \cdot X} - v \cdot X - \tau \cdot D \quad (2)$$

$$\pi_B = \lambda \cdot R \cdot D - \frac{o_B \cdot D}{Q} - \frac{h_B \cdot Q}{2} - \mu \cdot P \cdot D \quad (3)$$

The buyer's profit in Equation (3) is composed of the revenue, ordering cost, inventory holding cost, and purchasing cost. Due to the revenue sharing contract, the buyer obtains only the specific portion of his entire revenue from the sales to the retail market. The buyer retains the portion of his revenue based on the revenue share ratio. Instead, the wholesale price that the buyer pays to the supplier is lowered at the discount rate.

The supply chain model represents the supply chain system where the supplier and buyer seek to maximize their own profits. The supplier determines the wholesale price (P) and production rate (X) in a way to maximize his profit. The retail price (R) and order quantity (Q) are the decisions made by the buyer.

This study assumes that the revenue share ratio (λ) and the wholesale price discount rate (μ) are given according to the agreement between the supplier and buyer. When both revenue share ratio and

wholesale price discount rate become 100% ($\lambda = 1.0$ and $\mu = 1.0$), the mathematical models with Equations (2) and (3) indicate the traditional supply chain system without the revenue sharing contract.

3.2. Centralized System

The key objective of this research is to find out whether the revenue sharing contract coordinates the supply chain system. Based on the assumption that the centralized supply chain system corresponds to the supply chain coordination, this study compares the revenue sharing contract with the centralized system.

Under the centralized system, every operational decision is made by a single entity to maximize the whole supply chain profit. Equation (4) shows the profit of the centralized supply chain system, and it is composed of the revenue from the sales to the retail market, setup cost, ordering cost, inventory holding cost, production cost, and transportation cost.

$$\pi_{SC} = R \cdot D - \frac{o_B \cdot D}{Q} - \frac{h_B \cdot Q}{2} - \frac{o_S \cdot D}{Q} - \frac{h_S \cdot Q \cdot D}{2 \cdot X} - v \cdot X - \tau \cdot D \quad (4)$$

4. Numerical Analyses

In order to evaluate the performance of the revenue sharing contract, this study use the numerical examples of the proposed supply chain models. The parameters used in the numerical analysis are arbitrarily determined and their values in the base case are shown in Table 2.

Table 2: Parameters of Base Case

$k = 1{,}800$	$d = 5$	$l = 2{,}000$	$m = 5$	$v = 15$
$o_S = 200$	$h_S = 2$	$o_B = 150$	$h_B = 4$	$\tau = 5$

Five parameters including the potential demand size, setup cost, supplier's unit inventory holding cost, ordering cost, and buyer's inventory holding cost are adjusted to be different values, and each parameter are set to be five different levels. After all, the numerical analysis contains 3,125 cases in total (5^5 = 3,125). Furthermore, in the numerical examples of the revenue sharing contract, the revenue share ratio and wholesale price discount rate are varied in ten different levels to examine how the content of this contract affects the supply chain performance.

4.1. Comparison between Revenue Sharing Contract and Other Systems

In order to examine whether the revenue sharing contract realizes the supply chain coordinate, this study compares this contract with the centralized system in the numerical analysis. The traditional system without the revenue sharing contract is also considered in the numerical examples to find out that this supply chain contract improves the supply chain performance. Table 3 shows the averaged performances of three systems considered in the numerical examples. In particular, the outcome of the revenue sharing contract describes the case that this contract generates the greatest supply chain profit among all the combinations of different revenue share ratios and wholesale price discount rates. In Table 3, the demand, order quantity, and production rate represent the number of products, and all the prices, profits, revenues, and costs are valued in dollars ($).

Table 3 shows that the revenue sharing contract significantly increases the supply chain profit compared with the traditional system. The main reason of the increased supply chain profit in the revenue sharing contract is the enlarged demand size. The huge discount of the wholesale price under the revenue sharing contract causes the reduced retail price and it increases the demand at the retail market. Meanwhile, the supply chain profit of the revenue sharing contract is less than the one of the centralized system, even though their difference is quite small. The revenue sharing contract does not decrease the retail price to the sufficient level and fails to make the same amount of demand as the centralized system.

Table 3: Performances of Supply Chain Systems

	Traditional System	Revenue Sharing Contract	Centralized System
Demand	372.19	828.24	847.22
Retail Price	285.56	194.29	190.56
Wholesale Price	210.23	25.70	-
Order Quantity	168.29	251.12	316.51
Production Rate	372.19	828.53	847.22
Supplier			
Revenue	78,245.01	34,175.46	-
Setup Cost	444.69	663.59	537.69
Inventory Cost	168.28	251.12	312.20
Production Cost	5,582.89	12,427.95	12,708.35
Transportation Cost	1,860.96	4,142.65	4,236.12
Total Cost	8,056.83	17,485.30	-
Profit	70,188.18	16,690.16	-
Buyer			
Revenue	106,323.90	148,136.93	-
Purchasing Cost	78,245.01	21,293.98	-
Ordering Cost	333.15	497.14	403.22
Inventory Cost	333.15	497.14	628.72
Total Cost	78,911.31	22,288.26	-
Profit	27,412.59	125,848.67	-
Supply Chain System			
Revenue	184,568.91	182,312.38	161,482.91
Cost	86,968.14	39,773.56	18,826.30
Profit	97,600.77	142,538.82	142,656.62

With the assumption that the centralized system corresponds to the coordinated supply chain system, the revenue sharing contract fails to coordinate the supply chain system according to the outcomes of the numerical analysis. Meanwhile, the supply chain profit resulted by the revenue sharing contract is quite close to the profit of the centralized system, and the revenue sharing contract significantly increases the supply chain profit compared with the traditional system.

When the performances of the considered systems are evaluated in terms of each supply chain member's profit, the revenue sharing contract does not always outperforms the traditional system. The revenue sharing contract significantly increases the buyer's profit due to the enlarged retail market demand. On the other hand, the supplier obtains much lower profit with the revenue sharing contract than he does under the traditional system. In spite of the increased throughput, the supplier has to lose the profit due to the huge discount of the wholesale price.

4.2. Impact of Revenue Share Ratio and Wholesale Price Discount Rate

By considering different combinations of revenue share ratio and wholesale price discount rate, this study examines how the content of the revenue sharing contract affects its performance. Table 4 shows the supply chain profit corresponding to the different combinations of revenue share ratio and wholesale price discount rate. The specific values of μ and λ in Table 4 indicate the metric applied to the numerical examples, and they are arbitrarily determined in a way to prevent any negative profit.

According to the Table 4, the revenue sharing contract results in the greatest supply chain profit when the revenue share ratio is 0.92 ($\lambda = 0.92$) and the wholesale price discount rate is 0.10 ($\mu = 0.10$).

Table 4: Supply Chain Profit under Revenue Sharing Contract

	$\mu = 0.10$	$\mu = 0.20$	$\mu = 0.30$	$\mu = 0.40$	$\mu = 0.50$	$\mu = 0.60$	$\mu = 0.70$	$\mu = 0.80$	$\mu = 0.90$	$\mu = 1.00$
$\lambda = 0.64$	142,344	139,725	134,435	126,564	116,156	103,232	87,800	69,845	49,312	25,923
$\lambda = 0.68$	142,405	140,147	135,522	128,613	119,463	108,091	94,506	78,703	60,659	40,288
$\lambda = 0.72$	142,451	140,488	136,412	130,304	122,203	112,125	100,080	86,067	70,075	52,069
$\lambda = 0.76$	142,485	140,764	137,147	131,712	124,493	115,506	104,759	92,252	77,981	61,928
$\lambda = 0.80$	142,510	140,987	137,757	132,892	126,423	118,364	108,720	97,494	84,683	70,277
$\lambda = 0.84$	142,527	141,166	138,263	133,886	128,060	120,796	112,100	101,972	90,411	77,412
$\lambda = 0.88$	142,537	141,306	138,683	134,726	129,455	122,879	115,002	105,823	95,342	83,557
$\lambda = 0.92$	**142,539****	141,411	139,028	135,436	130,649	124,672	117,508	109,155	99,615	88,883
$\lambda = 0.96$	142,529	141,480	139,306	136,035	131,673	126,222	119,683	112,055	103,337	93,529
$\lambda = 1.00$	142,489	141,505	139,520	136,536	132,551	127,565	121,578	114,588	106,597	**97,601***

*Traditional System **Maximum

Table 5: Market Demand under Revenue Sharing Contract

	$\mu = 0.10$	$\mu = 0.20$	$\mu = 0.30$	$\mu = 0.40$	$\mu = 0.50$	$\mu = 0.60$	$\mu = 0.70$	$\mu = 0.80$	$\mu = 0.90$	$\mu = 1.00$
$\lambda = 0.64$	811	727	645	564	483	403	323	243	163	82
$\lambda = 0.68$	815	736	659	582	507	431	356	281	206	131
$\lambda = 0.72$	819	744	671	599	527	456	385	315	244	173
$\lambda = 0.76$	822	751	682	614	546	479	412	345	278	211
$\lambda = 0.80$	825	757	691	627	562	499	435	372	308	245
$\lambda = 0.84$	827	762	700	638	577	517	456	396	336	275
$\lambda = 0.88$	828	766	707	648	590	533	475	418	360	303
$\lambda = 0.92$	**829****	770	713	658	602	547	493	438	383	328
$\lambda = 0.96$	827	772	719	666	613	561	508	456	404	351
$\lambda = 1.00$	823	773	723	673	623	573	523	472	422	**372***

*Traditional System **Maximum

Table 5 shows the market demand with different values of revenue share ratio and wholesale price discount rate. The specific combination of revenue share ratio and wholesale price discount rate results in the greatest supply chain profit, because it makes the biggest market demand.

According to Table 6, the particular combination of revenue share ratio and wholesale price discount rate leads to the lowest retail price, which ultimately results in the largest market demand. This result implies that the revenue sharing contract achieves the biggest supply chain profit when the wholesale price is reduced to the maximum but the revenue is shared at the proper level.

The supply chain profit appeared in Table 4 indicates the overall performance of the revenue sharing contract. When the outcomes are evaluated in terms of individual supply chain member's performances, the supplier's and buyer's profits under the different combinations of revenue share ratio and wholesale price discount rate are described in Tables 7 and 8..

Table 6: Retail Price under Revenue Sharing Contract

	$\mu = 0.10$	$\mu = 0.20$	$\mu = 0.30$	$\mu = 0.40$	$\mu = 0.50$	$\mu = 0.60$	$\mu = 0.70$	$\mu = 0.80$	$\mu = 0.90$	$\mu = 1.00$
$\lambda = 0.64$	197.84	214.61	231.04	247.27	263.38	279.42	295.40	311.38	327.39	343.64
$\lambda = 0.68$	196.94	212.77	228.25	243.53	258.68	273.75	288.78	303.78	318.79	333.87
$\lambda = 0.72$	196.18	211.18	225.80	240.22	254.52	268.74	282.91	297.05	311.19	325.35
$\lambda = 0.76$	195.54	209.79	223.65	237.30	250.82	264.27	277.68	291.05	304.41	317.79
$\lambda = 0.80$	195.01	208.59	221.75	234.69	247.52	260.28	272.99	285.67	298.34	311.02
$\lambda = 0.84$	194.61	207.57	220.08	232.38	244.57	256.69	268.77	280.83	292.87	304.92
$\lambda = 0.88$	194.35	206.72	218.61	230.31	241.91	253.45	264.96	276.44	287.92	299.39
$\lambda = 0.92$	**194.29****	206.05	217.35	228.48	239.52	250.52	261.50	272.46	283.41	294.36
$\lambda = 0.96$	194.55	205.61	216.29	226.86	237.38	247.88	258.36	268.83	279.30	289.77
$\lambda = 1.00$	195.46	205.44	215.44	225.45	235.46	245.48	255.49	265.51	275.53	**285.56***

*Traditional System **Minimum

Table 7: Supplier's Profit under Revenue Sharing Contract

	$\mu = 0.10$	$\mu = 0.20$	$\mu = 0.30$	$\mu = 0.40$	$\mu = 0.50$	$\mu = 0.60$	$\mu = 0.70$	$\mu = 0.80$	$\mu = 0.90$	$\mu = 1.00$
$\lambda = 0.64$	58,661	72,518	81,629	86,285	**86,639****	82,773	74,731	62,523	46,103	25,194
$\lambda = 0.68$	52,473	66,892	76,922	82,880	84,920	83,131	77,556	68,217	55,104	38,136
$\lambda = 0.72$	46,302	61,199	72,001	79,052	82,517	82,481	78,994	72,078	61,737	47,945
$\lambda = 0.76$	40,165	55,469	66,919	74,897	79,572	81,032	79,325	74,477	66,497	55,377
$\lambda = 0.80$	34,087	49,732	61,724	70,486	76,196	78,940	78,765	75,697	69,748	60,917
$\lambda = 0.84$	28,101	44,020	56,456	65,880	72,475	76,327	77,479	75,955	71,768	64,921
$\lambda = 0.88$	22,266	38,371	51,151	61,127	68,481	73,291	75,597	75,420	72,773	67,657
$\lambda = 0.92$	16,690	32,837	45,851	56,273	64,270	69,909	73,223	74,228	72,932	69,340
$\lambda = 0.96$	11,598	27,501	40,600	51,358	59,892	66,247	70,442	72,486	72,384	70,138
$\lambda = 1.00$	7,577	22,499	35,461	46,427	55,394	62,360	67,323	70,284	71,239	**70,188***

*Traditional System **Maximum

Table 8: Buyer's Profit under Revenue Sharing Contract

	$\mu = 0.10$	$\mu = 0.20$	$\mu = 0.30$	$\mu = 0.40$	$\mu = 0.50$	$\mu = 0.60$	$\mu = 0.70$	$\mu = 0.80$	$\mu = 0.90$	$\mu = 1.00$
$\lambda = 0.64$	83,684	67,207	52,806	40,278	29,517	20,459	13,069	7,323	3,209	730
$\lambda = 0.68$	89,932	73,256	58,599	45,734	34,542	24,961	16,950	10,486	5,555	2,153
$\lambda = 0.72$	96,149	79,290	64,411	51,252	39,686	29,644	21,086	13,989	8,338	4,125
$\lambda = 0.76$	102,320	85,295	70,228	56,816	44,921	34,474	25,434	17,775	11,484	6,551
$\lambda = 0.80$	108,423	91,255	76,032	62,406	50,228	39,424	29,955	21,797	14,935	9,360
$\lambda = 0.84$	114,426	97,146	81,807	68,006	55,585	44,469	34,621	26,017	18,643	12,492
$\lambda = 0.88$	120,270	102,936	87,532	73,598	60,975	49,589	39,405	30,403	22,570	15,899
$\lambda = 0.92$	125,849	108,574	93,177	79,163	66,380	54,763	44,285	34,928	26,682	19,544
$\lambda = 0.96$	130,930	113,979	98,706	84,677	71,780	59,975	49,241	39,569	30,953	23,391
$\lambda = 1.00$	**134,911****	119,006	104,060	90,109	77,157	65,205	54,254	44,305	35,358	**27,413***

*Traditional System **Maximum

Table 7 indicates the supplier's profits under different combinations of revenue share ratio and wholesale price discount rate. The supplier profit becomes the maximum value when the revenue share ratio is 0.64 ($\lambda = 0.64$) and wholesale price discount rate is 0.50 ($\mu = 0.50$). The case that both revenue share ratio and wholesale price discount rate are 1.00 represent the traditional system where the revenue sharing contract is not implemented at all ($\lambda = 1.00$ and $\mu = 1.00$). The shaded area in Table 7 represents the case that the supplier's profit under the revenue sharing contract is greater than the one under the traditional system.

In Table 8, the buyer's profits are illustrated with distinct contents of the revenue sharing contract. When the revenue share ratio is 1.00 ($\lambda = 1.00$) and the wholesale price

discount rate is 0.10 ($\mu = 0.10$), the maximum of the buyer's profit is achieved. Within the shaded area of Table 8, the buyer obtains greater profit under the revenue sharing contract than the traditional system.

After all, the shaded area in Table 4 is the common zone from Table 7 and Table 8. This specified zone indicates the specific combinations of revenue share ratio and wholesale price discount rate, which allow both supplier and buyer to increase their profits with the revenue sharing contract compared with the traditional system.

5. Managerial Implications

The numerical analysis shows that the revenue sharing contract can significantly increase the supply chain profit compared with the traditional supply chain system. Meanwhile, the revenue sharing contract achieves less amount of the supply chain profit than the centralized system, even though their profit difference is quite small.

This result gives the managerial implication that the revenue sharing contract can be an effective program that improves the supply chain performance. In particular, the significantly enlarged market demand caused by the wholesale price discount increases the overall throughput in the entire supply chain system and results in the increased overall profit.

Regarding the proposition that the revenue sharing contract realizes the supply chain coordination, however, this study has the different outcome from most past studies that supports that proposition. Based on the assumption that the coordinated supply chain system needs to result in the same level of the overall performance as the centralized system (Gutierrez & He, 2011; Panda, 2014; Yao, Leung, & Lai, 2008), the result of the numerical analysis indicates that the supply chain system cannot attain the coordination by implementing only the revenue sharing contract. This outcome is against the conclusion made by the numerous past studies that support that the revenue sharing contract can achieve the supply chain coordination (Hsiao, Chen, & Xiong, 2019; Hu, Feng, & Chen, 2018; Wang, Fang, Gou, & Liang, 2017; Zhao & Zhu, 2017; Zhu, Kong, Xie, Li, & Cao, 2019). Instead, this study shares the same result with a group of the researchers who claim that the revenue sharing alone fails to coordinate the supply chain system (Xu, Chen, & Bai, 2016; Zhao, Xu, Chen, Liang, Yu, & Wang, 2020).

By implication, the supply chain system may need to have the special program in addition to the revenue sharing contract to achieve the complete coordination. In particular, the popular supply chain coordination program such as Vendor-Managed Inventory (VMI) and consignment can be used along with the revenue sharing contract to attain the same level of throughput as the centralized system (Chen & Cheng, 2012; Rasay & Mehrjerdi, 2017; Rasay, Mehrjerdi, & Nezhad, 2015; Zhao, Zhou, Cao, & Min, 2020).

When the revenue sharing contract simply aims to maximize the entire supply chain profit, it can result in the successful performance that is quite close to the one of the centralized system. With the maximum supply chain profit, however, only the buyer receives the benefit from the revenue sharing contract and the supplier suffers from the less profit compared with the traditional system. This result implies that the revenue sharing contract requires the proper incentive system that compensates the supplier's loss to become a fair contract for all of its participants.

The analysis on the different combinations of revenue share ratio and wholesale price discount rate reveals that the content of the revenue sharing contract must be properly designed to result in the acceptable outcomes for every member. Since the supplier still loses the profit when the revenue sharing contract simply pursues the maximum supply chain profit, the revenue share ratio and wholesale price discount rate must be carefully determined to make both supplier and buyer get benefits from the revenue sharing contract. By comparing every supply chain member's profit under the revenue sharing contract with the one under the traditional system, this study provides the feasible area representing the particular combinations of revenue share ratio and wholesale price discount rate, which both buyer and supplier agree to accept.

6. Conclusion

As the effective tool to coordinate the supply chain operations, the revenue sharing contract has been applied to various industries. While numerous past studies test whether the revenue sharing contract realizes the supply chain coordination, their outcomes are inconclusive.

This study examines whether the revenue sharing contract coordinates the supply chain system by using mathematical modeling. The proposed optimization model represents the supply chain system where a supplier and a buyer make the operational decisions to maximize their own profits. The numerical analysis is conducted to examine how the revenue sharing contract performs and it is compared with the centralized system to find out whether this supply chain contract attains its goal. By considering different contents of the contract in the numerical examples, this study seeks to identify the conditions that allow the revenue sharing contract to be acceptable by every supply chain member.

The numerical examples show that the revenue sharing contract significantly increases the supply chain profit, and it does not attain the same performance as the centralized system. When the revenue sharing contract pursues to

maximize the whole supply chain profit, it makes the profit that is quite close to the one of the centralized system, but the supplier gets even less amount of profit than he does without this contract.

According to the outcomes of the numerical analysis, the revenue sharing contract improves the supply chain performance and it becomes acceptable by all supply chain members only when this contract contains the particular combination of revenue share ratio and wholesale price discount rate.

The outcomes of the numerical analysis imply that the revenue sharing contract improves the whole supply chain performance even though it fails to achieve the perfect supply chain coordination. In order to satisfy all the supply chain partners and let them willingly participate in the revenue sharing contract, its content regarding how much revenue to be shared and how much wholesale price to be discounted must be carefully determined.

This study has some limitations that provide the future studies with valuable research guidelines. First, the results from the numerical analysis may not corresponds to the realistic situations of industries, since the parameters used in the numerical examples are arbitrarily determined values. Future studies can obtain practical findings about the revenue sharing contract by analyzing the data collected from real cases (Gui-xia, Yi-pin, Jian-guo, & Yue-hong, 2013; Kumar & Haider, 2011). Based on the empirical data sets of required parameters, in particular, the future researchers are expected to specify the right contents of the revenue sharing contract, which is suitable for the particular context of the supply chain system.

Second, this study focuses on only the performance of the revenue sharing contract. Meanwhile, many researchers address the diverse issues including reverse logistics (Heydari & Ghasemi, 2018; Zhao & Zhu, 2017), unstable market condition (Wang, Fang, Gou, & Liang, 2017; Zhao, Xu, Chen, Liang, Yu, & Wang, 2020), behavioral aspect of decision-making process (Sheu, 2011; Zhao, Si, Zhu, Xie, & Shen, 2019), and combination with the other coordination programs (Yang, Qi, & Li, 2015; Zhao, Zhou, Cao, & Min, 2020) in their studies on the revenue sharing contract. In the future, additional empirical and case studies would appear to reveal the multilateral nature of the revenue sharing contract under the particular regional supply chain system (Gui-xia, Yi-pin, Jian-guo, & Yue-hong, 2013) or compare the domestic and international supply chain systems.

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