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Impact of Revenue Sharing Contract on the Performance of Vendor Managed Inventory

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Abstract

Purpose: Focusing on the role of the special contract to collaborate the supply chain operations, this study investigates how the revenue sharing contract affects the performance of Vendor Managed Inventory (VMI). **Research design, data, and methodology:** The optimization model is formulated to represent two stage supply chain system where the supplier and retailer manage the operations to maximize their own profits. Three supply chain models including the traditional system, VMI, and VMI with revenue sharing contract are compared in the numerical examples. **Results:** According to the numerical analysis, the entire supply chain system has greater profit under VMI than the traditional system, while VMI alone sacrifices the supplier's profit. With the proper sets of revenue share ratio and wholesale price discount rate, VMI with revenue sharing contract results in the increased profit for both supplier and retailer compared with VMI alone as well as the traditional system. **Conclusions:** The numerical examples imply that VMI, when it is combined with the revenue sharing contract, can be the effective collaboration program that satisfies every supply chain member. To make VMI with revenue sharing contract to be fair to all supply chain members, they need to agree on the appropriate contract content.

Key words: Vendor Managed Inventory, Revenue Sharing Contract, Supply Chain Collaboration, Optimization Model.

JEL Classifications: M11, M19, M21, M29

1. Introduction

Vendor-Managed Inventory (VMI) is the well-known supply chain management program that effectively collaborates the operations in the supply chain system and improves the supply chain performance. Due to the successful achievement of the supply chain collaboration, VMI has been applied to diverse industries including consumer goods retail and high-tech electronics (Bookbinder et al., 2010; Tyan & Wee, 2003).

Subsequently, VMI has attracted heavy attentions from the academic filed and many researchers has investigated the various issues about this supply chain collaboration program (Govindan, 2013; Marques et al., 2010). Most researchers support that VMI successfully improves the overall supply chain performance in their studies. Meanwhile, a group of past studies point out the potential weakness that VMI possesses and recognize that the vendor

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suffers the financial loss due to his burden of extra costs for managing the buyer's inventory (Rasay et al., 2015; Zhang Tie & Wang Yue, 2008). By implication, VMI becomes the feasible supply chain management program that all the supply chain members are willing to join, only after it equips with the special feature designed to distribute its benefit to them.

As the special contract designed to distribute profits and losses between supply chain members, the revenue sharing contract is known to coordinate the supply chain operations and encourage the supply chain members to improve the supply chain performance in mutually beneficial ways (Bart et al., 2020). With the expectation that the revenue sharing contract equally distributes the benefit from VMI to the supply chain members, this study examines how the revenue sharing contract affects the performance of VMI. The mathematical model is formulated to represent two stage supply chain system where one supplier trades a single type of products with one retailer. In the proposed supply chain model, each supply chain member makes the operational decision in a way to maximize his own profit. On the purpose of identifying the pure effect of the revenue sharing contract, this study analyzes the numerical examples of the proposed mathematical models and compare three supply chain models including VMI with revenue sharing contract, VMI, and traditional system.

The numerical examples show that VMI makes the profit loss for the supplier even though the supply chain system improves its overall performance due to VMI. The increased market demand caused by the lowered price is identified as the main reason that VMI accomplishes greater supply chain profit than the traditional system. According to the additional analysis on the numerical experiment, with the proper combination of the revenue share ratio and wholesale price discount rate, VMI with revenue sharing contract makes greater profit for both supplier and retailer than VMI alone as well as the traditional system.

The outcomes from the numerical analysis provide the business practitioners with the valuable managerial implications. To be a feasible supply chain collaboration program that is acceptable by every supply chain member, VMI needs the supplement that fairly allocates its benefit to its members. When the collaboration program such as VMI is applied to the supply chain system, the total throughput must be carefully monitored to obtain the desirable outcome. After all, this study recommends the revenue sharing contract as the suitable supplement for VMI and it satisfies all the supply chain members only when they agree on the proper amounts of the revenue share and price discount.

2. Research Background

This study evaluates the performance of VMI with revenue sharing contract as the supply chain collaboration program. In the literature reviews, VMI and revenue sharing contract are addressed as key research issues.

2.1. Vendor Managed Inventory

Vendor Managed Inventory (VMI) is the famous supply chain initiative that is designed to collaborate the operations owned and managed by distinct entities in multiple echelons of the supply chain system. Under VMI, the vendor is responsible for the inventories stored at the buyer's warehouse (Alireza et al., 2018). By authorizing the vendor to determine the time and quantity of replenishment on behalf of the buyer, VMI aims at the supply chain collaboration through unphysical compression of the supply chain structure (Disney & Towill, 2003a; Disney & Towill, 2003b). VMI has been proven to be the effective supply chain collaboration program that improves the supply chain performance not only by the academic studies but also through the real business cases (Sari, 2008; Waller et al., 1999; Yao et al., 2007).

The past studies point out the specific advantages of VMI including decreased cost (Govindan, 2015; Mateen & Chatterjee, 2015; Tat et al., 2015), increased profit (Dong & Xu, 2002; Stalhane et al., 2014), lowered inventory level (Choudhary & Shankar, 2015; Yao & Dresner, 2008), and reduced bullwhip effect (Disney et al., 2004). Various research issues are addressed in the past studies and they include information sharing (Kim, 2004; Yu et al., 2009), inventory control (Bernstein et al., 2006; Paik & Kim, 2000), contract (Fry et al., 2001; Nagarajan & Rajagopalan, 2008), stock allocation (Al-Ameri et al., 2008; Jemai et al., 2013), and game (Almehdawe & Mantin, 2010; Bichescu & Fry, 2009).

While abundant past studies support that VMI would bring the significant benefit to the whole supply chain system, this program is still challengeable in practice. With VMI, the vendor holds the full responsible for the retailer's inventories and he even pays the extra cost of replenishing and keeping inventories, which he does not need to pay without VMI (Yao et al., 2007). The vendor is likely to avoid VMI, when he expects the increased cost and the risk of excessive stocks (Rasay & Mehrjerdi, 2017; Zhao et al., 2019). After all, VMI may become the infeasible program that the certain supply chain member refuses to join with their expectation of financial loss, even though this program ensures the overall performance improvement for the entire supply chain system.

2.2. Revenue Sharing Contract

The potential deficit of VMI leads to the necessity for the special contract that equally distributes the achievement from VMI to every supply chain member (Zhang Tie & Wang Yue, 2008). In particular, the revenue sharing contract has been employed with VMI in the various industries (Xide et al., 2022). The revenue sharing contract is the supply chain contract made between a supplier and a buyer and it is designed to allocate risk to both of them. According to the revenue sharing contract, the supplier provides the buyer with his products at the discounted price and, in return, the buyer commits to share a prearranged portion of his revenue with the supplier (Gui-xia et al., 2013; Hou et al., 2017; Qin, 2008).

Researchers have paid their attentions on VMI with revenue sharing contract and explored several relevant research issues. Cai et al (2017) focus on the potential problem of conventional revenue sharing contract and they expect that the competitive relationship between supply chain members would result in a failure of the optimal supply chain coordination. Under the supply chain system with VMI, their study proposes three contracts that have distinct ways to subsidize the surplus products. According to the numerical analysis of the proposed supply chain models, their new subsidy contracts results in the supply chain coordination and Pareto improvement by allowing the supply chain members to determine the optimal price, revenue sharing ratio, and inventory level.

Zhu et al. (2008) pays attentions to the point that the vendor may decline VMI due to the increased cost, and they examine the performance of the revenue sharing contract under VMI. In three stage supply chain system, they conduct discrete event simulation and compare (S,Q) inventory policy, VMI, and VMI combined with revenue sharing strategy. Their simulation analysis reveals that the revenue sharing strategy enhances the supply chain coordination that is acceptable to every supply chain member. Meanwhile, their proposed revenue sharing strategy assumes that the resultant supply chain profit is allocated to the supply chain members, and therefore, there is no difference in the overall supply chain profit between VMI alone and VMI combined with revenue sharing strategy.

Based on the Stackelberg gam theory, Rasay and Mehrjerdi (2017) develop two stage supply chin model with one vendor and multiple retailers and compare the revenue sharing contract with the wholesale price contract under VMI system. They find out that the original revenue sharing contract decreases the retailer's profit while both the whole system profit and the vendor's profit increase. Their study proposes the modified revenue sharing contract that ensures win-win result for both supplier and retailer. Regarding VMI with revenue sharing contract, the past studies address other issues including the algorithm development for effective revenue sharing contract (Alireza et al., 2018; Rasay et al., 2015), coordinated price and service level decisions for deteriorating product (Xiao & Xu, 2013), and the supply chain member's behavioral patterns (Xide et al., 2022; Zhao et al., 2019).

Different from the majority of the past studies that simply evaluate the performance of VMI combined with the revenue sharing contract, this study focuses on the supporting role of the revenue sharing contract under VMI through the direct comparison between VMI with revenue sharing contract and VMI alone. The numerical analysis shows that the revenue sharing contract successfully plays a role of supporting VMI by increasing the supplier's profit as well as the retailer's.

Furthermore, this study identifies the proper contract content that makes VMI with revenue sharing contract feasible in practice. According to the experimental analysis of this study, the revenue sharing contract becomes the effective collaborative supplement for VMI only when the wholesale price discount rate and revenue share ratio are properly determined in the agreement between the supply chain members.

3. Supply Chain Models

Focusing on the potential of the special contract made between the supply chain members for supporting the supply chain collaboration program, this study examines the impact of the revenue sharing contract on the performance of VMI. Based on the mathematical model representing the supply chain system, three supply chain models including the traditional system, VMI, and VMI with revenue sharing contract are compared to identify whether the revenue sharing contract successfully supports VMI to collaborate the supply chain operations. The proposed mathematical model describes two stage supply chain system that is consist of one supplier and one retailer. The supplier manufactures one kind of products and supplies them to the retailer. Once purchasing the products from the supplier, the retailer sells them at the retail market. The notations for the proposed mathematical model are defined in Table 1.

Table 1: Notations in Mathematical Models

Supplier		Retailer	
π_S	Profit	π_R	Profit
P	Wholesale price	R	Retail price
X	Production rate	Q	Order quantity
o_S	Setup cost	o_R	Ordering cost
h_S	Unit inventory holding cost	h_R	Unit inventory holding cost
v	Unit production cost	D	Market demand
τ	Unit transportation cost	d	Price sensitivity parameter

		k	Potential demand size
μ	Wholesale price discount rate	λ	Revenue share ratio

Figure 1 illustrates the fundamental differences in supply chain operations among three systems compared in this study. The traditional system indicates the conventional business process where the supplier replenishes the order made by the retailer. VMI allows the supplier to determine the orders on behalf of the retailer and replenish the order according to his own plan. The last supply chain system describes that the retailer shares his revenue with the supplier and get a price discount in return under VMI.

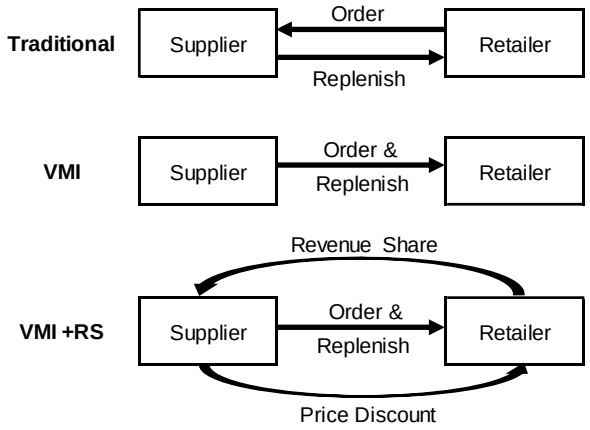

Figure 1: Three Supply Chain Systems

3.1. Traditional System

This study considers the traditional system to be the benchmark to be compared with VMI with revenue sharing contract. The traditional system represents the plain supply chain system that employs no particular feature for the supply chain collaboration. The following equations indicate the supplier's and retailer's profits under the traditional system

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

$$\pi_R = R \cdot D - \frac{o_R \cdot D}{Q} - \frac{h_R \cdot Q}{2} - P \cdot D \quad (2)$$

The supplier's profit (π_S) shown in Equation (1) contains the revenue from the sales to the retailer, setup cost, inventory holding cost, production cost, and transportation cost. The market demand (D) is assumed to be dependent on the retail price (R) as it is shown in Equation (3).

$$D = k - d \cdot R \quad (3)$$

The inventory control system is formulated based on the joint economic lot size model (Banerjee, 1986). In the proposed supply chain model, the supplier determines the wholesale price (P) and production rate (X) in a way to maximize his profit.

Equation (2) describes the retailer's profit (π_R), and it is consisted of the sale revenue from the retail market, ordering cost, inventory holding cost, and cost of purchasing the supplier's products. With the goal of obtaining the maximum profit, the retailer decides the retail price (R) and order quantity (Q).

3.2. VMI

VMI represents the supply chain system where the supplier controls the inventory stored at the retailer's warehouse. Since VMI requires the active coordination between the supplier and retailer, VMI is considered to be a collaborated supply chain system compared with the traditional system. The following equations indicate the supplier's and retailer's profits under VMI.

$$\pi_S = P \cdot D - \frac{o_S \cdot D}{Q} - \frac{h_S \cdot Q \cdot D}{2 \cdot X} - v \cdot X - \tau \cdot D - \frac{o_R \cdot D}{Q} - \frac{h_R \cdot Q}{2} \quad (4)$$

$$\pi_R = R \cdot D - P \cdot D \quad (5)$$

Compared with the case of the traditional system shown in Equation (1), the supplier's profit in VMI includes the ordering and inventory holding costs of the retailer's side as it appears in Equation (4). Since the authority on the retailer's inventory is given to the supplier under VMI, the supplier determines the order quantity in addition to the wholesale price and production rate to maximize his profit.

Meanwhile, the retailer does not have to pay the ordering and inventory holding cost under VMI, and his profit consists of only the sales revenue and purchasing cost as Equation (5) shows. In the proposed supply chain model of VMI, the retail price is the only decision made by the retailer

3.3. VMI with Revenue Sharing

The last supply chain system is characterized as VMI combined with the revenue sharing contract made between the supplier and retailer. Under VMI with revenue sharing contract, each individual supply chain member obtains the profit as the subsequent equations illustrate.

$$\pi_S = \mu \cdot P \cdot D + (1 - \lambda) \cdot R \cdot D - \frac{o_S \cdot D}{Q} - \frac{h_S \cdot Q \cdot D}{2 \cdot X} - v \cdot X - \tau \cdot D - \frac{o_R \cdot D}{Q} - \frac{h_R \cdot Q}{2} \quad (6)$$

$$\pi_R = \lambda \cdot R \cdot D - \mu \cdot P \cdot D \quad (7)$$

Since the supplier receives the portion of sales revenue

from the retailer and offers the lowered wholesale price in return, the supplier's profit in Equation (6) contains his share of retailer's revenue ($(1-\lambda)\cdot R\cdot D$) and discounted wholesale price ($\mu\cdot P$) according to the revenue sharing contract. The revenue share ratio (λ) and wholesale price discount rate (μ) are pre-agreed contract content made by the supplier and retailer.

Equation (7) shows the profit that the retailer gains in VMI with revenue sharing contract. Due to the revenue sharing contract, the retailer obtains merely the certain part of the sale revenue ($\lambda\cdot R\cdot D$) after he gives the rest of it to the supplier. Instead, the retailer gets the discount on the wholesale price when he pays to the supplier.

4. Numerical Analysis

On the purpose of finding out whether the revenue sharing contract supports VMI to collaborate the supply chain operations, this study examines the financial performances of three supply chain systems by numerically analyzing the proposed mathematical models. In the numerical examples, five parameters are altered in five different levels and they include the potential demand size, setup cost, ordering cost, and unit inventory holding costs of the supplier and retailer. The entire numerical examples comprise 3,125 cases (5^5 = 3,125). Table 2 describes the arbitrarily determined parameters employed in the base case of the numerical examples.

Table 2: Parameters of Base Case

Parameters			
$k = 3{,}000$	$d = 5$	$o_S = 1{,}000$	$h_S = 5$
$o_B = 500$	$h_B = 10$	$v = 10$	$\tau = 5$

4.1. Comparison among Three Supply Chain Systems

This study conducts the numerical analysis on three different supply chain systems to examine how the revenue sharing contract influences the performance of VMI. Table 3 shows the averaged outcomes of three supply chain systems obtained from the numerical experiments.

Table 3: Performances of Supply Chain Systems

Figures	Traditional System	VMI	VMI with Revenue Sharing
Demand	725.04	795.96	998.20
Retail Price	454.99	440.81	400.36
Wholesale Price	308.15	281.61	170.61
Order Quantity	268.16	541.05	538.23
Production Rate	1,459.27	1,451.12	1,436.05
Supplier			
Revenue	223,416.88	224,650.52	230,755.35
Setup Cost	2,772.36	2,205.60	2,780.55
Inventory Cost	334.64	3,418.62	3,595.38
Production Cost	14,592.70	14,511.20	14,360.53
Transportation Cost	3625.18	3,979.82	4,990.99
Total Cost	21,324.88	24,115.24	25,727.45
Profit	202,092.00	200,535.28	205,027.90
Retailer			
Revenue	330,886.00	35,1661.06	340,456.31
Purchasing Cost	223,416.88	22,4650.52	170,674.82
Ordering Cost	1,327.16	0.00	0.00
Inventory Cost	1,327.16	0.00	0.00
Total Cost	22,6071.20	224,650.52	170674.82
Profit	104,814.80	127,010.54	169,781.49
Supply Chain			
Revenue	554,302.88	576,311.58	571,211.66
Cost	247,396.08	248,765.76	196,402.28
Profit	306,906.80	327,545.82	374,809.38

The numerical examples indicate that VMI achieves greater supply chain profit than the traditional system. VMI can increase the supply chain profit mainly due to the increased market demand. VMI provides the supplier with the broad authority to determine the supply chain operations and the extensive cost responsibility. After all, the supplier under VMI decreases the wholesale price, and consequently the retailer can decrease the retailer price to increase the market demand.

When the individual supply chain member's profit is counted instead of the entire supply chain profit, the outcome is different. According to Table 3, VMI provides the retailer with greater profit than the traditional system. The supplier's profit, however, is lower under VMI than under the traditional system. VMI requires the supplier to sacrifice his profit because he should pay the additional costs for retailer's ordering and inventory holding.

VMI with revenue sharing contract accomplishes different performance depending on the specific values of the revenue share ratio and wholesale price discount rate. The outcome of VMI with revenue sharing contract appears in Table 3 represent the case of the maximum supply chain profit on the condition that every supply chain member obtains higher profit than VMI and the traditional system (λ = 0.85 and μ = 0.60) According to Table 3, VMI with revenue sharing contract makes greater supply chain profit than VMI. With the proper set of revenue share ratio and wholesale price discount rate, furthermore, the combination of VMI and revenge sharing contract results in higher profit for both supplier and retailer than VMI alone and the traditional system.

The increased demand caused by the lower retail price results in the increased supply chain profit under VMI with revenue sharing contract. According to the revenue sharing contract, the supplier provides the retailer with the discounted wholesale price, and then the retailer affords to

reduce the retail price to boost the market demand. In spite of the supplier's burden of the extra costs of retailer's ordering and inventory holding, the revenue sharing contract contributes the share of retailer's revenue to the supplier's profit. The retailer still saves the costs for ordering and inventory holding due to VMI.

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

This study conducts the additional experiments on VMI with revenue sharing contract to identify the specific contract content that results in the best performance. Table 4 indicates the total profit obtained by the entire supply chain system with the different combination of revenue share ratio (λ) and wholesale price discount rate (μ). When there is neither shared revenue nor wholesale price discount (λ = 1.00 and μ = 1.00), VMI with revenue sharing contract becomes VMI without revenue sharing contract.

According to Table 4, VMI with revenue sharing contract accomplishes the greatest supply chain profit when the retailer does not share his revenue with the supplier and the wholesale price is discounted at the highest rate (λ = 1.00 and μ = 0.60). Table 5 and Table 6 describes the market demand and retail price depending on the different combination of the revenue share ratio and wholesale price discount rate. The main reason that VMI with revenue sharing contract can increase the supply chain profit is the enlarged market demand caused by the lowered retail price.

Table 4: Supply Chain Profit

	λ = 0.60	λ = 0.65	λ = 0.70	λ = 0.75	λ = 0.80	λ = 0.85	λ = 0.90	λ = 0.95	λ = 1.00
μ= 0.60	327,761	341,699	352,728	361,599	368,835	374,809	379,793	383,986	387,541**
μ= 0.65	311,359	327,735	340,696	351,124	359,633	366,660	372,524	377,463	381,653
μ= 0.70	293,651	312,660	327,709	339,818	349,702	357,867	364,684	370,428	375,306
μ= 0.75	274,640	296,476	313,766	327,682	339,043	348,431	356,273	362,883	368,500
μ= 0.80	254,326	279,183	298,868	314,716	327,655	338,352	347,288	354,826	361,234
μ= 0.85	232,710	260,783	283,017	300,920	315,540	327,628	337,731	346,255	353,506
μ= 0.90	209,793	241,275	266,212	286,294	302,697	316,261	327,601	337,171	345,316
μ= 0.95	185,577	220,660	248,454	270,838	289,125	304,250	316,897	327,574	336,662
μ= 1.00	160,060	198,939	229,742	254,554	274,826	291,595	305,620	317,462	327,546*

** Maximum * VMI without revenue sharing contract

Table 5: Market Demand

	λ = 0.60	λ = 0.65	λ = 0.70	λ = 0.75	λ = 0.80	λ = 0.85	λ = 0.90	λ = 0.95	λ = 1.00
μ= 0.60	797	850	895	934	968	998	1,025	1,048	1,069**
μ= 0.65	739	797	846	888	925	958	986	1,012	1,035
μ= 0.70	682	744	797	842	882	917	948	976	1,000
μ= 0.75	624	691	747	797	839	877	910	940	966
μ= 0.80	567	638	698	751	796	837	872	904	932
μ= 0.85	510	585	649	705	754	796	834	868	898
μ= 0.90	452	532	600	659	711	756	796	832	864
μ= 0.95	395	479	551	613	668	716	758	796	830
μ= 1.00	338	426	502	568	625	675	720	760	796*

** Maximum * VMI without revenue sharing contract

Table 6: Retail Price

	λ = 0.60	λ = 0.65	λ = 0.70	λ = 0.75	λ = 0.80	λ = 0.85	λ = 0.90	λ = 0.95	λ = 1.00
μ= 0.60	440.64	430.04	420.98	413.16	406.34	400.36	395.09	390.42	386.27**
μ= 0.65	452.14	440.66	430.83	422.35	414.95	408.45	402.71	397.62	393.09
μ= 0.70	463.64	451.26	440.68	431.53	423.55	416.53	410.33	404.82	399.90
μ= 0.75	475.12	461.86	450.51	440.70	432.14	424.61	417.94	412.02	406.72
μ= 0.80	486.59	472.45	460.34	449.86	440.72	432.68	425.55	419.21	413.54
μ= 0.85	498.06	483.02	470.16	459.02	449.30	440.74	433.16	426.40	420.35
μ= 0.90	509.52	493.60	479.97	468.17	457.87	448.80	440.76	433.60	427.17
μ= 0.95	520.97	504.16	489.77	477.32	466.44	456.86	448.36	440.79	433.99
μ= 1.00	532.41	514.72	499.58	486.46	475.01	464.91	455.96	447.97	440.81*

** Minimum * VMI without revenue sharing contract

When the supply chain system can obtain the greatest profit, the supplier acquires merely poor profit. Table 7 shows that supplier's profit with λ = 1.00 and μ = 0.60 is quite lower than the maximum possible profit with λ =

6.00 and $\mu = 0.60$. When the wholesale price is discounted at the highest rate, the retail price is severely decreased to boost the market demand and VMI with revenue sharing contract can achieve the greatest profit of the entire supply chain system. At the same time, the retailer can secure more profit to support price-cut by sharing no revenue with the supplier. Consequently, the retailer obtains the maximum profit when VMI with revenue sharing contract makes the maximum supply chain profit as described in Table 7.

Even though the supply chain system can attain the maximum profit when VMI is employed with only the discounted wholesale price, this particular revenue share content is hardly realizable in practice because the supplier would not accept the unfair contract that demands his profit loss. Instead, this study looks for the proper revenue sharing contract that secures the increased profits for both supplier and retailer.

In Table 7, the underlined numbers indicate the cases that the supplier achieves the greater profit under VMI with revenue sharing contract than the traditional system. With the underlined numbers in Table 8, VMI with revenue sharing contract makes greater profit for the retailer than VMI alone. After all, the area of underlined numbers in Table 4 are duplicated between the areas of underlined numbers in Table 7 and Table 8. With these combinations of revenue share ratio and wholesale price discount rate, VMI with revenue sharing contract accomplishes greater profits for both supplier and retailer than VMI alone as well as the traditional system.

Table 7: Supplier's Profit

	λ = 0.60	λ = 0.65	λ = 0.70	λ = 0.75	λ = 0.80	λ = 0.85	λ = 0.90	λ = 0.95	λ = 1.00
μ= 0.60	251,391**	247,597	240,297	230,378	218,469	205,028	190,400	174,854	158,608
μ= 0.65	245,618	245,022	240,302	232,494	222,335	210,358	196,964	182,459	167,088
μ= 0.70	237,733	240,591	238,657	233,132	224,866	214,475	202,421	189,052	174,646
μ= 0.75	227,742	234,308	235,367	232,295	226,065	217,383	206,774	194,636	181,279
μ= 0.80	215,649	226,178	230,436	229,986	225,936	219,084	210,026	199,210	186,986
μ= 0.85	201,457	216,204	223,867	226,210	224,481	219,580	212,177	202,775	191,766
μ= 0.90	185,170	204,389	215,663	220,969	221,702	218,873	213,229	205,332	195,618
μ= 0.95	166,790	190,735	205,826	214,263	217,602	216,964	213,182	206,880	198,541
μ= 1.00	146,320	175,245	194,358	206,096	212,181	213,855	212,037	207,420	200,535*

** Maximum * VMI without revenue sharing contract

Table 8: Retailer's Profit

	λ = 0.60	λ = 0.65	λ = 0.70	λ = 0.75	λ = 0.80	λ = 0.85	λ = 0.90	λ = 0.95	λ = 1.00
μ= 0.60	76,370	94,102	112,431	131,221	150,366	169,781	189,392	209,132	228,934**
μ= 0.65	65,741	82,713	100,395	118,630	137,298	156,302	175,561	195,004	214,564
μ= 0.70	55,918	72,069	89,052	106,687	124,836	143,391	162,264	181,376	200,660
μ= 0.75	46,897	62,168	78,399	95,388	112,978	131,048	149,498	168,247	187,221
μ= 0.80	38,677	53,005	68,433	84,729	101,720	119,267	137,263	155,615	174,248
μ= 0.85	31,253	44,578	59,150	74,709	91,059	108,048	125,555	143,480	161,740
μ= 0.90	24,623	36,885	50,549	65,325	80,994	97,388	114,373	131,839	149,698
μ= 0.95	18,786	29,925	42,628	56,575	71,523	87,286	103,716	120,694	138,121
μ= 1.00	13,740	23,694	35,385	48,458	62,645	77,741	93,583	110,042	127,011*

** Maximum * VMI without revenue sharing contract

5. Discussion

This study focuses on the role of the revenue sharing contract under VMI, which is one of the famous supply chain collaboration programs. In order to identify the pure impact of the revenue sharing contract on the performance of VMI, three supply chain systems including VMI with revenue sharing contract, VMI, and traditional system are compared in the numerical examples of the proposed mathematical models. The numerical experiments reveal the crucial characteristics of VMI with revenue sharing contract, and they provide the business practitioners with the useful managerial implications.

First, VMI, to be applicable to real businesses, requires the supplement that equally distributes its benefit to every supply chain member. The numerical experiments indicate that the supplier obtains less profit under VMI than in the traditional system even though VMI increases the supply chain profit. This outcome is consistent with a group of the past studies concluding that VMI could be beneficial to only the buyer (Kannan et al., 2013; Mishra & Raghunathan, 2004; Yao et al., 2007). Consequently, VMI alone is hardly practicable to any supply chain systems without the unanimous consent of every supply chain member, and it demands the special supplementary function such as the revenue sharing contract to be a feasible supply chain collaboration program in any industries.

Second, it is important to increase total throughput of the supply chain system in any supply chain collaboration programs including VMI. According to the numerical examples, the main reason that VMI improves the supply chain profit is the increased market demand caused by the lowered price. Furthermore, the numerical analysis on VMI with revenue sharing contract reveals that the wholesale price discount results in even greater supply chain profit than the case that only VMI is employed. The past study points out that the buyer under VMI lowers his price due to the reduced inventory cost and consequently the entire supply chain system earns the increased sale volume (Disney et al., 2003). In the real cases, Quick Response employed by Dillard Department Stores, J.C. Penny, and Wal-Mart for supply channel coordination increase sales by 20% to 25% (Buzzell & Ortmeyer, 1995). By implication, when anyone uses the supply chain collaboration program, he should focus on the throughput of the entire supply chain system to achieve the expected success.

Lastly, the revenue sharing contract with the proper contract content becomes the effective collaborative supplement for VMI that is beneficial to every supply chain member. The numerical experiments on VMI with revenue sharing contract reveal that the revenue sharing contract with the particular sets of revenue share ratio and wholesale price discount rate results in greater profits for both supplier and retailer than VMI alone as well as the traditional system. This outcome implies that the revenue sharing contract can enhance VMI to be acceptable for every supply chain member as described in the past studies (Chen et al., 2010; Chen, 2018). Meanwhile, the supply chain members have to agrees with the appropriate contract content about the amount of revenue share and wholesale price cut to make VMI with revenue sharing contract to be the fair supply chain management program that effectively collaborates the supply chain operations.

6. Conclusion

This study focuses on the role of the revenue sharing contract under the supply chain collaboration program and finds out whether this contract supports VMI to improve the supply chain performance. VMI, to be acceptable by all supply chain members, requires the additional scheme, since the original VMI is known to be beneficial to only the retailer. By investigating how the revenue sharing contract performs under VMI, this study examines whether the revenue sharing contract becomes the effective supplement that equally distributes the benefits from VMI to every supply chain member.

The proposed supply chain model represents two stage supply chain system where one supplier trades a single type of products with a retailer. In the supply chain model, each individual member determines the operational decisions to maximize his own profit. Three supply chain systems including VMI with revenue sharing contract, VMI alone, and traditional system are tested in the numerical examples of the proposed mathematical models.

Compared from many past studies that merely examine the outcomes from VMI combined with revenue sharing contract, this study focuses on the role of the revenue sharing contract under VMI. Furthermore, the thorough analysis on the numerical examples is conducted to identify the proper contract content that enables both supplier and retailer to increase their profits. The numerical analysis generates valuable outcomes that implies useful managerial guidelines for the business practitioners.

First, the numerical experiments on the proposed supply chain models reveal that the supplier loses his profit due to VMI compared with the case without VMI. By employing VMI alone, only the retailer achieves the financial gain in spite of the increased overall supply chain profit. By implication, to be a realistic supply chain collaboration program that ensures every supply chain member's participation, VMI requires the extra device that equally distributes the resultant benefit to all participants.

Second, this study identifies that the key of successful supply chain collaboration is the enlarged throughput of the supply chain system. In the numerical examples, the larger market demand under VMI with revenue sharing contract as well as VMI alone is detected to lead to greater supply chain profit. This result implies that the business practitioners should pay attention to throughput of the supply chain system to obtain the best performance from the supply chain collaboration program.

Finally, this study finds out that VMI combined with the revenue sharing contract can be beneficial to both supplier and retailer. According to the numerical examples, even supplier can increase his profit under VMI with revenue sharing contract when the contract contains the proper set of revenues share ratio and wholesale price discount rate. Consequently, the revenue sharing contract can be the right supplement that enhances VMI to be an effective and feasible supply chain collaboration program.

This study has the following limitations and they give valuable implications about new research issues for the future studies. First, this study considers the mere situation that the contents of the revenue sharing contract are made based on the agreement with all supply chain members. Meanwhile, the past studies assume the diverse cases where either the supplier (Hu et al., 2018; Yao et al., 2016) or the retailer (Li et al., 2019; Zhao & Shi, 2011) decides the revenue share other than it is determined in their agreement (Bai et al., 2018; Chakraborty et al., 2015). By analyzing the extensive cases where different supply chain members

determine the revenue share, the future studies can figure out the comprehensive nature of the revenue sharing contract.

Second, the numerical examples used in this study rely on the arbitrarily determined data and its outcomes may not fully represent the real business situations. The future studies would collect the empirical data from the real industries and generate more realistic outcomes (Gui-xia et al., 2013; Kumar & Haider, 2011).

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