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MODELING SUPPLY CONTRACTS TO MANAGE OUTSOURCING RISKS OF LOGISTICS' ACTIVITIES

Winda Narulidea, Sekarsari Utami Wijaya
Logistics Engineering Department, Universitas Internasional Semen Indonesia

Abstract *In a decentralized supply chain condition, control of supply chain players towards third-party logistics service providers is limited, while the performance of logistics services affect product availability, quality, price and market. Outsourcing decisions on logistics activities are common practice and generally succeed in increasing the performance and efficiency of logistics costs for many companies. The kind of outsourcing could maintain their focus on the core business. On the other hand, these companies also need to keep minimizing distribution costs by managing relationships with third-party service providers to obtain the expected value of excellence in their operational performance. Therefore, in a decentralized supply chain, suitable supply contracts as the coordination mechanism among supply chain players are needed, moreover with the using of logistics outsourcing strategy. The supply contracts need to be designed so that all supply chain players could obtain the expected competitive advantage. In this research, there are revenue and inventory risk sharing contracts and quantity flexibility contracts developed to coordinate the supply chain consisting of manufacturers, retailers and third-party logistics service providers. An incentive and penalty scheme is applied based on the performance of the logistics service provider which affect the level of availability at the retailer, therefore the inventory risks could be allocated to all related players.*

***Keywords**: supply contracts, revenue and inventory-risk sharing contract, quantity flexibility contracts, logistics outsourcing*

1. Introduction

This study addresses issues in the supply chain where manufacturers supply products through third-party logistics providers to deliver products to distant market. Products delivered by third party logistics (3PL) providers to retailers for the selling season on the market. Problems come from the length of distance and extensive market penetration that must be considered in distribution processes. In a decentralized supply chain, manufacturer could not be in full control of the interests of 3PL providers. Problems occur when the products are not delivered as per the order quantity and distribution schedule of the manufacturer, so it will discourage the manufacturer effort to maintain market share and product quality received by the retailer. All players have higher risks when there is no coordination between supply chains. According to Chopra and Meindl [1], aligning incentives needs to be done to improve mutually beneficial relationships for all players in the supply chain.

This research develops a contract model of the coordination mechanism between players with logistics outsourcing involvement in the supply chain. Höhn [2] expressed there are many available supply contracts models such as revenue sharing contracts, quantity flexibility contracts, buyback contracts, etc. However in many previous researches, revenue sharing contracts are the common contracts model to determine contract parameters in newsvendor problems to coordinate the supply chain, for example in the studies conducted by Cachon and Lariviere [3] and Lariviere and Porteus [4]. The researches focus on a single retailer newsvendor model as the basic model for most of supply chain contracts. Further research is developed by Giannoccaro and Pontrandolfo [5] about revenue sharing contracts model in multi echelon supply chain. The revenue-sharing contract scheme was developed to coordinate three stage supply chain consists of suppliers, manufacturers and retailers.

* Corresponding author. Email : winda.narulidea@uisi.ac.id
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Another kind of supply contract that common to be used is quantity flexibility contracts. According to Tsay and Lovejoy [6] and Chopra and Meindl [1], in quantity flexibility contracts the manufacturer shares risk by allowing the retailer to adjust its order as better market information is received. Because no returns are required, these contracts can be more effective than buyback contracts when the cost of returns is high. When the supplier is selling to multiple retailers, these contracts are more effective than buyback contracts because they allow the supplier to aggregate uncertainties across multiple retailers and thus lower the level of excess inventory. Quantity flexibility contracts increase the average amount the retailer purchases and may increase total supply chain profits when structured appropriately. Further research by Cai et al. [7] is develop the model of contracts in decentralized supply chain with the involvement of logistics outsourcing in distribution processes. The availability and quality of products are being the concerns due to the customer demands are sensitive to both of these factors.

Collaboration in supply chain requires the effort to enable the information, risks, and benefit sharing among supply chain players. According to Mentzer et al. [8], Simatupang et al. [9], information sharing and incentive alignments are coordination mechanism that could affect supply chain performance. Lack of coordination impacts on high inventory costs, long delivery times, high transportation costs, high rates of loss and damage, and poor customer service as can been seen on the researches conducted by Li and Wang [10] and Wang [11]. Therefore, in this paper, the proposed model applies incentive and penalty schemes in accordance with the performance of third party logistics provider. The revenue and inventory-risk sharing contract model in this study is proposed to coordinate the supply chain by the existence of logistics outsourcing as the third party between manufacturers and retailers. The parameter values in the model are determined to increase each supply chain player's profit and win-win conditions can be achieved.

2. Parts of Manuscript

In the model, the supply chain consists of three players: a manufacturer, a retailer, and a 3PL provider. In the centralized condition as can be seen in Figure 1, both of the manufacturer and the retailer are under the same firm so that a coordination could be conducted to achieve an optimal decision and win-win condition for each player. Meanwhile, in the common practice, manufacturer and retailer are two different companies. They could be completely doing transactions that depend on the purchasing terms or more established procurement with common wholesale price contracts. This scheme of supply chain is called decentralized supply chain as can be seen in Figure 2. In the scheme, there are no or only minimum coordination in the supply chain, that every player makes efforts only to increase their own profits. The phenomenon leads to other problems when the double marginalization happened. Due to higher retail price that comes from high wholesale price from manufacturer could resulting on the decreasing customer demands.

In decentralized supply chain, logistics outsourcing is implemented to perform logistics activity for the manufacturer. 3PL provider will deliver products from manufacturer for selling season in retailers. In a decentralized supply chain, manufacturer cannot be in full control of the 3PL provider’s performance. All players have higher risks that incentive alignment should be conducted to ensure the logistics outsourcing’s performance by designing a supply contract as the coordination mechanism. The purpose is to obtain optimal decision for all supply chain players in win-win condition. Both the manufacturer and the retailer could ensure that 3PL provider deliver the products as per the distribution allocation quantity and schedule, so it will encourage the manufacturer’s effort to maintain market share and product quality received by the retailer.

By designing supply contracts, the supply chain could identify potential solutions that allow for risk sharing in a way that increases supply chain profits. There are multiple supply contracts that common to be used to solve risk-sharing problem among supply chain players. To improve overall profits, the supplier must share risk in a way that encourages the buyer to purchase more and increase the level of product availability. This requires the supplier to share in some of the buyer’s demand uncertainty. The following two approaches to risk sharing increase overall

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supply chain profits: revenue and inventory-risk sharing contracts and quantity flexibility contracts.

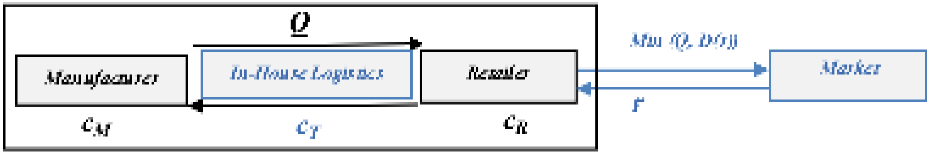

Fig 1 Model of In-house Logistics in Centralized Supply Chain

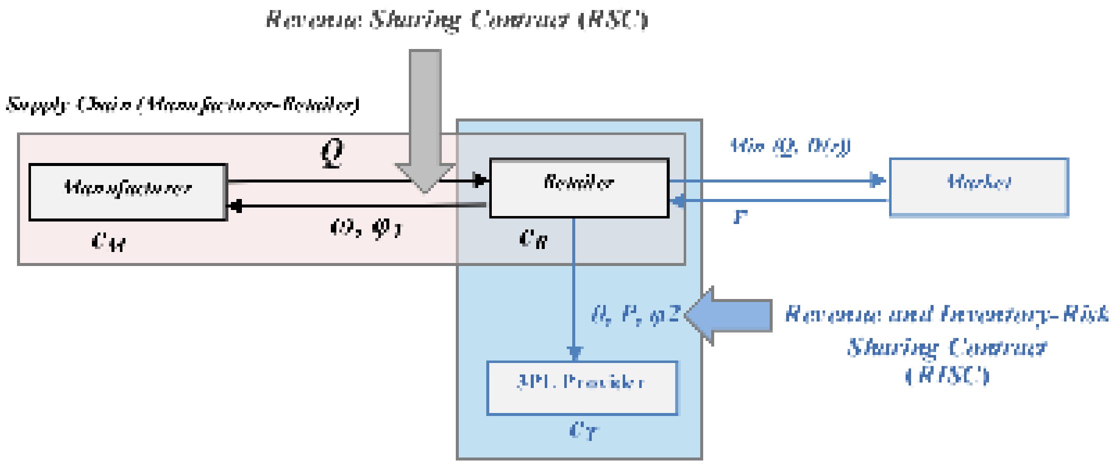

Fig 2 Model of Logistics Outsourcing under Revenue and Inventory-risk Sharing Contracts

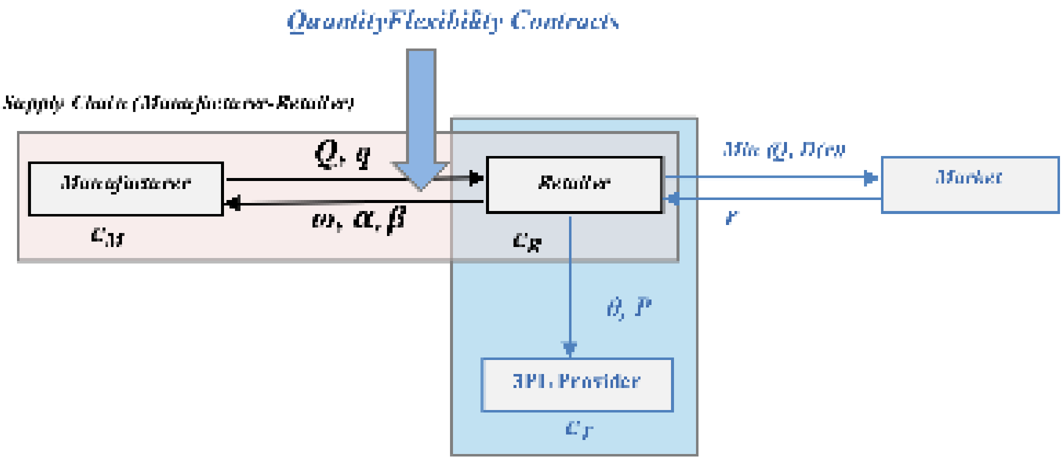

Fig 3 Model of Logistics Outsourcing under Quantity Flexibility Contracts

Assume that the retailer sells the products at a retail price *r*, and the marginal cost of the manufacturer, the retailer, and the logistics functions in the firm, respectively denoted as c_M, c_R, and c_T. When market demand during selling season is normally distributed, with expected value $\mu(1-\theta)$ and standard deviation $\sigma(1-\theta)$. Expected ratio of products delivered in full on time is denoted by $(1-\theta)$, while $(0 \leq \theta \leq 1)$. Therefore the optimal customer service level *CSL** is given by:

$$CSL^* \quad Probability\ (demand \leq Q) \quad \frac{c_u}{c_u + c_o} \tag{1}$$

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In *centralized supply chain*, the manufacturer and the retailer are under the same firm, meanwhile there is no 3PL services needed due to the logistics activities are conducted in-house by the form itself. All parties in the supply chain could make the optimal decision together, therefore, the cost of under stocking is $c_u = r - (c_M + c_T + c_R)$ and the cost of overstocking is $c_o = c_M + c_T + c_R$. The optimal customer service level and the optimal order quantity in centralized supply chain are evaluated using Equations (2) and (3).

$$CSL_c^* = \frac{r - (c_M + c_T + c_R)}{r} \quad (2)$$
$$Q^c = F^{-1}(CSL_c^*, \mu, \sigma) \quad (3)$$

When Q^c units are available in the retailer, the firm should handle the risk of overstocking or under stocking, depending on demand. The expected overstock o_R at the retailer at the end of selling season is given by:

$$o_R = (Q - \mu)Fs\left(\frac{Q-\mu}{\sigma}\right) + \sigma fs\left(\frac{Q-\mu}{\sigma}\right) \quad (4)$$

In the following formulas, Fs is the standard normal cumulative distribution function and fs is the standard normal density function.
Expected supply chain profit in centralized condition is given by:

$$\pi_{SC}^c = r(Q^c - o_R) - (c_M + c_T + c_R)Q^c \quad (5)$$

In the *decentralized supply chain*, each player of the manufacturer, the retailer, and the 3PL provider act on the objective of maximizing their own profit. Assume that the manufacturer has a production cost ω and a logistics service price *P* given by 3PL provider. Therefore the cost of under stocking at the retailer is given by $c_u = r - (\omega + P + c_R)$ and the cost of overstocking is $c_o = (\omega + P + c_R)$. We thus obtain:

$$CSL_d^* = \frac{r - (\omega + P + c_R)}{r} \quad (6)$$

By the optimal order quantity Q^d obtained using the same calculation in Equation (3), the expected profit of each player in decentralized supply chain, respectively is given by:

$$\pi_R^d = r(Q_R^d - o_R) - (\omega + (1-\theta)P + c_R)Q_R^d \quad (7)$$

$$\pi_M^d = (\omega - c_M)Q_R^d \quad (8)$$
$$\pi_T^d = PQ_R^d - c_T Q_R^d \quad (9)$$

While the expected supply chain profit is obtained by the total of all those supply chain players profit.

R*evenue and inventory-risk sharing contracts* is proposed to coordinate among players in decentralized supply chain. In revenue and inventory-risk sharing contracts, the manufacturer offers a lower wholesale price to the retailer, and the 3PL provider offer a lower logistics services price. However, as the consequences, both the manufacturer and the 3PL provider shares fractions φ of the retailer's revenue.

In revenue and inventory-risk sharing contracts, the cost of under stocking at the retailer is given by $c_u = (1 - (\varphi_1 + \varphi_2))r - (\omega + (1-\theta)P + c_R)$ and the cost of overstocking is $c_o = (\omega + (1-\theta)P + c_R)$. We thus obtain:

$$CSL_{rs}^* = \frac{[1-(\varphi_1+\varphi_2)]r - (\omega + (1-\theta)P + c_R)}{[1-(\varphi_1+\varphi_2)]r} \quad (10)$$

The manufacturer obtains the wholesale price ω for each unit purchased by the retailer and a share of the revenue φ_1 for each unit sold by the retailer. The expected manufacturers profit is evaluated as:

$$\pi_M^{rs} = (\varphi_1 r + \omega)(Q - o_R) - c_M Q \quad (11)$$

The 3PL provider will be paid of *P* by retailer for only each item delivered in full on time. Expected ratio of products delivered in full on time is denoted by $(1-\theta)$, while $(0 \le \theta \le 1)$. The 3PL provider also obtains fraction of revenue φ_2 from retailer for each unit sold. The expected 3PL provider profit is evaluated as:

$$\pi_T^{rs} = [\varphi_2 r + (1-\theta)P](Q^{rs} - o_R) - c_T Q^{rs} \quad (12)$$

The retailer obtains revenue of $1 - (\varphi_1 + \varphi_2)$ for each unit sold. The expected retailers profit is given by:

$$\pi_R^{rs} = [1 - (\varphi_1 + \varphi_2)]r(Q^{rs} - o_R) - (\omega + (1-\theta)P + c_R)Q^{rs} \quad (13)$$

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If players try to maximize each of their own profits, the equation of optimal order quantity is:

$$Q^{*rs} = F^{-1}\left(\frac{[1-(\varphi_1+\varphi_2)]r-[\omega+(1-\theta)P-c_R]}{[1-(\varphi_1+\varphi_2)]r}\right) \quad (14)$$

To obtain coordination in the supply chain, the contract parameters φ_1, φ_2, and ω are determined so the win-win condition could be achieved for each of supply chain players, therefore the order quantity as $Q^{rs} = Q^{c}$, and the equations is given as:

$$F^{-1}\left(\frac{[1-(\varphi_1+\varphi_2)]r-[\omega+(1-\theta)P+c_R]}{[1-(\varphi_1+\varphi_2)]r}\right) = F^{-1}\left(\frac{r-(c_R+c_M+c_T)}{r}\right)$$

$$\frac{[1-(\varphi_1+\varphi_2)]r-[\omega+(1-\theta)P-c_R]}{[1-(\varphi_1+\varphi_2)]r} = \frac{r-(c_R+c_M+c_T)}{r} \quad (15)$$

$$\omega = [1-(\varphi_1+\varphi_2)](c_R+c_M+c_T) - c_R - (1-\theta)P \quad (16)$$

Contract parameter φ_1 and φ_2 are range between 0 to 1 and follow:

$$\varphi_1+\varphi_2 < 1 - \frac{c_R}{c_R+c_M+c_T} \quad (17)$$

Beside the revenue and inventory-risk sharing contracts, there is *quantity flexibility contracts* that common to be used to solve risk-sharing problem among players in supply chain. Under quantity flexibility contracts, the manufacturer allows the retailer to change the quantity ordered within upper and lower limits after observing demand through forecasting or real time data. If a retailer orders *O* units, the manufacturer commits to supply the products up to $Q = (1+\alpha)O$ units, while retailer is committed to buy minimum equals to $q = (1-\beta)O$ units. Contract parameter α and β are range between 0 and 1.

The retailer could purchase anywhere between *q* and *Q* units, depending on the demand it observes. If the retailer orders *O* units, the manufacturer is committed to supply *Q* units. Therefore, we assume that the manufacturer produces equals to *Q* units. The retailer purchases *q* units if demand *D* is less than *q*, *D* units if demand *D* is between *q* and *Q*, and *Q* units if demand *D* is greater than *Q*.

The expected quantity purchased by retailer is obtained by:

$$Q_R^{qf} = qF(q) + Q[1-F(Q)] + \mu\left[F_S\left(\frac{Q-\mu}{\sigma}\right) - F_S\left(\frac{q-\mu}{\sigma}\right)\right] - \sigma\left[f_S\left(\frac{Q-\mu}{\sigma}\right) - f_S\left(\frac{q-\mu}{\sigma}\right)\right] \quad (18)$$

Expected quantity sold by retailer,

$$D_R^{qf} = Q[1-F(Q)] + \mu F_S\left(\frac{Q-\mu}{\sigma}\right) - \sigma f_S\left(\frac{Q-\mu}{\sigma}\right) \quad (19)$$

Expected overstock at manufacturer,

$$O_M^{qf} = Q_R^{qf} - D_R^{qf} \quad (20)$$

The expected profit of each player (the retailer, the manufacturer, and the 3PL provider, respectively is given by:

$$\pi_R^{qf} = rD_R - [\omega+(1-\theta)P+c_R]Q_R^{qf} \quad (21)$$

$$\pi_M^{qf} = \omega Q_R^{qf} - c_M Q \quad (22)$$

$$\pi_T^{qf} = (1-\theta)PQ_R^{qf} - c_T Q_R^{qf} \quad (23)$$

3. Results and Discussion

Numerical experiments are performed to verify the proposed model and if win–win condition could be achieved in supply chain. The objective is to determine the contract parameters to coordinate all players. The numerical experiments use the data in Table 1 and 2 from the similar data in the basic model by Giannoccaro and Pontrandolfo [5].

In *decentralized supply chain*, from Table 3, under different parameter of logistics service price *P*, ratio of products delivered not *on time and in full* (OTIF) θ, and wholesale price ω, we can see the expected profit of each supply chain players that obtained from Equations (6)-(9). Further, it is known that the expected profit of the manufacturer, the retailer, and 3PL provider are lower than the other contracts scheme.

Table 1. Problem Data

Variable	Value
c_R	1
c_T	2
c_M	4
price *r*	30
demand *D(r)*	Normal distribution, μ=100, σ=30

Likewise, the expected supply chain profits are relatively lower than under

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centralized condition and the other contracts schemes. When the double marginalization

Table 2. Profits under Different Ratio θ in Centralized Supply Chain

θ	Q^c	a_R	π_{SC}^c
0,00	122	26	2025
0,10	110	23	1823
0,20	97	21	1620
0,30	85	18	1417
0,40	73	16	1215
0,50	61	13	1012
0,60	49	10	810
0,70	37	8	607
0,80	24	5	405
0,90	12	3	202

occurred, the wholesale price ω and logistics service price *P* tend to increase time to time. This phenomenon result on suboptimal supply chain profit. As can be seen from the decreasing expected profit of the retailer, it is known that the retailer takes most of the risks. The retailer has to maintain a competitive retail price while taking all the risks of overstock, under stock, and including the risks of late delivery and product defects during distribution by 3PL provider. The retailer could decrease the order quantity to minimize these risks, therefore the as can be seen in Table 3, this decreasing order quantity could also impact on the manufacturer and the 3PL profit.

Meanwhile under *revenue and inventory risk sharing contracts*, in Table 4 and

Table 3. Profits under Different Parameter *P*, θ, and ω in Decentralized Supply Chain Without Contracts

θ	P	ω	π_M^d	π_T^d	π_R^d	π_{SC}^d
0,00	7	11	628	449	761	1839
0,20	7	11	503	359	610	1471
0,30	7	11	440	314	534	1288
0,00	8	12	674	506	587	1767
0,20	8	12	539	404	471	1415
0,30	8	12	472	354	414	1240
0,00	9	13	703	547	425	1675
0,20	9	13	563	438	342	1343
0,30	9	13	492	383	302	1178

Table 5, it can be seen the expected supply

Table 4. Profits under Revenue and Inventory-Risk Sharing Contracts with Different Parameter φ_1, φ_2, *P*, and ω for θ = 0

φ_1	φ_2	P	ω	π_M^{rs}	π_T^{rs}	π_R^{rs}	π_{SC}^{rs}
0,2	0,2	2	4	484	517	893	1894
0,3	0,3	2	4	725	743	360	1828
0,2	0,2	1,5	3	386	476	1061	1923
0,3	0,3	1,5	3	662	734	507	1903
0,2	0,2	1	2	278	427	1239	1944
0,3	0,3	1	2	576	708	669	1953
0,2	0,2	0,5	1	155	371	1430	1956
0,3	0,3	0,5	1	467	668	847	1982

Table 5. Profits under Revenue and Inventory-Risk Contracts with Different Parameter φ_1, φ_2, *P*, and ω for θ = 0,02

φ_1	φ_2	P	ω	π_M^{rs}	π_T^{rs}	π_R^{rs}	π_{SC}^{rs}
0,2	0,2	2	4	387	386	749	1522
0,3	0,3	2	4	587	576	318	1481
0,2	0,2	1,5	3	307	358	876	1542
0,3	0,3	1,5	3	532	569	431	1532
0,2	0,2	1	2	220	326	1011	1557
0,3	0,3	1	2	460	553	553	1566
0,2	0,2	0,5	1	122	288	1155	1565
0,3	0,3	0,5	1	372	526	687	1586

chain profit for both ratio θ = 0 and θ = 0,02; with different parameter fraction of retailer revenue shared φ_1 and φ_2, logistics service price *P*, and wholesale price ω. The expected supply chain profits are higher than in decentralized supply chain. It indicates that the supply chain performances are better under revenue and inventory risk sharing contracts. Moreover, the expected profit for each supply chain players is higher than decentralized condition; it also indicates that the desirability of contracts is high among the manufacturer, the retailer, and the 3PL provider. It is effective that the wholesale prices charged by the manufacturer and logistics service price charged by the 3PL provider are low, so there is no double marginalization occurred, and higher

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supply chain profit are obtain.

Table 6. Profits Under Quantity Flexibility Contracts With Different Parameter φ_1, φ_2, P, and ω for θ = 0

α	β	P	ω	π_M^{qf}	π_T^{qf}	π_R^{qf}	π_{SC}^{qf}
0,00	0,00	7	11	700	500	741	1941
0,05	0,05	7	11	680	500	811	1991
0,20	0,20	7	11	620	500	964	2084
0,00	0,00	8	12	800	600	541	1941
0,20	0,20	8	12	720	600	764	2084
0,30	0,30	8	12	680	600	825	2105
0,00	0,00	9	13	900	700	341	1941
0,20	0,20	9	13	820	700	564	2084
0,30	0,30	9	13	780	700	625	2105

Table 7. Profits Under Quantity Flexibility Contracts With Different Parameter φ_1, φ_2, P, and ω for θ = 0,02

α	β	P	ω	π_M^{qf}	π_T^{qf}	π_R^{qf}	π_{SC}^{qf}
0,00	0,00	7	11	700	360	558	1618
0,05	0,05	7	11	647	349	567	1564
0,20	0,20	7	11	500	321	602	1423
0,00	0,00	8	12	800	440	378	1618
0,20	0,20	8	12	589	392	442	1423
0,30	0,30	8	12	503	375	511	1389
0,00	0,00	9	13	900	520	198	1618
0,20	0,20	9	13	678	463	281	1423
0,30	0,30	9	13	588	443	358	1389

Under the revenue and inventory risk sharing contracts, the manufacturer is sharing risk because the retailer's cost is lower if demand is low. Even if no returns are allowed, the lower wholesale price decreases the overstock cost to the retailer. Under these benefits from the contracts, the retailer could increase the level of product availability; obtain higher profits for all players (the manufacturer, the retailer, and the 3PL provider) when the contracts parameters are suitably designed. From some fraction of retailer revenue shared to the manufacturer and the 3PL provider could lead to higher profit and better risks allocation among players. It is clear that the revenue and inventory-risk sharing mechanism could coordinate the supply chain.

In *quantity flexibility contract scheme*, as can be seen in Table 6 and Table 7, the expected supply chain profits are higher than the other scheme in decentralized and revenue sharing contracts. Moreover, it is known from result obtained that on certain ratios of θ, the expected supply chain profit under contracts is higher than the centralized condition. It indicates that the incentive and punishment scheme for 3PL provider could drive the performance improvement of in full and on time delivery rate.

While for most of the expected profits of each supply chain player are also higher than the other schemes and contracts. Therefore, it is also clear that the desirability of the contracts are high and could drive a win-win condition among supply chain players. In the quantity flexibility contract, the manufacturer is sharing risk of overstocking, to give chance for retailer to make better planning on determining optimal order quantity that could be flexible on certain agreed upper and lower limits. It could minimize overstocking cost in manufacturer and also in the overall pipeline in supply chain.

Furthermore, under the quantity flexibility contracts, the retailer could increase the level of product availability, resulting in higher profits for the manufacturer, the retailer, and the 3PL provider. From manufacturer and retailer's perspective, good supply chain coordination could obtain high profit as it improves the value of total cost-to-serve effectiveness and responsiveness towards customers demand.

4. Conclussion

Revenue and inventory-risk sharing model and quantity flexibility contracts were developed to allocate profits and to share risks between players in the supply chain under the implementation of the logistics outsourcing strategy in the supply chain. In addition, to improve or maintain the performance of the 3PL provider, penalty and incentive schemes are considered in the model in accordance with the logistics outsourcing performance.

The results of numerical experiments indicate that quantity flexibility contracts and revenue inventory risk sharing contracts are giving higher expected supply chain profit and

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higher expected profit for each supply chain players than in decentralized supply chain. Moreover, under quantity flexibility contracts in certain ratios of products not delivered on time in full (OTIF) condition, the expected supply chain profit under quantity flexibility contracts is higher than profit in the centralized supply chain. So, both the proposed contracts are effective to improve the coordination and logistics performance in decentralized supply chain. There are also high desirability levels of both proposed contracts indicated by higher expected profit among all supply chain player compared to profits in decentralized supply chain.

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