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Research Article

The Profit Distribution of Supply Chain under E-Commerce

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With the development of e-commerce, its influence on supply chain and supply chain management is becoming increasingly significant too. In this paper, the literature on the supply chain profit is reviewed first, and then a two-level and four-party supply chain which consists of a supplier, an e-commerce platform, third-party logistics, and demander is taken into consideration. The profit function of supply chain under e-commerce is formulated by taking the price of product and the maximum supply amount under certain investment as decision-making variables and taking the expected value of random variables of price as the setting sales quantity. Finally, the existence of maximum profit in the supply chain is proved in the model, and the coordination of supply chain under e-commerce environment can be achieved by setting coordination parameters when the relevant cost parameters of supply chain members satisfy certain conditions.

1. Introduction

Competition in the 21st century no longer takes place between one enterprise and another, but among supply chains. The supply chain connects an enterprise and its suppliers, distributors, and customers together organically to make it a function network which includes information flow, material, and cash flow. The development of e-commerce is becoming more and more mature along with the vigorous development and increasing perfection of network economy. In the meantime, the influence of e-commerce on supply chain and its management also gets increasingly significant. E-commerce can provide customers with direct sales, collecting all kinds of channels of information. Additionally, it can accelerate product to enter market and facilitate the transfer of effective funding, so that a series of opportunities will be created to increase the profit for the enterprise or supply chain. Furthermore, e-commerce has favorable impact on supply chain cost; for example, the cost of product management can decrease as the supply chain is shortened, the cost of inventory can be reduced with centralization, and the coordination of supply chain can be improved via information sharing [1].

In the e-commerce environment, the realization of information sharing and cooperation commerce makes the supply chain respond to market demand quickly and helps improve the operation efficiency of the whole supply chain. What is more, it also brings huge benefits to the supply chain. On the basis of the cooperation of individual firms, the supply chain could operate efficiently through close coordination in production, logistics, inventory, sales, and others so as to improve the competition and profitability of the overall supply chain [2]. However, the chain enterprises are independent economic entity, and each of them aims at maximizing their own profits. Consequently, reasonable profit distribution of supply chain and effective cooperation mechanism play a key role in fostering a long-term and stable cooperative relationship among chain enterprises.

The difference of the supply chain under e-commerce environment and in the traditional condition is embodied not only by the timely updating of product information and the real-time transmission of the need information, but also by the various forms of payment and the resulting complex cash flows. Unlike the traditional supply chain with one level of supplier and retailer, there are at least four party members in the supply chain under e-commerce environment: supplier or manufacturer, e-commerce platform, third-party logistics, and demander. Therefore, the profit distribution of supply chain under the e-commerce environment is different from that in the traditional environment; the former must consider the profit coordination of two-level and four-party members and the relationship among information flow, cash flow, and profit point as well. Based on the established supply chain model under e-commerce environment, the profit distribution of supply chain under e-commerce environment is analysed from two aspects: the existence of maximum profit in supply chain under the e-commerce environment and the role to coordinate supply chain members in this model.

2. Literature Review

According to the analysis of the previous literature, the fact that the study of supply chain is mainly done in the following several fields can be found.

(1) Take the newsboy problem as background to further discuss how to coordinate the supply chain by various contracts, such as buy-back contract, revenue sharing contract, quantity flexibility contract, sales commission contract, and finally maximizing the profit of the whole supply chain. For example, the pieces of literature [3–6] have studied the profit distribution of supply chain based on a variety of supply chain coordination contracts. Literature [3] pointed out three basic requirements for the reasonable profit allocation mechanism against the newsvendor problem, and literature [4] takes the newsvendor problem as background to coordinate the supply chain with the compensation strategy. Additionally, literature [5] and literature [6] have studied the profit distribution of supply chain by revenue sharing contract.

(2) Expand the study of two-echelon supply chain to three-echelon supply chain and the study of supply chain with single retailer and wholesaler to that with several retailers and wholesalers, such as pieces of literature [7–10]. Literature [7] proposed a model of profit sharing and transfer pricing for network companies. Literature [8] studied cooperative behaviors and profit allocation in the supply chain which consists of one supplier and several retailers under the decentralized control on the premise of replenishment allowed. Literature [9] investigated coordination in a three-echelon supply chain, examined the impact of subsupply chain coordination, and pointed out that both the supplier and the retailer would prefer to act alone rather than to coordinate with the manufacturer when subsupply chain coordination is suggested. Literature [10] considered the coordination mechanism with revenue sharing and developed a coordination mechanism for a supply chain made up of one manufacturer and n Cournot competing retailers when the production cost and demands are simultaneously disrupted.

(3) Use Game Theory to analyse profit distribution in supply chains. Literature [11] and Literature [12] discussed how the producer prices and how the retailer decides the order quantity under the Stackelberg Game structure and developed a cooperative game model to implement profit sharing between the manufacturer and the retailer utilizing Nash bargaining model, respectively. Literature [13] analysed the impact of surplus division in supply chains on investment incentives with a biform-game approach, and literature [14] analysed both simultaneous-move and leader-follower games to determine the Nash and Stackelberg equilibrium, respectively, and achieved the globally optimal solution that maximizes the system-wide expected profit.

(4) Take the e-commerce as a decision-making variable to study supply chain. Literature [4] and Literature [15] researched the supply chain by taking the e-commerce as a decision-making variable. Literature [4] studied whether the supplier and the customer are willing to complete the transaction through e-commerce in the perishable product sales which is based on random demand, and literature [15] identified the B2B e-commerce usage patterns in North American small- and medium-sized enterprises (SMEs) in their supply chains, the contextual factors that influence usage patterns, and the subsequent effects of these patterns on firm performance.

Additionally, literature [16] and literature [17] have studied the relationship among supply chain members based on profit distribution. Literature [16] put forward a profit distribution plan among supply chain partnerships according to the maximum profit of supply chain and their respective risk proportion by analyzing supplier-retailer relationship model. Literature [17] studied how an informal, long-term relationship between a manufacturer and a retailer performs in turbulent market environments characterized by uncertain demand.

Based on the analysis we can find that many scholars take the traditional two-echelon or three-echelon supply chain as background to discuss supply chain profit distribution with mathematical model and Game Theory. But it is still not very common to study the supply chain profit distribution under e-commerce environment, and most study is mainly done on a single level supply chain. This paper takes the two-level and four-party supply chain which consists of a supplier, an e-commerce platform, third-party logistics, and a demander into consideration first, and next we take the product price and the maximum supply amount under certain investment as decision-making variables, take the setting sales quality as an expected value of random variables of price to create a profit function, and then study the supply chain profit distribution model under e-commerce environment via the analysis of the profit function.

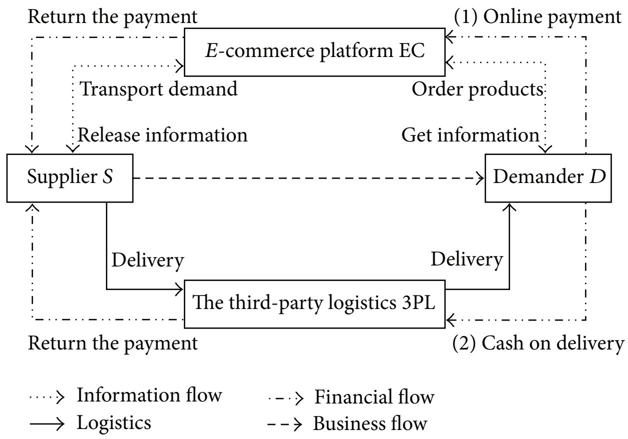

Figure 1: The supply chain model under e-commerce environment.

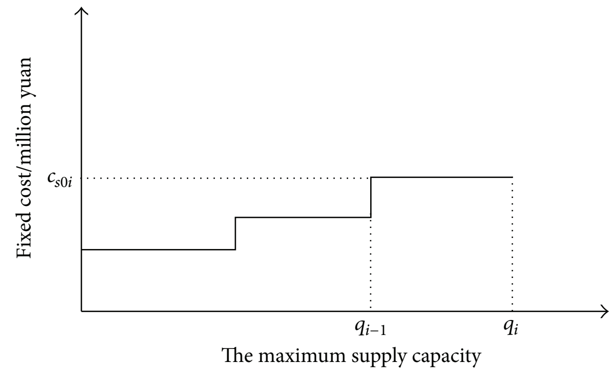

Figure 2: The relationship between fixed cost and the maximum supply capacity.

3. Model Establishment

3.1. Hypothesis

(1) Assume that we only take the supply chain which consists of a supplier S, an e-commerce platform EC, third-party logistics 3PL, and demander D into consideration (as shown in Figure 1).

(2) This model only considers a specified sales cycle and the product is single in the supply chain.

(3) The supplier releases product information in the e-commerce platform, the demander will obtain the required information through the platform, and the order will also be completed in the e-commerce platform. After the order information is received through e-commerce platform, the supplier will manufacture or purchase products and then entrust the third-party logistics to take and deliver goods and finally the logistics will be completed.

(4) There are two approaches to payment for demander: ① online payment, namely, it is paid through online bank and e-commerce platform; ② cash on delivery, namely, the payment is collected by third-party logistics. The demander paid the same in both kinds of payment methods.

(5) For e-commerce platform, it can be profitable only when a cash flow generated the information flow (such as releasing and obtaining product information, order, etc.) which is produced in the deal of both sides of supply and demand does not create profit point. There are two profit points in third-party logistics: the profit of cash flow from collection on delivery; the profit of shipping goods.

(6) There is no condition of asymmetric information in the whole supply chain, the supplier, e-commerce platform investor, and three-party logistics are all risk-free, and their target is to maximize their own profit.

3.2. Symbols and Meanings

(1) S sold the product to EC at unit price w_1 and sold the product to 3PL at unit price w_2; EC and 3PL both sold product to D at unit price $p(w_1 < p,\ w_2 < p)$. ϕ_1 of the EC income for goods as the revenue sharing to S; similarly, ϕ_2 of the 3PL income for goods as the revenue sharing to S.

(2) In a certain sales cycle, the transportation cost which D paid to 3PL shared per unit is t.

(3) The proportion of online payment for payment is α, while the proportion of cash on delivery is $1-\alpha$.

(4) In a certain sales cycle, the relationship between the fixed cost for the product purchase or production and the maximum supply capacity after receiving the need information as shown in Figure 2, the maximum supply capacity (namely, the maximum product number that you can purchase or produce under a certain amount of investment) taken as decision variable is a series of discrete values $\{q_1, q_2, \ldots, q_n\}$. The fixed cost corresponding to the maximum supply capacity q_i is c_{s0i}. The unit variable cost is c_{s1}.

(5) In a certain sales cycle, the construction and maintenance of the fixed cost share of the e-commerce platform by the platform business are c_{e0}, and the variable cost per unit of product that is produced by the transaction is c_{e1}.

(6) In a certain sales cycle, the fixed cost share for transporting goods by 3PL is c_{p0}, and the variable cost per unit of product produced by the transaction is c_{p1}.

(7) In a certain sales cycle, when the sales price of the product is p, the demand for product from user is a random variable with deterministic distribution $D(p)$, and its distribution function and density function, respectively, are $F(q_i \mid p)$ and $f(q_i \mid p)$ $(q_i \geq 0)$. $F(q_i \mid p)$ is differentiable about p, and $\partial F(q_i \mid p)/\partial p > 0$.

(8) $Q(q_i \mid p)$ is the expected value of the number of products in actual trading when the product price is p; then

$$\begin{aligned} Q(q_i \mid p) &= E\{\min(q_i, D(p))\} \\ &= \int_0^\infty \min(q_i, y) f(y \mid p)\, dy \\ &= \int_0^{q_i} y f(y \mid p)\, dy + q_i \int_{q_i}^\infty f(y \mid p)\, dy \\ &= q_i - \int_0^{q_i} F(y \mid p)\, dy. \end{aligned} \tag{1}$$

3.3. Model Establishment. Based on the above assumptions and conditions, we can obtain the profit functions of supply chain.

The profit function of supplier S is

$$\begin{aligned} \Omega_s(q_i, p) &= w_1 \alpha Q(q_i \mid p) + \phi_1 p \alpha Q(q_i \mid p) \\ &\quad + w_2(1-\alpha) Q(q_i \mid p) + \phi_2 p (1-\alpha) Q(q_i \mid p) \\ &\quad - c_{s1} Q(q_i \mid p) - c_{s0i} \\ &= [\alpha w_1 + (1-\alpha) w_2] Q(q_i \mid p) \\ &\quad + [\alpha \phi_1 p + (1-\alpha)\phi_2 p] Q(q_i \mid p) \\ &\quad - c_{s1} Q(q_i \mid p) - c_{s0i}. \end{aligned} \tag{2}$$

The profit function of e-commerce platform is

$$\begin{aligned} \Omega_e(q_i, p) &= (1-\phi_1) p \alpha Q(q_i \mid p) - w_1 \alpha Q(q_i \mid p) \\ &\quad - c_{e1} Q(q_i \mid p) - c_{e0}. \end{aligned} \tag{3}$$

The profit function of 3PL is

$$\begin{aligned} \Omega_p(q_i, p) &= (1-\phi_2) p (1-\alpha) Q(q_i \mid p) \\ &\quad - w_2(1-\alpha) Q(q_i \mid p) - c_{p1} Q(q_i \mid p) \\ &\quad - c_{p0} + t Q(q_i \mid p). \end{aligned} \tag{4}$$

The profit function of supply chain is

$$\begin{aligned} \Omega(q_i, p) &= p Q(q_i \mid p) - (c_{s1} + c_{e1} + c_{p1}) Q(q_i \mid p) \\ &\quad - c_{s0i} - c_{e0} - c_{p0} + t Q(q_i \mid p) \\ &= (p+t) Q(q_i \mid p) - (c_{s1} + c_{e1} + c_{p1}) Q(q_i \mid p) \\ &\quad - c_{s0i} - c_{e0} - c_{p0}. \end{aligned} \tag{5}$$

4. The Research on Profit and Coordination of Supply Chain under E-Commerce Environment

4.1. The Existence of Maximum Profit of Supply Chain. Finding the first and the second derivative of $\Omega(q_i, p)$ of p for a given q_i according to (5), we can obtain

$$\begin{aligned} \frac{\partial \Omega(q_i, p)}{\partial p} &= Q(q_i \mid p) + p \frac{\partial Q(q_i \mid p)}{\partial p} \\ &\quad + (t - c_{s1} - c_{e1} - c_{p1}) \frac{\partial Q(q_i \mid p)}{\partial p} \\ &= Q(q_i \mid p) - (p + t - c_{s1} - c_{e1} - c_{p1}) \\ &\quad \times \int_0^{q_i} \frac{\partial F(y \mid p)}{\partial p} dy, \end{aligned} \tag{6}$$

$$\begin{aligned} \frac{\partial^2 \Omega(q_i, p)}{\partial p^2} &= 2 \frac{\partial Q(q_i \mid p)}{\partial p} + (p + t - c_{s1} - c_{e1} - c_{p1}) \\ &\quad \times \frac{\partial^2 Q(q_i \mid p)}{\partial p^2} \\ &= -2 \int_0^{q_i} \frac{\partial F(y \mid p)}{\partial p} dy - (p + t - c_{s1} - c_{e1} - c_{p1}) \\ &\quad \times \int_0^{q_i} \frac{\partial^2 F(y \mid p)}{\partial p^2} dy. \end{aligned} \tag{7}$$

Analyzing (5) and (6), then we get that the maximal value exists when certain conditions are satisfied.

Theorem 1. *When the conditions $\partial^2 F(y \mid p)/\partial p^2 > 0$ and $p \geq c_{s1} + c_{e1} + c_{p1} - t$ are met, there exists only one p_i^* for maximum supply quantity of each product, which makes the profit of supply chain maximum.*

Proof. For $\partial F(y \mid p)/\partial p > 0$, $\partial^2 F(y \mid p)/\partial p^2 > 0$ and $p \geq c_{s1} + c_{e1} + c_{p1} - t$; then

$$\begin{aligned} \frac{\partial^2 \Omega(q_i, p)}{\partial p^2} &= -2 \int_0^{q_i} \frac{\partial F(y \mid p)}{\partial p} dy \\ &\quad - (p + t - c_{s1} - c_{e1} - c_{p1}) \\ &\quad \times \int_0^{q_i} \frac{\partial^2 F(y \mid p)}{\partial p^2} dy < 0. \end{aligned} \tag{8}$$

That is, $\Omega(q_i, p)$ is a concave function on p.

When $p_1 = c_{s1} + c_{e1} + c_{p1} - t$, for $F(y \mid p_1) \le 1$, then $\int_0^{q_i} F(y \mid p_1)dy \le q_i$, and

$$\begin{aligned}\left.\frac{\partial\Omega(q_i,p)}{\partial p}\right|_{p=p_1} &= Q(q_i \mid p_1) - (p_1 + t - c_{s1} - c_{e1} - c_{p1}) \cdot \int_0^{q_i} \left.\frac{\partial F(y \mid p)}{\partial p}\right|_{p=p_1} dy \\ &= q_i - \int_0^{q_i} F(y \mid p_1)\, dy \ge 0.\end{aligned} \tag{9}$$

Letting $\Delta = \int_0^{q_i} (\partial F(y \mid p)/\partial p)|_{p=p_1} dy$, with the hypothesis $\partial F(y \mid p)/\partial p > 0$, we get $\Delta > 0$.

Since $\partial^2 F(y \mid p)/\partial p^2 > 0$, then $\partial F(y \mid p)/\partial p$ is a increasing function of p.

So, when $p_2 > p_1$, then $(\partial F(y \mid p)/\partial p)|_{p=p_2} > (\partial F(y \mid p)/\partial p)|_{p=p_1}$ holds and $\int_0^{q_i}(\partial F(y \mid p)/\partial p)|_{p=p_2} dy > \int_0^{q_i}(\partial F(y \mid p)/\partial p)|_{p=p_1} dy = \Delta$ holds.

If we let $p_2 > c_{s1} + c_{e1} + c_{p1} - t + (q_i/\Delta)$, then

$$\begin{aligned}\left.\frac{\partial\Omega(q_i,p)}{\partial p}\right|_{p=p_2} &= q_i - \int_0^{q_i} \partial F(y \mid p)\Big|_{p=p_2} dy \\ &\quad - (p_2 - c_{s1} - c_{e1} - c_{p1} + t) \times \int_0^{q_i} \left.\frac{\partial F(y \mid p)}{\partial p}\right|_{p=p_2} dy \\ &\le q_i - (p_2 - c_{s1} - c_{e1} - c_{p1} + t) \times \int_0^{q_i} \left.\frac{\partial F(y \mid p)}{\partial p}\right|_{p=p_2} dy \\ &\le q_i - \frac{q_i}{\Delta}\Delta = 0.\end{aligned} \tag{10}$$

From (9) and (10), we know that there exist p_1 and p_2 for maximum supply quantity q_i of each product, which makes $(\partial\Omega(q_i,p)/\partial p)|_{p=p_1} \ge 0$ and $(\partial\Omega(q_i,p)/\partial p)|_{p=p_2} \le 0$ true. According to the Zero Theorem, we obtain that there must be only one p_i^* for each q_i, which makes $(\partial\Omega(q_i,p)/\partial p)|_{p=p_i^*} = 0$ true, and then the profit of the whole supply chain achieves the maximum value.

In the supply chain model under e-commerce environment, we suppose that the profit of supply chain achieves the maximum value $\Omega(q_{\text{opt}}, p^*_{\text{opt}})$ when the supply quantity of S is q_{opt} and the corresponding final price of product of EC and 3PL is p^*_{opt}. □

4.2. The Coordination in Behavior of Supply Chain Members. When the maximum supply quantity of product is q_{opt}, the final selling price is p^*_{opt}; that is, when the profit of supply chain achieves the maximum, the profit functions in the supply chain and each member in this model are as follows.

The profit function of supplier S is

$$\begin{aligned}\Omega_s(q_{\text{opt}}, p^*_{\text{opt}}) &= w_1\alpha Q(q_{\text{opt}} \mid p^*_{\text{opt}}) + \phi_1 p^*_{\text{opt}}\alpha Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad + w_2(1-\alpha)Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad + \phi_2 p^*_{\text{opt}}(1-\alpha)Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad - c_{s1}Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{s0\text{opt}} \\ &= [\alpha w_1 + (1-\alpha)w_2 + \alpha\phi_1 p^*_{\text{opt}} + (1-\alpha)\phi_2 p^*_{\text{opt}} - c_{s1}] \\ &\quad \times Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{s0\text{opt}}.\end{aligned} \tag{11}$$

The profit function of e-commerce platform is

$$\begin{aligned}\Omega_e(q_{\text{opt}}, p^*_{\text{opt}}) &= (1-\phi_1)p^*_{\text{opt}}\alpha Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad - w_1\alpha Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{e1}Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{e0} \\ &= [\alpha(1-\phi_1)p^*_{\text{opt}} - \alpha w_1 - c_{e1}]Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{e0}.\end{aligned} \tag{12}$$

The profit function of 3PL is

$$\begin{aligned}\Omega_p(q_{\text{opt}}, p^*_{\text{opt}}) &= (1-\phi_2)p^*_{\text{opt}}(1-\alpha)Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad - w_2(1-\alpha)Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{p1}Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad - c_{p0} + tQ(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &= [(1-\alpha)(1-\phi_2)p^*_{\text{opt}} - (1-\alpha)w_2 - c_{p1} + t] \\ &\quad \times Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{p0}.\end{aligned} \tag{13}$$

The profit function of supply chain is

$$\begin{aligned}\Omega(q_{\text{opt}}, p^*_{\text{opt}}) &= p^*_{\text{opt}}Q(q_{\text{opt}} \mid p^*_{\text{opt}}) - (c_{s1} + c_{e1} + c_{p1})Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad + tQ(q_{\text{opt}} \mid p^*_{\text{opt}}) - c_{s0\text{opt}} - c_{e0} - c_{p0} \\ &= (p^*_{\text{opt}} + t - c_{s1} - c_{e1} - c_{p1})Q(q_{\text{opt}} \mid p^*_{\text{opt}}) \\ &\quad - (c_{s0\text{opt}} + c_{e0} + c_{p0}).\end{aligned} \tag{14}$$

Analysing (11), (12), (13), and (14), then we get that $\Omega_s(q_{\text{opt}}, p^*_{\text{opt}})$, $\Omega_e(q_{\text{opt}}, p^*_{\text{opt}})$, $\Omega_p(q_{\text{opt}}, p^*_{\text{opt}})$, and $\Omega(q_{\text{opt}}, p^*_{\text{opt}})$ are all unary functions of $Q(q_{\text{opt}} \mid p^*_{\text{opt}})$. Therefore, if there exist constants λ_1, λ_2, $0 \leq \lambda_1 \leq 1$ and $0 \leq \lambda_2 \leq 1$ can meet the following conditions

$$\begin{aligned}
&\alpha w_1 + (1-\alpha) w_2 + \alpha\phi_1 p^*_{\text{opt}} + (1-\alpha)\phi_2 p^*_{\text{opt}} - c_{s1} \\
&\quad = \lambda_1 \left(p^*_{\text{opt}} + t - c_{s1} - c_{e1} - c_{p1}\right), \\
&\alpha(1-\phi_1) p^*_{\text{opt}} - \alpha w_1 - c_{e1} = \lambda_2 \left(p^*_{\text{opt}} + t - c_{s1} - c_{e1} - c_{p1}\right), \\
&(1-\alpha)(1-\phi_2) p^*_{\text{opt}} - (1-\alpha) w_2 - c_{p1} + t \\
&\quad = (1-\lambda_1-\lambda_2)\left(p^*_{\text{opt}} + t - c_{s1} - c_{e1} - c_{p1}\right), \\
&c_{s0\text{opt}} = \lambda_1 \left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right), \\
&c_{e0} = \lambda_2 \left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right), \\
&c_{p0} = (1-\lambda_1-\lambda_2)\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right).
\end{aligned} \tag{15}$$

Then we obtain

$$\begin{aligned}
\Omega_s\left(q_{\text{opt}}, p^*_{\text{opt}}\right) &= \lambda_1 \Omega\left(q_{\text{opt}}, p^*_{\text{opt}}\right), \\
\Omega_e\left(q_{\text{opt}}, p^*_{\text{opt}}\right) &= \lambda_2 \Omega\left(q_{\text{opt}}, p^*_{\text{opt}}\right), \\
\Omega_p\left(q_{\text{opt}}, p^*_{\text{opt}}\right) &= (1-\lambda_1-\lambda_2)\,\Omega\left(q_{\text{opt}}, p^*_{\text{opt}}\right).
\end{aligned} \tag{16}$$

Since $\lambda_1, \lambda_2 \in [0,1]$ and $\Omega_s(q_{\text{opt}}, p^*_{\text{opt}})$, $\Omega_e(q_{\text{opt}}, p^*_{\text{opt}})$, and $\Omega_p(q_{\text{opt}}, p^*_{\text{opt}})$ can be seen as unary functions with coefficient greater than zero of $\Omega(q_{\text{opt}}, p^*_{\text{opt}})$, supplier S, e-commerce platform EC, and the third-party logistics 3PL achieve the maximum profit when the entire supply chain gets maximum profit. And they get λ_1, λ_2, and $(1-\lambda_1-\lambda_2)$ part of the maximum profit of entire supply chain, respectively. Then we know that the maximum profit of supply chain is consistent with the maximum profit of each member, and then the model realizes the coordination effect on supply chain members.

With the set of unary equations (15), we have

$$\begin{aligned}
\lambda_1 &= \frac{c_{s0\text{opt}}}{c_{s0\text{opt}} + c_{e0} + c_{p0}}, \\
\lambda_2 &= \frac{c_{e0}}{c_{s0\text{opt}} + c_{e0} + c_{p0}}.
\end{aligned} \tag{17}$$

Let

$$\begin{aligned}
\phi_1 &= 1 - \frac{\lambda_2}{\alpha} = \frac{\alpha\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right) - c_{e0}}{\alpha\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right)}, \\
\phi_2 &= \frac{\lambda_1 + \lambda_2 - \alpha}{1-\alpha} = \frac{c_{s0\text{opt}} + c_{e0} - \alpha\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right)}{(1-\alpha)\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right)}.
\end{aligned} \tag{18}$$

Then

$$\begin{aligned}
w_1 &= \frac{c_{e0}\left(c_{s1} + c_{p1} - t\right) - c_{e1}\left(c_{s0\text{opt}} + c_{p0}\right)}{\alpha\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right)}, \\
w_2 &= \frac{t\left(c_{s0\text{opt}} + c_{e0}\right) + c_{p0}\left(c_{s1} + c_{e1}\right) - c_{p1}\left(c_{s0\text{opt}} + c_{e0}\right)}{(1-\alpha)\left(c_{s0\text{opt}} + c_{e0} + c_{p0}\right)}.
\end{aligned} \tag{19}$$

According to the requirement of revenue sharing ratio, ϕ_1 and ϕ_2 should meet constraints $0 < \phi_1 < 1$ and $0 < \phi_2 < 1$, respectively. And since S sells the product to EC and 3PL at prices of w_1, w_2, respectively, then $w_1 > 0$, $w_2 > 0$.

Analysing (18), we get that if $0 < \phi_1 < 1$ and $0 < \phi_2 < 1$, we must have $c_{e0}/(c_{s0\text{opt}} + c_{p0}) < \alpha/(1-\alpha)$ and $(c_{s0\text{opt}} + c_{e0})/c_{p0} > \alpha/(1-\alpha)$. Analysing (19), we know that if $w_1 > 0$ and $w_2 > 0$, then $c_{e0}/(c_{s0\text{opt}} + c_{p0}) > c_{e1}/(c_{s1} + c_{p1} - t)$ and $c_{p0}/(c_{s0\text{opt}} + c_{e0}) > (c_{p1} - t)/(c_{s1} + c_{e1})$. Consequently, we can realize the coordination of the supply chain under e-commerce environment according to (18) and (19) to set the coordinate parameters ϕ_1, ϕ_2, w_1, and w_2 when relevant cost parameters of each member meet the above conditions.

Above all, the constructed model of profit distribution of supply chain in e-commerce environment can maximize the profit of supply chain when $\partial^2 F(y \mid p)/\partial p^2 > 0$, supply quantity of product is q_{opt}, and the corresponding selling price is $p^*_{\text{opt}} \geq c_{s1} + c_{e1} + c_{p1} - t$. Furthermore, coordinate parameters of supply chain ϕ_1, ϕ_2, w_1, and w_2 can be obtained from (18) and (19), when relevant cost parameters of each member satisfy the conditions $c_{e0}/(c_{s0\text{opt}} + c_{p0}) < \alpha/(1-\alpha)$, $(c_{s0\text{opt}} + c_{e0})/c_{p0} > \alpha/(1-\alpha)$, $c_{e0}/(c_{s0\text{opt}} + c_{p0}) > c_{e1}/(c_{s1} + c_{p1} - t)$, and $c_{p0}/(c_{s0\text{opt}} + c_{e0}) > (c_{p1} - t)/(c_{s1} + c_{e1})$. Then the entire supply chain achieves the maximum profit, and supply chain members S, EC, and 3PL earn the maximum profit at the same time. S, EC, and 3PL can get $\alpha\phi_1 + (1-\alpha)\phi_2$, $\alpha(1-\phi_1)$, and $(1-\alpha)(1-\phi_2)$ part of the profit of supply chain, respectively. Moreover, the shared ratio of profit only lies in the cost parameters of each member; that is, it has nothing to do with the demand.

5. Conclusion

In this paper, literature on profit distribution of supply chain is analysed first, and based on the analysis, we study a two-level and four-party supply chain which is composed of a supplier, an e-commerce platform, the third-party logistics, and demander; then a mathematical model of supply chain's profit is formulated. The profit distribution of supply chain under e-commerce is investigated from two aspects: the existence of maximum profit of supply chain and the model to coordinate the behaviors of members through the analysis of the profit functions of supply chain and each member.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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