Analysis of Supplier Competitiveness in Supply Chain Profit Distribution from the Perspective of Quantity Supplied and Price Research Based on Cournot Model and Bertrand Model

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Keywords: supply chain, Cournot model, Bertrand model, quantity supplied, price competition

Abstract. The relationship between retailers and suppliers is an important link in supply chain management. With the formation of buyer's market, the competition between suppliers and retailers is becoming increasingly fierce. This paper uses Cournot model and Bertrand model to study how suppliers enhance their competitiveness from the perspective of quantity supplied and price to obtain more profit distribution rights in supply chain.

1. Introduction

Nowadays, the true portrayal of the poor operation of some logistics enterprises (hereinafter referred to as logistics suppliers) manifested in economic depression, small volume of freight, fierce competition, Customer drain result from refuse to accept the demand side of cargo owner enterprise (hereinafter referred to as the demand side of logistics). Logistics suppliers in a relatively weak position want to obtain competitive advantage in the process of cooperation with demand-side of logistics unless they maintain a competitive and cooperative relationship with each other. In this essay, the Cournot model and Bertrand model of Game Theory will be introduced to analyze the competitive strategies of logistics suppliers.

2. Supply Strategy Based on Cournot Competition Model

Cournot competition model is a kind of production competition model, which takes supply quantity as competition means. According to the assumption of Cournot competition model, suppose logistics supplier 1 and logistics supplier 2 provide homogeneous logistics service[1].Suppose the logistics supply quantity of logistics supplier 1 is q_1, the logistics supply quantity of logistics supplier the logistics supplier 2 is q_2, and the total logistics supply quantity expression is $q = q_1 + q_2$; If the demand curve expression of logistics market is $q = a - p$ (p expressed as the price of logistics service, a is constant), then the inverse demand function expression of logistics market is $p(q) = a - q$.

Providing the total cost of providing q_i unit service products by logistics provider i is $c_i q_i$, where c_i is a normal number ($i = 1,2$), which described the competition model of logistics supplier 1 and logistics supplier 2 as a strategic competition model[2]. The three elements of the model are as follows:

1). Two players: logistics supplier 1 and logistics supplier 2;

2). The strategy set of any logistics supplier game is the set of logistics supply quantity which can be selected by the logistics supplier, given as $[0,+\infty)$;

3). The profit function of each logistics provider is:

$$\pi_i(q_1, q_2) = (a - q_1 - q_2)q_i - c_i q_i \qquad (1)$$

  DOI: 10.25236/icsm.2019.003

When the supply of logistics service products exceeds the demand, the problem that logistics supplier 1 and logistics supplier 2 should consider is how to determine the supply of logistics service in order to achieve the goal of profit maximization[3]. The following uses the test method of continuous Nash equilibrium to find the Nash equilibrium of game of logistics supplier 1 and logistics supplier 2. According to the profit function of the logistics supplier, the following equation holds:

$$\pi_1(q_1, q_2) = (a - q_1 - q_2)q_1 - c_1q_1 = -q_1^2 + (-q_2 + a - c_1)q_1 \qquad (2)$$

$$\pi_2(q_1, q_2) = (a - q_1 - q_2)q_2 - c_2q_2 = -q_2^2 + (-q_1 + a - c_2)q_2 \qquad (3)$$

Furthermore, according to the necessary conditions of Nash equilibrium, the Nash equilibrium (q_1^*, q_2^*) is the solution of the following two equations:

$$\frac{\partial \pi_1(q_1,q_2)}{\partial q_1} = -2q_1 - q_2 + a - c_1 = 0 \qquad (4)$$

$$\frac{\partial \pi_2(q_1,q_2)}{\partial q_2} = -q_1 - 2q_2 + a - c_2 = 0 \qquad (5)$$

The equations of (4) and (5) can be obtained by sorting out the equations:

$$q_1^* = \frac{a+c_2-2c_1}{3} \qquad (6)$$

$$q_2^* = \frac{a+c_1-2c_2}{3} \qquad (7)$$

Then calculate the second derivative of equations (2) and (3) equations, the following results are obtained:

$$\frac{\partial^2 \pi_1(q_1,q_2)}{\partial q_1^2} = -2 < 0 \qquad (8)$$

$$\frac{\partial^2 \pi_2(q_1,q_2)}{\partial q_2^2} = -2 < 0 \qquad (9)$$

The computational results of (8) and (9) prove that (q_1^*, q_2^*) is the Nash equilibrium of the game between the two suppliers of logistics. When the value of c_1 is infinitely close to that of c_2, $\lim q_1^* = \lim q_2^* = \frac{a}{3}$. In conclusion, in order to prevent the demand side of logistics service from suppressing the market price of logistics service, logistics supplier 1 and logistics supplier 2 should control the supply of logistics service product properly in the process of internal competition[4]. According to the results of Cournot model, for the sake of avoiding the internal contradiction and keeping the profit from being eroded by the demand side of logistics service, logistics supplier 1 and logistics supplier 2 should have adequate product supply.

Cournot competition model is used to describe the market game behavior, therefore, we should find a set of logistics service product supply quantity and a market price that satisfy the market equilibrium condition, which meet the following two conditions[5]:

1). When service price is $\widehat{P}$, logistics demand $q(\hat{p})$ equals $\left(\hat{q}_1 + \hat{q}_2\right)$;

2). $\left(\hat{q}_1, \hat{q}_2\right)$ is the supply of logistics services that two logistics suppliers are willing and able to provide at a price of $\widehat{P}$.

3). When the supply quantity of logistics supplier 1 and logistics supplier 2 is q_1^* and q_2^* respectively, the market price is:

$$p^* = a - q_1^* - q_2^* = a - \frac{a+c_2-2c_1}{3} - \frac{a+c_1-2c_2}{3} = \frac{a+c_1+c_2}{3} \qquad (10)$$

When the price is p^*, the demand is:

$$q(p^*) = a - p^* = \frac{2a-c_1-c_2}{3} \qquad (11)$$

Because of:

$$q_1^* + q_2^* = \frac{a+c_2-2c_1}{3} + \frac{a+c_1-2c_2}{3} = \frac{2a-c_1-c_2}{3} \qquad (12)$$

$q(p^*) = q_1^* + q_2^*$, that is, (11) = (12): when the market price is p^*, the logistics demand is exactly the sum of the supply of logistics services provided by the two logistics suppliers when

Nash equilibrium. The equilibrium supply on this price can maximize the profit of logistics supplier 1 and logistics supplier 2.

Through the Nash equilibrium analysis of the Cournot competition model mentioned above, the following three conclusions can be drawn[6]:

1). There is competition among logistics suppliers, but more cooperation is needed. Jointing restrictions on the supply of logistics services can effectively resist the wanton reduction of prices on the demand side of logistics services;

2). The equation $q(p^*) = q_1^* + q_2^*$ is established as long as the service supply of the logistics provider is equal to the equilibrium demand of the logistics market. The price of logistics services $p^* = \frac{a+c_1+c_2}{3}$ is determined by the supply and demand relationship in the logistics market, not by the demand side unilaterally;

3). The equation $q(p^*) = q_1^* + q_2^*$ is established, the equilibrium supply of logistics services at this price can maximize the profit of the two logistics suppliers.

3. Price Strategy Based on Bertrand Competition Model

Bertrand competition model is a price competition model, which uses price as a means of competition[3]. The following study will focus on the competitive behavior between the suppliers and the demanders from the perspective of price[7].

3.1. Enterprise pricing Strategy under the condition of Homogeneous Competition

Assuming that logistics supplier 1 and logistics provider 2 choose the prices of p_1 and p_2 respectively, the market demand for the service products of logistics provider i is as follows:

$$q_i(p_i, p_j) = a - p_i + bp_j, \quad i = 1,2, i \neq j, \qquad (13)$$

In this formula $a, b > 0$, where $b > 0$ measures the degree of substitution of the products of the logistics supplier j to the products of the logistics supplier i. Similar to Cournot competition model, Bertrand model provides that logistics supplier has no fixed production cost, and the marginal cost is a common constant c, where $c < a$. The two logistics suppliers choose their respective prices to compete in the market. The competition model of logistics supplier 1 and logistics supplier 2 is still expressed as a strategic competition model in the essay, the three elements of the model are as follows:

1). Two players: logistics supplier 1 and logistics supplier 2;

2). Supposing that the price less than 0 has no meaning, the logistics supplier is free to choose any non-negative price[8];

3). The set of strategy of each logistics supplier's pricing is represented as $S_i = [0, \infty]$, i.e., the set of strategy S_i is the price $p_i \geq 0$ chosen by the enterprise i;

4). There is no difference in logistics services provided by logistics supplier 1 and logistics supplier 2.

When the logistics supplier i chooses price p_i and the competitor chooses p_j, the profit of the logistics supplier i is as follows:

$$\pi_i(p_i, p_j) = q_i(p_i, p_j)[p_i - c] = [a - p_i + bp_j]\,[p_i - c], i = 1,2, i \neq j \qquad (14)$$

According to the necessary conditions for the Nash equilibrium in a continuous case, the Nash equilibrium of the price game (p_1^*, p_2^*) is the following two equations:

$$\frac{\partial \pi_1(p_1, p_2)}{\partial p_1} = -2p_1 + bp_2 + a + c = 0 \qquad (15)$$

$$\frac{\partial \pi_2(p_1, p_2)}{\partial p_2} = bp_1 - 2p_2 + a + c = 0 \qquad (16)$$

By sorting out the equations of (15) (16), we can obtain:

$$p_1^* = p_2^* = \frac{a+c}{2-b} \qquad (17)$$

Then calculate the second derivative of equations (15) and (16), the following results are obtained:

$$\frac{\partial^2 \pi_1(p_1,p_2)}{\partial p_1^2} = -2 < 0 \qquad (18)$$

$$\frac{\partial^2 \pi_2(p_1,p_2)}{\partial p_2^2} = -2 < 0 \qquad (19)$$

The calculation of the second derivative further shows that the Nash equilibrium of the game is $p_1^* = p_2^* = \frac{a+c}{2-b}$, i.e., the optimal pricing strategy for logistics supplier 1 and logistics supplier 2.

3.2. Enterprise Pricing Strategy Under the Condition of Differential Competition

Considering the differences of service quality, timeliness and service region between the two logistics providers, the paper reconstructs Bertrand's competition model[9]. When logistics supplier 1 and logistics supplier 2 choose the price of p_1 and p_2 respectively, the market demand function of the two logistics suppliers is as follows:

$$q_1(p_1, p_2) = a - p_1 + \beta p_2 \qquad (20)$$

$$q_2(p_1, p_2) = a - p_2 + \beta p_1 \qquad (21)$$

Where a is a constant, β denotes the degree of substitutability of the service products of two logistics suppliers. $\beta \in [0, 1]$, when the service products of two logistics providers are not substituTable, $\beta = 0$; When the service products of the two logistics providers are completely substituted, $\beta = 1$, i.e., the greater the β, the stronger the substitution of service products, and the more obvious the homogeneity is[10].

The total cost of the logistics supplier is C, and the profit function of the two suppliers can be expressed as:

$$\pi_i = q_i(p_i, p_j) * p_i - C \qquad (22)$$

According to the principle of profit maximization, $p_i^* = \mathrm{argmax}\,\pi_i(p_i, p_j)$ is obtained, and the first order partial derivation of π_i is obtained that is equal to 0:

$$\frac{\partial \pi_i}{\partial p_i} = a - 2p_i + \beta p_i = 0 \qquad (23)$$

According to the necessary conditions for the Nash equilibrium in a continuous case, the Nash equilibrium of the price game (p_1^*, p_2^*) is the following two equations:

$$a - 2p_1 + \beta p_2 = 0 \qquad (24)$$

$$a - 2p_2 + \beta p_1 = 0 \qquad (25)$$

Simultaneous equations (24) and (25) can obtain:

$$p_1^* = p_2^* = \frac{a}{2-\beta} \qquad (26)$$

Finally, calculate the second derivative of equations (24) and (25), and the following results are obtained:

$$\frac{\partial^2 \pi_1(p_1,p_2)}{\partial p_1^2} = -2 < 0 \qquad (27)$$

$$\frac{\partial^2 \pi_2(p_1,p_2)}{\partial p_2^2} = -2 < 0 \qquad (28)$$

The calculation of the second derivative further shows that the Nash equilibrium of this game is $p_1^* = p_2^* = \frac{a}{2-\beta}$, i.e., the optimal pricing strategy of logistics supplier 1 and logistics supplier 2 under the condition of differential competition[11]. It can be seen from the calculation results that the higher the service substitution and the greater the β value, the greater the profit space of the logistics supplier.

4. Conclusion

Cournot competition model and Bertrand competition model are based on the complete rationality of both sides of the game, i.e., the two logistics suppliers in the game know the competitor's reaction function, profit, output and pricing decision, etc.

Modern enterprises are faced with how to determine supply quantity and price to achieve the goal of profit maximization, at the same time, there is fierce competition among logistics suppliers[4]. The model calculation shows that maintaining competitive and cooperative relationship is conducive to enhancing the overall competitiveness of logistics suppliers and improving their discourse power during the supply chain distribution mechanism.

Through the introduction of Cournot model and Bertrand model and under the duopoly competition market pattern, the optimal supply strategies of logistics supplier 1 and logistics provider 2 are as follows: $q_1^* = \frac{a+c_2-2c_1}{3}$, $q_2^* = \frac{a+c_1-2c_2}{3}$. The second derivative calculation further proves that in order to avoid the demand-side of logistics services taking advantage of the competitive advantage of the market to arbitrarily suppress the market prices of logistics services, logistics supplier 1 and logistics supplier 2 should properly control the supply of logistics service products in the process of competition, therefore, reach the optimal solution of Nash equilibrium.

Under the condition that there is no difference in service products, the optimal pricing strategy for logistics supplier 1 and logistics provider 2 is as follows: $p_1^* = p_2^* = \frac{a+c}{2-b}$. The calculation of the second derivative further indicates that $p_1^* = p_2^* = \frac{a+c}{2-b}$ is the Nash equilibrium of the homogeneous game[12]. Under the condition that the service product is different, the optimal pricing strategy of logistics supplier 1 and logistics supplier 2 is as follows: $p_1^* = p_2^* = \frac{a}{2-\beta}$, The calculation of the second derivative further manifests that $p_1^* = p_2^* = \frac{a}{2-\beta}$ is the Nash equilibrium of the differential game. The greater the β value, the higher the service substitution of the logistics suppliers and the greater the profit space of the logistics suppliers.

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