Rural logistics service providers pricing and competition-cooperation research considering the 3PL accessibility

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Abstract

Rural logistics service providers pricing and competition-cooperation problems are researched in this article considering the 3PL accessibility in which the post logistics dominants. In the competition stage a model of master-slave Stackelberg game is to be established, and in the stage of cooperation, a cooperation model under different circumstances and the optimal pricing scheme without government intervention are discussed. This study could provide some economic phenomena existing explanations, as well as a reference and theoretical support for the decision-making act of Postal Logistics and other rural logistics-related subject.

Keywords: agricultural products logistics, post logistics, pricing, game theory, rural logistics

1 Introduction

With the rapid development of industrialization of agriculture and rural economic and social integration, it puts forward higher requirements of modernization of production, supply and consumption patterns on functions, methods and efficiency of agro-food logistics. The rapid rise of Third Party Logistics (3PL) provides more convenient for the exchange of goods between urban and rural areas in developed regions and greatly reduces the cost of circulation of agricultural products and agricultural production. At the same time, it also brought greater competition and challenges to traditional postal logistics. However, in the less developed areas of the rural economy, coverage of 3PL is still very low in addition to the postal logistics, and then the relationship between Postal Logistics and third party logistics companies faces not only competition but also a lot of possible cooperation. Therefore, under the rapid development of third-party logistics background, the study of competing and pricing problem between agricultural logistics and multi-service providers has a theoretical reference value, which can ensure effective express of urban agricultural logistics needs and reasonable conduct of rural logistics supply.

2 Theoretical review

The third-party logistics refers to a business model that the logistics service is provided by companies beside the demand side and the supply side. In other countries, it is also known as contract logistics, logistics or logistics alliance externalizing [1]. With the development of the social division of labour, more and more companies focused on their core business, logistics outsourcing to more specialized companies. Currently, 3PL is widely used in various industries, including pricing method such as the transaction affecting pricing, operating cost pricing, cost-plus pricing method, pricing and revenue sharing pricing as well as benchmark price method [2]. These methods have advantages and disadvantages. For example, the transaction affecting pricing is simple but not flexible, and operating cost pricing calculates accurate but more complex, while cost-plus pricing method is likely to cause controversy. In practical applications, one or several methods (or deformation) are often used, and some also include other incentives or punitive measures, which is not conducive to effective communication, management and coordination between the main supply chain members [3]. Therefore, some scholars start from different systems state, and consider balancing strategy of 3PL pricing decisions in different ways. In recent years, pricing issues of logistics provider's service studied by scholars have increased gradually. Lei L (2006) [4] studied the optimal pricing of third-party logistics service providers and their downstream when the needs of price-sensitive. Bernstein [5] discussed the issue of price equilibrium under price and service competition. Liu and Wu (2011) [6] analysed the coordination of the two-stage supply chain system including the logistics service providers to participate and discussed the wholesale contract price in the two-step charges. Most of these studies are based on the expanded supply chain. In addition, there have been many scholars who began to focus on the interaction problem between the main of supply chain logistics. Xiao [7] and other agricultural products from the behaviour of the main logistics and cooperation tend to prefer starting the main

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agricultural products between the logistics demand, revenue between the main supply, cooperation and non-cooperation between the supply and demand sides in case of a comparative analysis. Although their study covering both supply and demand of agricultural products, but not yet involved in agricultural logistics service providers. Based on evolutionary game theory, Li Lihue [8] studied the problem of cooperation and coordination of logistics of the same business logistics alliance in the state below the asymmetric nature. Guo [9] analysed the distribution of benefits with the idea of using non-cooperative game method when both supply and demand sides in logistics alliance faced different costs of information and consumption coefficients. The research mainly considered the optimal allocation of interests in co-operation and non-cooperative cases, but the reality is often more complicated. The situation between cooperation and non-cooperation is not identical same in different scenarios, even the same subject reacts differently in different geographical conditions.

This article conducts in-depth and refinement research based on this, specifically discusses the pricing and competing issues of supply chain logistics service providers. Service pricing and competition and cooperation issues of rural logistics service providers (in agricultural logistics, for example) are researched under the circumstances that the third-party logistics(excluding postal logistics) has or not owned outlets of logistics in remote rural areas, respectively. Assuming logistics providers' demand for agricultural products has certain needs rigidity. The total amount of logistics is fixed. Products are sent to buyers through third-party logistics, producing a certain loss in transit. Agricultural products demanders determine their optimal pricing strategies and decisions selected through the game theory, in order to provide some theoretic support of decision making for Postal Logistics and other agricultural products logistics related subjects.

3 Research model

The flow of agricultural products is from farmers to urban demanders. For agricultural logistics service provider, its cost function is $C(x)=F+v(x,l)$, and x – transport tonnage, l – routes, $v(x,l)$ – changes in freight costs. In the formula, $v(x,l)=\eta_1 x+\eta_2 l$ and η_1 – the affected factor of shipping volume on changes in freight cost, η_2 – the affected factor of transport distance on changes in freight cost. The revenue function is $\pi(x)=pxl$, and p – tonne-kilometres freight.

For agricultural products logistics demanders, the cost to choose a logistics service provider is $C\ x\ =\pi\ x\ +t\delta\ x\ +T\ t$ and t – transport time, δ – loss of agricultural units per unit of time, $T\ t\ =\lambda t$ is psychological and other costs for waiting t to get the products. Its size may reflect the level of agricultural logistics service, and λ – the cost of per unit of time.

There are two logistics service providers on the market, Postal Logistics and third party logistics. To show the difference, note Postal Logistics subscript 1, and the third-party logistics 2.

3.1 PRICING AND CASE SOLVING IN COMPETITION

Between the agricultural products demander and supplier, there is third-party logistics besides Postal Logistics network. That is to say, other third party logistics server can cover both, and the road is good. Assuming the amount of agricultural products logistics needs is fixed, i.e. $x_0=x_1+x_2$. So for two logistics companies operating independently and competing with each other, want to attract more suppliers of agricultural products (or the needs of providers) to choose their own service by adjusting price under certain conditions. If it comes to the equilibrium state, it should be met:

$$C_1=C_2;\ x_1>0, x_2>0, \tag{1}$$

$$C_1>C_2;\ x_1=0, x_2>0, \tag{2}$$

$$C_1<C_2;\ x_1>0, x_2=0. \tag{3}$$

Equation (1) represents that the two logistics companies make the same price, and there are people who commission them to transport agricultural products. Equation (2) means that all agricultural products are issued by the third party Logistics Company as a result of a lower price compared with the Post Logistics. Equation (3) is just the opposite to Equation (2). Obviously, as a rational man, any logistics company will not let the latter two cases be true. It can be calculated from Equation (1):

$$x_1=\frac{p_2x_0l+t_2\delta x_0+\lambda(t_1-t_2)}{(p_1+p_2)l+(t_1+t_2)\delta}, \tag{4}$$

$$x_2=\frac{p_1x_0l+t_1\delta x_0+\lambda(t_1-t_2)}{(p_1+p_2)l+(t_1+t_2)\delta}. \tag{5}$$

Conclusion 1. In circumstances of certain total logistics demand, to attract more customers, an alternative strategy is to cut price or increase the reaction rate (the waiting time is shorter), and lower customer waiting costs (also reduces losses during circulation of agricultural products).

Proof: From the partial derivative of Equation (4) and (5), we get

$$\frac{\partial x_1}{\partial p_1}=\frac{-x_1l}{(p_1+p_2)l+(t_1+t_2)\delta}\le 0,$$

$$\frac{\partial x_1}{\partial t_1}=\frac{-(\lambda+\delta x_1)}{(p_1+p_2)l+(t_1+t_2)\delta}\le 0.$$

Similarly, $\frac{\partial x_2}{\partial p_2} \le 0$, $\frac{\partial x_2}{\partial t_2} \le 0$.

The transportation volume of each logistics company is the decreasing function of its shipping rates and transit time, so the above conclusion holds.

Conclusion 2. When the two logistics companies change their strategy, one's increase speed of logistics amount is the reduce speed of the other.

Proof: Through derivation, we know

$$\frac{\partial x_2}{\partial p_2} = -\frac{\partial x_1}{\partial p_1},\ \frac{\partial x_1}{\partial p_1} = -\frac{\partial x_2}{\partial p_1},\ \frac{\partial x_1}{\partial t_1} = -\frac{\partial x_2}{\partial t_1},\ \frac{\partial x_1}{\partial t_2} = -\frac{\partial x_2}{\partial p_2}.$$

The problem is proved.

Due to the postal logistics' larger size, multi-network, wide area coverage, so it dominates the decision-making process. The third-party logistics company chooses its own best decisions based on the postal logistics' decisions. This process constitutes a Stackelberg game, which can be calculated with backward induction method.

The third-party logistics' decision problem is:

$$\max R_2 = \max \quad p_2 x_2 l - \eta_1 x_2 - \eta_2 l - F_2 \quad . \tag{6}$$

Since R_2 is the concave function of P_2, the optimal reaction function can be calculated from form Equation (6):

$$p_2^* = R_2^{'}(p_2) = \frac{(p_1 l^2 + (t_1+t_2)\delta l + \eta_1 l)(p_1 l x_0 + t_1 \delta x_0 + \lambda(t_1 - t_2))}{(p_1 l + t_1 \delta + p_2 l + t_2 \delta)^2}. \tag{7}$$

The decision problem of Postal Logistics is:

$$\max R_1 = \max \quad p_1 x_1 l - \eta_1 x_1 - \eta_2 l - F_1 \quad = \max\left\{\frac{(p_2 x_0 l + t_2 \delta x_0 - \lambda(t_1 - t_2))(p_1 l - \eta_1)}{(p_1 + p_2) l + (t_1 + t_2)\delta} - \eta_2 l - F_1\right\}. \tag{8}$$

S.t

$$p_2^* = \frac{(p_1 l^2 + (t_1+t_2)\delta l + \eta_1 l)}{(p_1 l + t_1 \delta + p_2 l + t_2 \delta)^2} \times (p_1 l x_0 + t_1 \delta x_0 + \lambda(t_1 - t_2))$$

$$\left(\frac{\eta_1 x_1 + \eta_2 l + F_1}{x_1 l}, \frac{\eta_1 x_2 + \eta_2 l + F_2}{x_2 l}\right) \in (p_1, p_2). \tag{9}$$

3.2 MUTUAL COOPERATION AND PRICING

Scenario 1. Postal Logistics and third party logistics enterprises have outlets in both the agricultural products suppliers and the demanders, but the road condition has changed. Assuming rural road length l_1, length of urban highway l_2, the total length is $l = l_2 + l_2$. Taking into account the urban road traffic is better, the relative complexity of rural road conditions, the road coefficient $\rho(\rho \succ 1)$ [10] is introduced to facilitate the discussion. Then for the country road whose actual distance is l_1, the weighted distance is $l_1^{'} = \rho l_1$. Demand of those, who need logistics service is a function on the logistics prices, expressed as $x(p) = b - kp$ [11]. And b is market capacity, k is a factor sensitive to demand and price. As the competition will reduce their income, the two logistics company could co-exist. Considering it is unlikely for the Postal Logistics to be solely responsible for the rural sections, and cooperate with 3PL in roads of towns by each responsible for part of the products, so pricing issues will be discussed below under two cooperation situation respectively.

The two companies each is responsible for a certain volume of agricultural products, with transport distance of the whole journey $l^{'} = \rho l_1 + l_2$. At this time, the Postal Logistics Company's revenue is

$$R_1 = p_1 x_1 l^{'} - v(x_1, l^{'}) - F_1.$$

The third party logistics company's revenue is

$$R_2 = p_2 x_2 l^{'} - v(x_2, l^{'}) - F_2.$$

Equivalent behavioural strategy of both companies is to maximize its total revenue, namely:

$$\begin{aligned}\max R_{(1)} &= \max \quad p_1 x_1 l^{'} - F_1 - v(x_1, l^{'}) + p_2 x_2 l^{'} - F_2 - v(x_2, l^{'}) \quad = \\ &-k p_1^2 l^{'} + (b l^{'} + k\eta_1) p_1 - k p_2^2 l^{'} + (b l^{'} + k\eta_1) p_2 \\ &-2\eta_1 b - 2\eta_2 l^{'} - F_1 - F_2.\end{aligned} \tag{10}$$

The graphics of $R_{(1)}$ is a parabola opening down on p_1 and p_2, so the maximum value can be obtained at the apex.

From $\begin{cases} \frac{\partial R_{(1)}}{\partial p_1} = -2kp_1 l^{'} + b l^{'} + k\eta_1 = 0 \\ \frac{\partial R_{(1)}}{\partial p_2} = -2kp_2 l^{'} + b l^{'} + k\eta_1 = 0 \end{cases}$,

we get:

$$p_1 = p_2 = \frac{b(\rho l_1 + l_2) + k\eta_1}{2k(\rho l_1 + l_2)} = \frac{b l^{'} + k\eta_1}{2kl^{'}}. \tag{11}$$

Conclusion 3. If the final amount of logistics $x \to b$, the price elasticity of demand can be is launched reversibly 0. That is to say, due to the rigid demand, logistics demanders will choose the logistics services at all costs.

Proof: From $x(p) = b - kp$, we have $k = (b - x)/p$, if $x \to b$, then $k \to 0$, the problem is proved.

Conclusion 4.

$$R_{(1)} = \frac{(bl' + k\eta_1)^2}{2kl'} - 2\eta_1 b - 2\eta_2 l' - F_1 - F_2$$

is the total revenue of logistics service providers. The problem is easy to prove by substituting Equation (11) into (10).

The Postal Logistics Company responsible for rural roads, the transport distance is l_1. The 3PL Company responsible for urban highway, the transportation distance is l_2. When the product flows from farmers to urban providers, the Postal Logistics first contact with logistics demanders. At this point it develops a price p to maximize the total revenue, and the whole income is $r = pxl'$.

All the cost is

$$c = v(x, l_1') + F_1 + v(x, l_2) + F_2 .$$

Equivalent behavioural strategy of both companies is to maximize its total revenue, namely:

$$\begin{aligned} R_{(2)} &= pxl' - v(x, l_1') - F_1 - v(x, l_2) - F_2 = \\ &-kl' p^2 + (bl' + 2k\eta_1) p - 2b\eta_1 - \eta_2 l' - \sum F_i \end{aligned} \tag{12}$$

From $\frac{\partial R_{(2)}}{\partial p} = -2kl' p + bl' + 2k\eta_1 = 0$,

the best price is

$$p = \frac{2k\eta_1 + bl'}{2kl'} . \tag{13}$$

Conclusion 5. The total revenue is

$$R_{(2)} = \frac{(bl' + 2k\eta_1)^2}{4kl'} - 2\eta_1 b - \eta_2 l' - \sum F_i .$$

The problem can be proved by substituting Equation (13) into Equation (12).

Scenario 2. There is no 3PL outlets from agro-food providers to demanders except the postal logistics. Then the Postal Logistics will face two different choices, one is transportation alone, and the other is cooperating with 3PL on downtown roads where there is 3PL outlets. Mark the total distance l, where rural road transport distance l_1, urban highway transportation distance is l_2.

1) Postal Logistics Company's network coverage is more comprehensive, with greater choice autonomy. It might be seen as the Postal Logistics commission 3PL to continue the carriage on the town road (regulatory costs neglected).Then the two have formed a secondary principal-agent relationship. As above, logistics demanders' linear inverse demand function is $x(p)$. In this case, the third party logistics company's revenue function is:

$$R_2 = p_2 l_2 x_2 - F_2 - v(x_2, l_2) =$$

$$p_2 l_2 (b - kp_2) - \eta_1 (b - kp_2) - \eta_2 l_2 - F_2 ,$$

$$\text{S.t } x_2 \le x_1 \tag{14}$$

Construct the Lagrangian function:

$$L = p_2 l_2 (b - kp_2) - \eta_1 (b - kp_2) - \eta_2 l_2 - F_2 + \varphi(x_1 - b + kp_2),$$

and solve the problem with Kuhn Tucker conditions to obtain the 3PL's optimal pricing decisions:

$$p_2^* = \frac{\partial R_2}{\partial p_2} = \frac{bl_2 + \eta_1 k}{2kl_2} . \tag{15}$$

Due to the volume of Postal Logistics in rural sections l_1 is x_1, urban roads $x_1 - x_2$, so converted into an equivalent volume level of the entire road is

$$\tilde{x} = \frac{x_1 l_1' + l_2 (x_1 - x_2)}{l'} = x_1 - \frac{x_2 l_2}{l'} .$$

The Postal Logistics Company's revenue function is:

$$\begin{aligned} R_1 &= p_1 l' x_1 - F_1 - v(\tilde{x}, l') - p_2 l_2 x_2 = \\ &p_1 l' (b - kp_1) - F_1 - \eta_1 \tilde{x} - \eta_2 l' - p_2 l_2 x_2 \end{aligned} . \tag{16}$$

Eventually we obtain Postal Logistics' optimal pricing:

$$p_1 = \frac{bl' + k\eta_1}{2kl'} . \tag{17}$$

2) When postal logistics company selected to ship alone, its revenue function can be expressed as:

$$\begin{aligned} R_1' &= p_1 xl' - F_1 - v(x, l') = \\ &p_1 l' (b - kp_1) - F_1 - \eta_1 (b - kp_1) - \eta_2 l' \end{aligned} . \tag{18}$$

Ditto, the optimal pricing is:

$$p_1' = \frac{bl' + k\eta_1}{2kl'} . \tag{19}$$

Conclusion 6. When 3PL not cover rural areas, the Postal Logistics' pricing has nothing to do with whether it commissioned 3PL to transport the agro-food. It can be verified from Equation (17) and (19).

Conclusion 7. When the Postal Logistics commissioned 3PL to transport the agro-food, its revenue is less than when carrier alone.

Proof: Substitute the Equations (15) and (17) into (16):

$$R_1 = \frac{b^2 l' - b^2 l_2}{4k} + \frac{2b\eta_1 l_2 - k\eta_1^2}{4l'} + \frac{k\eta_1^2}{4l_2} - F_1 - \frac{\eta_1 b}{2} - \eta_2 l' . \tag{20}$$

Substitute the Equation (19) into (18):

$$R_1' = \frac{b^2 l'}{4k} + \frac{k\eta_1^2}{4l'} - \eta_2 l' - F_1 - \frac{1}{2}\eta_1 b . \tag{21}$$

By subtracting Equation (20) from Equation (21) we have:

$$R_1^{'} - R_1 = \frac{k\eta_1^2}{2l^{'}} + \frac{b^2 l_2}{4k} - \frac{k\eta_1^2}{4l_2} = \frac{2k^2\eta_1^2 l_2 + (b^2 l_2^2 - k^2\eta_1^2)l^{'}}{4kl_2 l^{'}} > 0.$$

Therefore, the problem is proved.

4 Numerical example

For a more intuitive understanding of the model above, further analysis is made as the following. Since the revenue under competition must be less than the income in case of mutual cooperation, a brief analysis of the following two cases were mainly on mutual cooperation. Assuming the parameters in the model is k =1, $l_1 = l_2$ =50, $\eta_1 = \eta_2$ =0.5, ρ =1.2, F_1 =30, F_2 =20, b =100. By the Mat lab programming, we know the two logistics companies are both priced at 50, and the total revenue is 5.5×10^5 in Scenario 1. The first cooperation mode in Scenario 2, the revenue of postal logistics changes as the price, shown in Figure 2. In the Figure, its highest income is between 2.5 × 10^5 and 3 × 10^5. While selecting carriers alone, the graph of its revenue is a parabola that changes with price as shown in Figure 3, and the highest point value is 2.75 × 10^5. Because it is assumed that the haul and traffic have the same coefficient impacting on the cost during numerical example, and the value of total distance and total volume is equal, the result displayed in this case shows that the income is the same whatever Postal Logistics transports alone or cooperate with the third-party logistics.

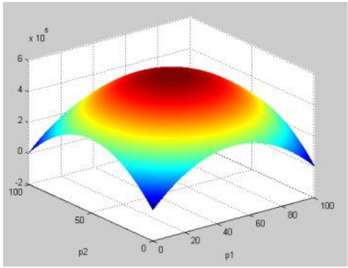

FIGURE 1 The changes of logistics service providers' total revenue with price

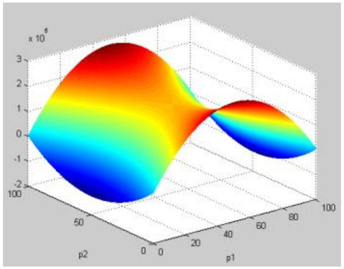

FIGURE 2 The changes of Postal Logistics' total revenue with price in Scenario 2(1)

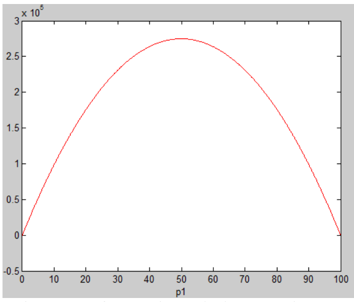

FIGURE 3 The changes of Postal Logistics' total revenue with price in Scenario 2(2)

5 Conclusion

This article gives a detailed analysis of several situations where postal logistics and third party logistics may meet with in the process of agro-food transport from rural to urban areas, and the results are verified by the use of Numerical example. In the case without prejudice to the interests of consumers, cooperation between postal logistics and third party logistics is conducive to reducing costs. However, with the existence of market information asymmetry, the subjects involved in rural logistics usually move toward the direction which is most favourable to their own marketing activities. When logistics service providers take collusion, it is easy to form a monopoly, which not only harms the interests of consumers but to some extent inhibits the market demand. It is not conducive to the healthy development of the logistics industry in rural areas. Therefore, in subsequent studies, it is necessary to take government intervention and activities of other related subjects into account, and further enrich the theory on agricultural logistics and pricing issues in competition as well as cooperation.

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