Static Game Distribution Service Pricing Method Considering Consumers' Green Preference and Consumption Level

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Abstract. In the context of developing circular economy and achieving carbon neutrality as an important issue for China's sustainable economic development, consumers' green preferences for products and services are increasing, and such preferences will directly affect market demand and enterprises' production decisions. Considering that the relocation of logistics and distribution enterprises will increase the negative externalities generated by distribution activities and will cause social welfare losses, it is important to consider consumers' green preferences in the pricing of distribution services. In this paper, we divide consumers according to their green preferences, and construct a distribution service pricing model based on the static game approach, using equilibrium price theory and consumer surplus theory. After numerical simulation analysis, the results found that as the proportion of consumers in the interval and the consumption level increase, the demand in the interval also increases; and the degree of green preference of consumers in the interval is positively correlated with the profit of enterprises.

Keywords: Consumers' green preference · Consumer surplus · Externality theory · Relocation of logistics facilities · Static game · Nash equilibrium

1 Introduction

With the development of urbanization, logistics and distribution companies in large cities at home and abroad, such as Paris, Los Angeles, Toronto, Tokyo, and Wuhan, have seen the phenomenon of relocation of facilities [2, 3, 5, 9, 11]. The relocation of logistics facilities inevitably increases the distribution distance, which in turn generates greater negative externalities of distribution, including air pollution, energy consumption and traffic congestion [11], which is inconsistent with the modern green logistics system that requires each link in the logistics chain to build and operate according to the green concept [7], and contradicts the concept of achieving sustainable development. In the absence of external incentives, enterprises have no motivation to implement green logistics actively, and the development of green logistics relies heavily on the incentives of external factors such as government supervision [16]. In fact, consumers with green preferences who

are willing to pay a premium can also promote the implementation of green services by enterprises [12]. Therefore, it is of great theoretical and practical significance to explore the pricing of distribution services of logistics and distribution companies considering the factors of consumers' green preferences.

In recent years, more and more scholars have started to study the behavior of firms from the perspective of externality and green development. Takanori et al. (2019) studied the relationship between the layout of logistics facilities and their level of externality in the Tokyo area and concluded that the scarcity of logistics facilities near high-demand are as exacerbates negative externalities. Wei Zhang et al. (2020) studied the hierarchical pricing of green products and argued that firms can make pricing decisions based on different green preferences and consumption levels of consumers. Hu et al. (2021) studied the two-sided evolutionary game between government and manufacturers considering carbon taxes, subsidies and consumers' low-carbon preferences and argued that consumers' low-carbon preferences have a significant impact on manufacturers' low-carbon decisions.

However, there are few papers that apply game theory to the pricing of distribution services of logistics and distribution enterprises, especially those that take into account consumers' green preferences, and most of the game literature on logistics externalities does not link green preferences with consumption levels, but only as an isolated parameter of enterprise profits. The theory of equilibrium price is the basic belief of Western economics, and since Adam Smith proposed the "invisible hand", the price mechanism has been generally considered as an important way to regulate the market economy, which is also the most basic embodiment of the essence of market economy. The equilibrium price is the price of a commodity when the quantity demanded is equal to the quantity supplied. At this time, the price of demand and supply of the commodity is equal to the equilibrium price, the quantity of demand and supply of the commodity is equal to the equilibrium quantity. The equilibrium price theory believes that the price of a commodity is determined by the equilibrium of forces between supply and demand in the market, and from this perspective, the pricing of distribution services is the result of the joint action of supply and demand.

In addition, consumer surplus is the difference between the maximum price a consumer is willing to pay in his mind when purchasing an item and the actual price of that item in the market [8]. The difference between these two reflects the subjective psychological satisfaction consumers receive when purchasing the item and is an important indicator of consumer welfare. Consumer surplus theory is mainly used to guide pricing in practice. The literature [18] considered consumer preferences in calculating benefits and analyzed the impact of consumers' environmental preferences on firm pricing and firm utility. The literature [19] and [20] analyzed how to improve the performance of green supply chain management. Li Hong [1] applied the consumer surplus theory to analyze how road transportation enterprises should stand in the consumer's perspective to formulate the problem of enterprise's market development strategy. Wu Qun-qi et al. (2009) applied consumer surplus theory and proposed a new consumer surplus-based pricing method for logistics services in order to better guide the pricing behavior of logistics enterprises. Consumer surplus theory has been widely used in the pricing and policy effect analysis of tourism, library service, civil aviation, electric power, medical

industry and even public infrastructure sector, and it is also applicable to logistics service industry.

This paper constructs a distribution service pricing model based on the equilibrium price theory and consumer surplus theory considering consumer consumption level and green preference, and analyzes indicators such as consumer demand and enterprise profit accordingly based on the model, which provides some reference for enterprises' logistics and distribution service pricing.

The outline of this article is given as below. Some preliminaries and problem formulations are provided in Sect. 2. The main results of this paper are presented in Sect. 3, followed by an illustrative example in Sect. 4. Eventually, the conclusions are given in Sect. 5.

2 Preliminaries and Model Formulation

In this section, some theories and necessary assumptions will be introduced, and the model formulation is derived via the Consumers' green preference, Nash equilibrium and Consumer surplus.

2.1 Preliminaries

2.1.1 Nash Equilibrium

Chiang et al. (2003) first proposed to determine the sales volume of a product based on the difference in consumer's perception of the utility of the consumer product.

In the topological space based on Euclid's theorem, let X be a set, O be a family of subsets of X, (X, O) is called a topological space, if the empty set and X belongs to O, O in any number of elements of and still belongs to O, O in a finite number of elements of the intersection still belongs to O of the three conditions hold then, the elements in X is called a point, O in the elements of the open set, O is a topology on X. The above theory can be understood as follows: the topology is a collection of points and distances, and the space is a matrix of arrangements. In such a co-ordinate space, there exists a mathematical and theoretical coordinate center (which may not be the positive center of the position), so that the intersection of the coordinate distances between any combination of points in the space, and the computational center of the set of merges point to the total center of the coordinates of the space.

Game theory assumes that all players are rational, and that all players will try to reduce the cost of their behavior. When the game reaches a certain equilibrium point, because when one player changes his strategy, the other players will make an immediate confrontation strategy to keep their interests intact, then each player will tend to remain inactive, and the equilibrium point is called a Nash equilibrium point. In addition, game theory also assumes that the participants of the game board are strict, decision information is open, and there must be confrontation.

In a two-player game, when two people have different strategies, there will be a pair of strategies. A pair of strategies a^* (belonging to strategy set A) and strategy b^* (belonging to strategy set B) is called an equilibrium pair, and for any strategy a

(belonging to strategy set A) and strategy b (belonging to strategy set B), there is always: even pair (a, b^*) even pair (a^*, b^*) even pair (a^*, b).

When developing an N-person game, in the game $G = (N, S_i, \mu_i)$ with N participants, N denotes the number of players, S denotes the strategy, and μ denotes the ending.

Let the decisions of player i be different S_i^*, and the group outcomes that will occur are different μ_i^*, where the strategy combination $S(1 - n)$ of N individuals is consistent with $s^* = (s_1^*, s_i^* ..., s_n^*)$, the decision of someone i is consistent with $s_i^* \in s_i$ and the other competing groups $s_{-i}^* \in s/s_i$. s_i occurs when player i chooses the optimal individual benefit such that its own choice brings the smallest benefit loss $\mu_i(s_i^*, s_{-i}^*) \geq \mu_i(s_i, s_{-i}^*)$, which is called a Nash equilibrium point (NE), and the optimal solution of the combination most favorable to individual i itself appears: max $\mu_i(s_i, s_i^*)(s_i \in S_i)$.

When player i's optimal choice s_i is nonequilibrium and different from anyone else's choice, i.e., $s_i \neq s_{-i}^*$ in the space, call the combination of all people's strategies s^* at this time as the n-player game assumes that player i is different from all other players in the game. The n-player game assumes that player i and all other players $-i(n - 1)$ appear as decision pairs, and that player i's decisions are fully informative and transparent. This inevitably leads all other players $-i(n - 1)$ to make immediate antagonistic decisions to keep their interests unchanged. This inevitably leads all other insiders $-i(n - 1)$ to make instant contradictory decisions to keep their interests intact.

2.1.2 Consumer Surplus

The theory of consumer surplus is a theory in which the market considers the optimal marginal profit and society considers consumer surplus, as proposed by Marshall, Van Rijn and others and finally summarized by A. K. Dixit and Stigley [15]. Consumer surplus is the difference between the maximum price that consumers are willing to pay when consuming a certain quantity of a good and the actual market price of these goods. It is a subjective feeling of consumers, and the price that different consumers are willing to pay for the same good varies, and is a concept that is influenced by various factors such as income, education level, and family environment. The size of consumer surplus can intuitively reflect the "value for money", "value for money" or "value for money" felt after consuming a commodity, and this consumer psychology can intuitively have a negative or positive impact on the subsequent consumption behavior.

In the traditional business model, by targeting different types of consumers, on the one hand, different types of products are targeted, and on the other hand, price discrimination is used for the same type of products to different consumers to obtain maximum revenue. However, with the development of society, easy access to information and the diversification of products, the different types of consumption set in the traditional consumption to reflect the distinction is less and less favored by consumers. Products with higher price/performance ratio are more favored by consumers, and consumers can obtain greater consumer surplus and bring "value-for-money" consumer experience.

In addition, the number of consumptions changes even for the same consumer and the same good Consumer surplus. A good has an initial value in the consumer's eyes, but as the As the number of times a consumer consumes or the quantity consumed increases, the degree of satisfaction brought to the consumer by each additional consumption or

one unit of consumption is gradually reduced, feeding back to the consumer's behavior is reflected in a decrease in the consumer's willingness to consume this commodity, but the willingness to consume does not decrease indefinitely, because the consumer's willingness to consume is not infinite. But the willingness to consume does not decrease indefinitely, because with the increase in the number or quantity of consumption, it is possible to gradually transform into a necessity of production. May be gradually transformed into a production necessity, at this time, although the consumer's willingness to consume decreases, but there will still be a very large at this point, although the consumer's willingness to consume decreases, there will still be a very large amount of consumption. By giving up some of the benefits, the company can make the same By giving up part of the benefits, the enterprise can make the same consumer switch from occasional consumption to inevitable consumption of a certain product. Although the profit from a single consumption is reduced, the overall profit is guaranteed.

2.1.3 Assumption

The following assumptions were made to determine the price of a green distribution service that takes into account graded green preferences.

Assumption 1. Non-out-migrating enterprises are closer to urban areas, and the fixed cost C_1, including land rental cost, is higher than the fixed cost C_2 of out-migrating enterprises, which must be green upgraded to provide green distribution services, $C_1 = C_2 + C_u + C_e$, where C_u is the green upgrade cost and C_e is the other additional fixed cost brought by non-out-migration.

Assumption 2. The market only exists for the non-outbound enterprises providing green distribution and the outbound enterprises providing traditional distribution. The two distribution services are homogeneous and functionally substitutable outside the green attributes, and the categories of distribution services are clearly distinguished in the final product with logo certification, packaging, etc.

Assumption 3. Consumer green preferences are distributed in n intervals in a decreasing equal series, and as the interval increases, consumer consumption level, green payment ability gradually decreases and sensitivity to service price gradually increases. The highest price consumers are willing to pay for green delivery service in the ith interval is $x_i = (1 + e)U - (i - 1)(1 + e)U/n$, and the highest price they are willing to pay for traditional delivery service is $y_i = U - (i - 1)U/n$. There are $x_i > y_i$, e for green preference, and U is the distribution of the highest price consumers are willing to pay for traditional delivery service on the ith interval, which obeys the uniform distribution on $[0, \alpha]$ (Ferguson 2010), and α is the highest reasonable price all consumers are willing to pay for traditional delivery service.

Assumption 4. The percentage of consumers in the ith interval is r_i, there is $\sum_{i=1}^{n} r_i = 1$, and the total number of consumers is D. For simplicity, let the demand be proportional to the number of consumers and the ratio is 1.

Table 1. Information of each interval

Interval	D_i	Green distribution service		Traditional distribution service	
		Max pay x_i	non-out-migration X_i	Max pay y_i	out-migrating Y_i
1	$r_1 D$	$x_1 = (1+e)U$	X_1	$y_1 = U$	Y_1
2	$r_2 D$	x_2	X_2	y_2	Y_2
...	...	...	...	...	...
i	$r_i D$	x_i	X_i	y_i	Y_i
...	...	...	...	...	...

Assumption 5. The pricing of unit green distribution service by non-outbound firms in the ith interval is X_i, and the pricing of unit traditional distribution service by outbound firms is Y_i. The unit variable costs are C_{xi} and C_{yi}, respectively, with $C_{yi} = C_{y\,max} - (i-1)C_{y\,max}/n$, $C_{xi} = pC_{yi} + q$, where $p > 0$. $C_{y\,max}$ is the maximum variable cost of providing the best traditional distribution service in the 1st interval.

Combining Assumption 3, Assumption 4 and Assumption 5, information on consumers' willingness to pay for different delivery services and pricing levels of delivery companies can be obtained for each interval, as shown in Table 1.

2.2 Model Formulation

According to the above assumptions and marginal utility value theory, since consumers are divided into n intervals according to their preferences and consumption levels, and the distribution services are homogeneous outside the green attribute, we can get the consumer surplus of the ith interval consumers who purchase green distribution services as $S_{xi} = x_i - X_i$, and the consumer surplus of traditional distribution services as $S_{yi} = y_i - Y_i$. Consumers will tend to choose the service that maximizes their consumer surplus, then having a certain type of willingness to pay represents that the consumer surplus of the interval consumers who purchase one type of distribution services is greater than the consumer surplus of another type of distribution services.

The condition that consumers in the ith interval have the willingness to pay green is $(S_{xi} > 0) \wedge (S_{xi} > S_{yi})$, i.e.

$$\begin{cases} (1+e)U - (i-1)(1+e)U/n - X_i > 0 \\ (1+e)U - (i-1)(1+e)U/n - X_i > U - (i-1)U/n - Y_i \end{cases} \tag{1}$$

where $e > 0, i = 1, 2, \ldots, n$.

The collation leads to

$$\begin{cases} U > nX_i/[(n-i+1)(1+e)] \\ U > n(X_i - Y_i)/[(n-i+1)e] \end{cases}, e > 0, i = 1, 2, \ldots, n \tag{2}$$

The pricing of distribution services by both types of firms should satisfy $X_i > (1+e)Y_i$. Under this condition we can obtain

$$U > n(X_i - Y_i)/[(n-i+1)e] > X_i/[(n-i+1)(1+e)] \tag{3}$$

Since U obeys a uniform distribution on $[0, \alpha]$, the integration yields that the demand of consumers with green payment willingness on the ith interval is

$$
\begin{aligned}
D_{xi} &= D_i \int_{n(X_i-Y_i)/[(n-i+1)e]}^{\alpha} 1/\alpha dU \\
&= D_i\{1 - n(X_i - Y_i)/[\alpha e(n - i + 1)]\}
\end{aligned}
\tag{4}
$$

Since $i = 1, 2, \ldots, n$, it is found that the total consumer demand for green delivery services in the market is

$$
D_x = \sum_{i=1}^{n} D_{xi} = \sum_{i=1}^{n} D_i \int_{n(X_i-Y_i)/[(n-i+1)e]}^{\alpha} 1/\alpha dU
\tag{5}
$$

Notice that in any interval there are

$$
\begin{cases}
\frac{\partial^2 Q_{xi}}{\partial X_i^2} = -2nD_i/[\alpha e(n - i + 1)] < 0 \\
\frac{\partial^2 Q_{yi}}{\partial Y_i^2} = -2n(1 + e)D_i/[\alpha e(n - i + 1)] < 0
\end{cases}
\tag{6}
$$

Therefore, the profit amount of green delivery service and traditional delivery service is a concave function of the pricing of their corresponding companies, and the profit will be maximized when the pricing takes a certain value. Then according to the Nash equilibrium, the optimal pricing for any interval can be calculated by finding the first-order derivative condition $\frac{\partial Q_{xi}}{\partial X_i} = \frac{\partial Q_{yi}}{\partial Y_i} = 0$, respectively, as

$$
\begin{cases}
X_i^* = \{2\alpha e(1 + e)(n - i + 1) \\
\quad + n(1 + e)[2C_{xi} - (7 + 8e)C_{yi}]\}/[n(3 + 4e)] \\
Y_i^* = \{\alpha e(n - i + 1) + n[C_{xi} - 2(1 + e)C_{yi}]\}/[n(3 + 4e)]
\end{cases}
\tag{7}
$$

3 Analysis Results

Based on the constructed pricing model for logistics and distribution services considering consumers' green preferences, the model is analyzed in detail next.

Theorem 1. First, the pricing model derived above is substituted into the enterprise profit formula to obtain the total profits of green and traditional distribution service enterprises as follows.

$$
\begin{aligned}
Q_x &= \sum_{i=1}^{n} Q_{xi} \\
&= \sum_{i=1}^{n} (X_i - C_{xi})D_i\{1 - n(X_i - Y_i)/[\alpha e(n - i + 1)]\} - C_1
\end{aligned}
\tag{8}
$$

$$Q_y = \sum_{i=1}^{n} Q_{yi}$$

$$= \sum_{i=1}^{n} (Y_i - C_{yi}) D_i n[X_i - (1+e)Y_i]/[\alpha e(n-i+1)] - C_2 \tag{9}$$

Theorem 2. The demand for green delivery service is positively correlated with the proportion of consumers in the interval and consumers' willingness to purchase, and the demand for green delivery service is zero when the consumer segmentation interval reaches a certain critical value.

Proof. When $D_{xi} = D_i\{1 - n(X_i - Y_i)/[\alpha e(n-i+1)]\} = 0$, we have $\left(1 - \frac{n(X_i-Y_i)}{\alpha e(n-i+1)}\right) = 0$. That is $n(X_i - Y_i) = \alpha e(n - i + 1)$. We can derived that $n(X_i - Y_i) - \alpha en = \alpha e(1 - i), n(X_i - Y_i - \alpha e) = \alpha e(1 - i)$

Therefore, it follows that

$$n = \frac{\alpha e(1 - i)}{(X_i - Y_i - \alpha e)} \tag{10}$$

Theorem 2 reveals the influence of consumer proportion and consumption level on the demand for green delivery service. When the number of segmentation interval satisfies $n \geq \frac{\alpha e(1-i)}{(X_i-Y_i-\alpha e)}$, the consumer demand for green delivery service will decrease to zero. With the increase of consumer proportion and consumption level in the interval, the demand for green delivery service will keep increasing. Based on the hypothesis of this paper, the basis of consumer interval di- vision is the consumption level of consumers, so when the consumer interval is more and more finely divided, it means that consumers' willingness to pay for green delivery service will also decrease, which leads to consumers after a certain interval to give up purchasing green delivery service.

4   Simulation

In order to further help enterprises to rationalize pricing, simulation values are introduced to determine the impact of consumers' green preferences on the demand, pricing, and profit of green delivery services, and Yang Haihong points out in his study that the interval division mainly depends on the realistic situation, and it is appropriate to facilitate realistic operation, and it is generally best to divide 3 to 5 intervals [19]. To simplify the research process, the parameter values are normalized in this paper, and the parameter values are shown in Table 2.

Now we observe the pricing and profitability of distribution firms when n varies from 1 to 5 in these two cases at e = 0.3 or 0.5, respectively. The changes in dairy pricing, sales and profit with N are shown in Tables 3 and 4.

The numerical simulation results show that when n is larger, the sales volume of green delivery service is smaller, and when n satisfies the condition of Theorem 2, the demand for green delivery service will be 0. When e = 0.5, compared with e = 0.3,

Table 2. Parameter values

Parameter	n	D	α	$C_{y\,max}$	p	q	C_1	C_2
values	5	30000	100	1	2	10	4000	1000

Table 3. When e = 0.3, Changes in dairy pricing, sales and profit with N

n	X_i	Y_i	D_{xi}	D_{yi}	Q_{xi}	Q_{yi}
1	23.0905	9.3810	3258.0952	2179.0476	35333.8277	18062.4943
2	19.7105	7.9810	3067.6190	2333.8095	24079.8512	16558.9751
3	16.3305	6.5810	2750.1587	2591.7460	13309.6239	15301.1096
4	12.9505	5.1810	2115.2381	3107.6190	3748.7692	14657.3787
5	9.5705	3.7810	210.4762	4655.2380	−974.5950	16470.1859

Table 4. When e = 0.5, Changes in dairy pricing, sales and profit with N

n	X_i	Y_i	D_{xi}	D_{yi}	Q_{xi}	Q_{yi}
1	33.9000	11.8000	3348.0000	1944.0000	72521.2000	20795.2000
2	28.3200	9.8400	3228.0000	2034	53172.1600	18187.3600
3	22.7400	7.8800	3028.0000	2184.0000	34143.1200	15699.5200
4	17.1600	5.9200	2628.0000	2484.0000	15914.0800	13511.6800
5	511.5800	3.9600	1428	3384.0000	885.0400	12523.8400

consumers have a higher level of green preference and higher pricing affordability for green delivery service, so that the model pricing considering consumers' green preference can obtain higher profit. Similarly, when consumers' green preference decreases, in such a market environment, companies should appropriately reduce the supply of green delivery services and lower the price of traditional delivery services, so as to attract more consumers to buy traditional delivery services and avoid the situation that delivery services are unattended in the market.

5   Conclusion

This paper analyzes the pricing, demand and profit problems of green delivery service and traditional delivery service in different intervals based on static game, using equilibrium price theory and consumer surplus theory, considering consumers' green preferences, and constructs a pricing model of delivery service considering consumers' green preferences, and verifies the reliability of the model through numerical simulation, and the following conclusions can be obtained: First, the First, the premise of reasonable pricing

of green delivery service is the existence of green features in consumers' preference and the difference in consumers' willingness to purchase. Secondly, the demand for green delivery services in the interval is positively related to the number of consumers and consumption level in the interval. Third, the pricing of green delivery service is positively proportional to the green preference of consumers, and the profit of enterprises will increase as the purchase intention of consumers continues to increase.

In the complex market environment, how to price according to the green preferences of consumers is the core issue of concern to the author. Based on the above research findings, the following pricing decision recommendations have been proposed: First, in pricing and decision making, the consumer segmentation is not the smaller the better, but should be based on actual operational needs, generally using 3 to 5 as the best. In the actual pricing process, it is a complex process for enterprises to identify consumer segments. Enterprises can introduce different levels of green delivery services according to different green preferences and consumption levels of consumers, so as to meet the needs of different levels of consumers. Secondly, in the same interval, when consumers' green preference increases significantly, enterprises should raise the price of green delivery services and increase the supply of green delivery services. With the continuous progress of society, the green preference of consumers will become more and more obvious in the future, especially in the field of green distribution logistics, the price sensitivity will continue to decrease and the green attribute sensitivity will gradually increase, so the enterprises should appropriately increase the price of green distribution services and increase the market supply when making pricing decisions. Third, when the consumption level increases, enterprises should raise the price of both traditional and green distribution services. As consumers' income increases, the demand for delivery services will expand rapidly. In the face of such market situation, enterprises should raise the prices of both green and traditional delivery services to meet the needs of consumers at different levels. Finally, in the long run, enterprises should steadily adjust prices according to the changes in market laws to create greater surplus for consumers and enhance the satisfaction of consumers in the market purchase.

In the production decision process, consumer demand is not constant, but is changing rapidly with the market environment. Companies need the ability to continuously raise awareness in the market environment and optimize pricing decisions using consumer preferences in terms of green.

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