A Study of Competition and Quality of Service Pricing for Duopoly Shipping Companies Considering Uncertain Demand

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Abstract. Affected by the trade war and the new crown pneumonia epidemic, freight demand has fluctuated sharply, and the freight rate market has also experienced huge changes. International shipping prices are gradually returning to a reasonable range after soaring. In the face of this volatile situation and fierce competition, container companies need to develop a reasonable pricing strategy to keep the transportation system continuously evolving. Considering the uncertain market structure of the oligopoly market, this paper examines the competitive and service-quality pricing strategies of shipping companies. By establishing the Gounod competition model, this paper analyzes the influence of important factors such as market competition intensity and service quality on the optimal pricing and profit level of shipping companies by comparing the three situations in which a shipping company chooses high-quality service transportation at the same time, a shipping company chooses high-quality transportation services, and shipping companies choose conventional transportation services at the same time. The results show that: (1) From conventional transportation to high-quality service transportation, improving the service quality level is conducive to improving the company's profits. (2) The intensity of price competition and market competition will affect the profit level of shipping companies. Moderate competition is good for improving the profits of shipping companies, while too much competition can hurt corporate profits.

Keywords: Maritime Pricing; Gounod Competition; quality of service; Uncertain of demand

1 Introduction

Over the past two decades, maritime transport has experienced steady growth and has become a major mode of international shipping. According to a 2022 United Nations report on maritime transport, more than 80% of global trade is transported by sea. However, the growth rate of maritime trade is projected to slow down to 1.4% in 2022, with an average annual growth rate of 2.1% expected for the period of 2023-2027. This is lower than the average growth rate of3.3% seen in the past three decades. Container trade, which has been the fastest growing segment, is expected to have sluggish growth of 1.2% in 2022, with a slight recovery to 1.9% in 2023 (UNCTAD,2022).Currently, global shipping companies typically offer similar liner services on a weekly basis, such as Asia-Europe, trans-Pacific, or trans-Atlantic routes.

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However, competition among shipping companies is fierce due to the capital-intensive nature of scheduled shipping services.

Shipping companies have two types of customer demand conditions: long-term contract demand and spot market demand. Long-term demand is typically contracted on an annual basis with fixed prices, while spot market demand allows for dynamic negotiations between the shipping line and the shipper or freight forwarder on a daily or weekly basis. In recent years, shippers have increasingly favored lower freight rates in the spot market. This trend has intensified competition among shipping companies and made cargo volumes more unpredictable for some shipping lines. The uncertainty of customer demand has become a major challenge for shipping companies in their quest to thrive in this competitive environment. Therefore, in a highly competitive and uncertain spot market, it is crucial for shipping companies to adopt the right pricing strategy to maximize their revenue. It is important to note that shipping enterprises have distinct characteristics, including differences in resources, technology, total fixed costs, and brand influence. The characteristics of transport services make them inherently heterogeneous, necessitating the consideration of non-price competition, such as the improvement of service quality. Enhancing service quality, however, comes with increased costs, which in turn affects the pricing of services. Moreover, it alters the expectations and requirements of customers. Therefore, selecting the appropriate level of service quality in relation to the price of shipping services can help shipping enterprises balance their demand and cost, ultimately maximizing their profits. Building upon this background, this paper delves into the competitive pricing and service quality strategies of shipping companies under conditions of demand uncertainty. The objective is to explore optimal shipping strategies from the perspective of shipping enterprises, considering pricing and quality strategies in response to uncertain potential demand. In this context, the paper assumes that latent demand follows a random variable pattern. A Cournot competition model is proposed to elucidate the competitive behavior of two liner container shipping companies in the market.

2 Literature review

Shipping container pricing has long been a subject of extensive research by scholars, both domestically and internationally. Scholars have consistently shown a keen interest in studying this issue in depth. The pricing decisions of container transportation enterprises are primarily influenced by three key factors: cost, demand, and service quality. Given the intense price competition and the ever-growing complexity of the competitive environment, it becomes imperative to explore novel freight pricing methods through a comprehensive study of the shipping competitive market.

Early studies on demand pricing decisions primarily focused on examining the determinants of demand. For instance, Gang proposed a market competition model for container road transport, considering two key factors: freight service and the offers made by freight forwarders to sensitive shippers under conditions of demand determination [1]. Gao developed a deterministic two-stage model that explored long-term and medium-term capital investments in container procurement, as well as the operating costs associated with leasing, distribution, and storage of empty containers [2]. Additionally, Zhou and Lee et al. were the first to establish a price competition game model for duopoly shipping enterprises, taking into account empty container transportation, and describing the Nash equilibrium pricing strategy [3]. Building upon Zhou and Lee's model [3], Xu et al. extended it to construct a Stackelberg game model, analyzing the optimal joint pricing strategy and cost-sharing strategy of empty container transportation from the perspective of the entire supply chain [4].

In the global container transportation system, customer demand for container transportation is influenced by numerous factors and is often unpredictable, particularly in the competitive spot market. Currently, several studies have explored the pricing strategies of container transportation under conditions of uncertain demand. Yin and Kim examined the optimal freight rates that shipping companies can offer to freight forwarders with the aim of maximizing profits [5]. Wu and Luo et al. investigated price competition between Chinese pharmacies and hospitals in the Chinese drug supply chain using game theory in the presence of uncertain demand [6]. However, while the aforementioned research accounts for demand uncertainty, it does not consider the competition among shipping enterprises.

Najaf et al. conducted a study on the development of a pricing and quality setting strategy for shipping companies that need to transport empty containers in the face of uncertain demand [7]. In a duopoly market structure, Huang et al. investigated demand information forecasting and sharing strategies for shipping companies, taking into account the competitive environment of price and product quality [8]. Following that, Jia and Shi et al. examined how government behavior influences game decisions to ensure the stable operation of the container shipping market. They constructed a tripartite game model involving the government, shipping companies, and shippers, considering fluctuations in shipping market demand during the pandemic [9].

At present, many studies have explored the relationship between service quality, customer loyalty and corporate profits. According to the characteristics of shipping enterprises, we can take on-time delivery, accident rate and other value-added services as variables to analyze pricing strategies [10]. Table 1 briefly summarizes the relevant analysis literature and this paper.

Table 1. Literature review and contribution

Literature	Uncertain demand	Competition	Quality service
Zhou and Lee	no	yes	no
Liu and Yang	yes	no	no
Najaf et.al	yes	no	yes
Han et.al	no	no	yes
This paper	yes	yes	yes

The rest of this article is organized as follows. Section 3 introduces notation, assumptions, and competition issues. Section 4 establishes Cournot competition model. In Section 5, a numerical example is given to illustrate the applicability of the proposed model. Then, the conclusion is given.

3 Duopoly shipping enterprise competition and service quality pricing model

3.1 Parameter symbol description

Table 2 shows the parameter symbols used in the model.

Table 2. Parameter definitions

symbol	definitions
Decision variable	
p_i	Unit freight of shipping enterprise i, $p_i \geq 0$
q_i	Shipping enterprise i is 1 when choosing high-quality transportation services, otherwise 0
Model parameter	
i, j	Shipping enterprise, i, $j \in \{1, 2\}$, $i \neq j$
c_i	Unit transportation cost of shipping enterprise i, $c_i > 0$
D_i	Potential demand of shipping enterprise i, $D_i > 0$
d_i	Realized demand of shipping enterprise i, $d_i > 0$
α	Price sensitivity factor, $\alpha > 0$
β	The coefficient of competition intensity in the market, $\beta > 0$
γ	Service quality sensitivity coefficient, $\gamma > 0$
k	The increase in transportation cost ofq_i selected by the enterprise, $k > 0$
π_i	Liner formula i profit

3.2 Model construction

The problem studied in this paper is the shipping market under the duopoly, and the competition model is constructed to quantitatively analyze the possible competition between the two container liner transport enterprises that provide container transport services from Port A to Port B. Two container shipping companies serve two ports located on different continents. Carriers present in the container liner transport market will face potential competitors, and according to market assessment and analysis, shipping companies may react differently to the actions of competitors. Cournot competition games are considered in this paper. In Cournot competition, two operators compete with each other on the same level, and each can perfectly predict the other's market behavior. For the game considered, each shipping company takes the response of its competitors into consideration, and aims to maximize profits by setting its own freight rate and service quality.

This paper considers three scenarios: Scenario N Both shipping companies choose high-quality services for transportation; Scenario S Shipping enterprises 1 choose high-quality transport services, shipping enterprises 2 choose conventional transport services; Scenario R Both shipping companies choose conventional transport services.

3.3 Cournot competition model

Consider two duopoly container shipping companies, represented by 1 and 2 respectively, competing in the container shipping market for shipping services between two ports (represented by A and B, respectively). Without losing its generality, this paper focuses only on the container transportation needs from Port A to Port B. Under the assumption that the market demand is uncertain, duopoly shipping enterprises compete on freight rate and service quality at the same time. According to the existing literature [8], it is assumed that the demand of a shipping enterprise has a linear relationship with its own price, the price of its competitors and the service quality. The demand function d_i of shipping enterprise i is as follows,

$$d_i = D - \alpha(p_i - c_i) + \beta(p_j - p_i) + \gamma q_i + \varepsilon \tag{1}$$

Where D represents the potential demand of the market, β represents the degree of market competition, and α represents price sensitivity. Obviously, the greater the β value, the more competitive the market will be. γ represents the shipper's level of service quality. ε is a random variable that describes the uncertainty of demand, we assume $E[\varepsilon] = 0$, variance $V[\varepsilon] = \sigma^2$. In scenario R, competing shipping companies do not choose high-quality transport services. In scenario S, shipping enterprise i chooses high-quality transportation services, and the demand prediction formula is $\Delta = \varepsilon + \varepsilon_a$. The goal of a shipping enterprise is to determine the price and quality of shipping services in order to maximize the following profit function:

$$max\pi_i = (p_i - c_i - k{q_i}^2)d_i \tag{2}$$

Where $k{q_i}^2$represents the service cost increased by shipping enterprises when the service quality is q_i and $k(> 0)$represents the service quality cost coefficient. The assumptions in this article are as follows: (1) Suppose both competing companies are risk-neutral and that the decision-makers are completely rational. (2) Assume that the potential market demand is the consensus of both competitors. This means that $c_1 = c_2 = c$.(3) It is assumed that the sum of other operating costs of the shipping enterprise is 0. The purpose of this hypothesis is to simplify model derivation. (4) In the equilibrium state, the demand of shipping enterprises is positive and the profit is non-negative.

$$d_1 = D - \alpha(p_1 - c) + \beta(p_2 - p_1) + \gamma q_1 + \varepsilon \tag{3}$$

$$d_2 = D - \alpha(p_2 - c) + \beta(p_1 - p_2) + \gamma q_2 + \varepsilon \tag{4}$$

$$\pi_1 = (p_1 - c - k{q_1}^2)d_1 \tag{5}$$

$$\pi_2 = (p_2 - c - k{q_2}^2)d_2 \tag{6}$$

In scenario N, $q_1 = 1$, $q_2 = 1$, the expected revenue of shipping enterprise i is:

$$\pi_1 = (p_1 - c - k{q_1}^2)d_1 \tag{7}$$

$$\pi_2 = (p_2 - c - k{q_2}^2)d_2 \tag{8}$$

In scenario S, $q_1 = 1$, $q_2 = 0$, the expected revenue of shipping enterprise i is:

$$\pi_1 = (p_1 - c - k{q_1}^2)d_1 \tag{9}$$

$$\pi_2 = (p_2 - c)d_2 \tag{10}$$

In scenario R, $q_1 = 0$, $q_2 = 0$, the expected revenue of shipping enterprise i is:

$$\pi_1 = (p_1 - c)d_1 \tag{11}$$

$$\pi_2 = (p_2 - c)d_2 \tag{12}$$

In each scenario, the decision order is as follows: (1) Enterprises 1 and 2 determine product quality level q_1 and q_2, (2) Shipping enterprises 1 and 2 determine the optimal price $p_1$and $p_2$on the basis of determining service quality level. An equilibrium solution can be obtained in each case, as shown in Lemma 1. First, the optimal product price is determined by shipping enterprises 1 and 2, and the optimal solutions are ${p_1}^*$,${p_2}^*$from the first derivative of 0. Substituting the above price expression into the enterprise income function, we can get Table 3.

Table 3. Equilibrium solution of scenario N, S and R

scenario **N**	scenario **S**	scenario **R**
1	1	0
1	0	0
$\frac{D+k(\alpha+\beta)+c(2\alpha+\beta)+\gamma+\epsilon}{2\alpha+\beta}$	$c+\frac{D(2\alpha+3\beta)+2(\alpha+\beta)(k(\alpha+\beta)+\gamma)+(2\alpha+3\beta)\epsilon}{(2\alpha+\beta)(2\alpha+3\beta)}$	$\frac{D+2c\alpha+c\beta+\epsilon}{2\alpha+\beta}$
$\frac{D+k(\alpha+\beta)+c(2\alpha+\beta)+\gamma+\epsilon}{2\alpha+\beta}$	$c+\frac{k\beta(\alpha+\beta)+D(2\alpha+3\beta)+\beta\gamma+2\alpha\epsilon+3\beta\epsilon}{(2\alpha+\beta)(2\alpha+3\beta)}$	$\frac{D+2c\alpha+c\beta+\epsilon}{2\alpha+\beta}$
$\frac{(\alpha+\beta)(D-k\alpha+\gamma+\epsilon)^2}{(2\alpha+\beta)^2}$	$\frac{(\alpha+\beta)(D(2\alpha+3\beta)-k(2\alpha^2+4\alpha\beta+\beta^2)+2(\alpha+\beta)\gamma+}{(2\alpha+\beta)^2(2\alpha+3\beta)^2}$	$\frac{(\alpha+\beta)(D+\epsilon)^2}{(2\alpha+\beta)^2}$
$\frac{(\alpha+\beta)(D-k\alpha+\gamma+\epsilon)^2}{(2\alpha+\beta)^2}$	$\frac{(\alpha+\beta)(k\beta(\alpha+\beta)+D(2\alpha+3\beta)+\beta\gamma+2\alpha\epsilon+3\beta\epsilon)^2}{(2\alpha+\beta)^2(2\alpha+3\beta)^2}$	$\frac{(\alpha+\beta)(D+\epsilon)^2}{(2\alpha+\beta)^2}$

3.4 Analysis of equilibrium results

Inference 1: The service quality level of shipping enterprises will affect the optimal pricing level of shipping enterprises. When enterprises choose transport levels with different service quality, the optimal price level decision will also change, as shown in Table 3,when $q_i^N > q_i^R$ 时， $p_i^N > p_i^R$， $\pi_i^N > \pi_i^R$, It shows that the higher the level of service quality, the higher the freight rate of shipping enterprises, and the profits of enterprises will also increase. Therefore, in terms of service quality decision-making, shipping enterprises need to weigh the cost of improving the level of service quality to improve the income.

Inference 2: In scenario S, $q_1^S > q_2^S, p_1^S - p_2^S = \frac{2k\alpha^2+2k\alpha\beta)+k\alpha\beta+k\beta^2+\alpha\gamma}{(2\alpha+\beta)(2\alpha+3\beta)} > 0$, In the case of the same demand information (such as scenario N and scenario S), the cost of service quality directly affects the equilibrium pricing of enterprises. In scenarios N and R, pricing is the same, but shipping companies set higher transport prices for the consideration of quality of service costs and pass on the cost of quality of service to consumers. In scenario S, in addition to the cost of service quality, the pricing of shipping firm 1 is also affected by the price sensitivity of shippers. Obviously, if the cost of service quality is 0, the higher the price sensitivity of shippers, shipping firm 1 will set higher prices to increase marginal revenue. Conversely, if the shipper is less price sensitive, shipping firm 1 sets a lower price to ensure a higher market demand.

Inference 3: In scenario N and R,， $\pi_1 = \pi_2$， In scenario S,， $\pi_1 - \pi_2 =$

$$\frac{[(2\alpha+\beta)\gamma - k(2\alpha^2+3\alpha\beta)][(2D+\gamma)(2\alpha+3\beta)+2(2\alpha+3\beta)\epsilon - k(2\alpha^2+4\alpha\beta+\beta)]}{(2\alpha+\beta)^2(2\alpha+3\beta)^2}$$

Let k=0, $\pi_1 - \pi_2 > 0$, in the case of the same level of service quality, such as scenario N and scenario R, the revenue of shipping enterprises is related to the cost of service quality. In scenario S, shipping firm 1 expects lower returns due to service costs. When the service quality cost is coefficient 0 (k=0), the expected return of shipping enterprise 1 is higher than that of shipping enterprise 2. At this time, the profit of shipping enterprises is related to market competition and price competition, and the increase of competition will increase the profit of shipping enterprises.

4 Conclusion

The basic market parameters are as follows: potential market demand $D = 10$, price sensitivity coefficient $\alpha = o.5$, market competition intensity coefficient $\beta = o.5$, service quality sensitivity coefficient $\gamma = o.5$ service quality cost coefficient $k = 1$ and unit transportation cost $c = 1$. Using Mathematica software, the profits of shipping enterprises are numerically analyzed and graphically described.

The profit of shipping enterprises is affected by the quality of service. Figure 1 confirms this conclusion. When shipping enterprise 1 chooses high-quality transportation, shipping enterprise 1's profit is higher than shipping enterprise 2's. When the service cost is greater than a certain critical value, the profit return of shipping enterprise 1 is lower than that of shipping enterprise 2. At the same time, it can be seen from Figure 1 that with the increase of competition intensity, the critical value decreases. That is, as the intensity of competition increases, the benefit from the same service cost decreases. This also means that fierce competition will reduce the incentive for shipping companies to improve service quality.

Figure 2 analyzes the influence of different competition intensity on profits in scenario S, and compares the earnings of shipping enterprises when $\beta = o.1$,0.5,1,respectively. As can be seen from Figure 2, with the increase of competition intensity, the higher the service cost, the larger the profit difference. Under the fierce competition, the impact of transportation service cost on pricing is more significant, and the change of enterprise pricing will directly lead to the change of enterprise profit.

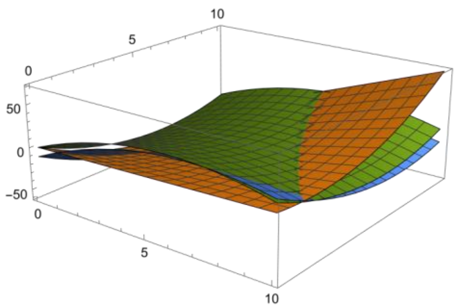

Figure 1. Comparison of revenue of shipping enterprises under three scenarios

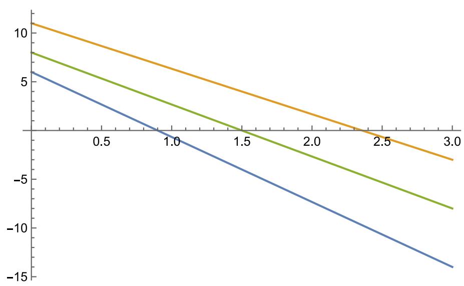

Figure 2. Revenue comparison of shipping enterprises in scenario S

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