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Advances in Economics, Business and Management Research, volume 91

1st International Symposium on Economic Development and Management Innovation (EDMI 2019)

Study of Express Service Pricing based on Generalized Bertrand Model

Chenxia Jin [a], Lulu Ren [b, *] and Fachao Li [c]

School of Economics and Management, Hebei University of Science and Technology, Shijiazhuang 050018, China.

[a]jinchenxia2005@126.com, [b, *] 15613569308@163.com, [c]lifachao@tsinghua.org.

Abstract. Reasonable service pricing is a key factor for express enterprises to gain competitive advantage. The market demand uncertainty makes the pricing problem more complicated. This paper establish a Generalized Bertrand pricing model based on effect mean, which regard market demand as a random variable and introduce the concept of effect mean to compound quantitative the variable. Then, we analyze its characteristics and the pricing strategy. Finally, we compare the pricing model with Bertrand model by combining with real cases. The results show that the generalized Bertrand pricing model, which has certain application value, not only takes into account the market demand volatility, making it more conform with the actual development law, but also effectively solves the express pricing under the condition of uncertain demand.

Keywords: Express pricing; effect mean; Bertrand model; Generalized Bertrand.

1. Introduction

The rapid growth of express demand has filled the international express market with fierce competition. If Chinese firms want to stand firmly, they must improve competitiveness. Sung-hyun Yoon [1] believes that price is the most important factor, followed by reliability and speed. Reasonable prices help enterprises focus on improving service quality.

About service pricing, traditional methods are mostly single-oriented. So, domestic and foreign scholars introduced the game theory. In the classic model of price competition established by Bertrand [2], enterprises produce homogeneous products at marginal cost. Pavlo [3] put forward the Logit demand function, believing that the more price sensitive consumers are, the lower equilibrium price is. Lu et al. [4] considered the impact of delivery period and studied pricing strategies. To sum up, the existing literature has studied pricing from different aspects. But research on uncertain demand is lacking. Most applications of Bertrand model only consider the pricing when the demand is determined. However, the demand has great deviation, which will affect the reliability of the pricing decision. In this paper, a generalized Bertrand pricing model based on effect mean is established by considering expectation and variance of random variables. Then we analyze the specific pricing strategy under different circumstances with a practical case.

2. Characteristic Analysis of Bertrand Pricing Model

Bertrand Model is a pricing competition Model. The basic form is as follows:

$$\begin{cases} \max \pi_1 = (p_1 - c_1) q_1 = (p_1 - f_1 - v_1 r)(a - \varepsilon_1 p_1 + b_1 p_2) \\ \text{s.t.} p_1 \ge c_1 \\ \max \pi_2 = (p_2 - c_2) q_2 = (p_2 - f_2 - v_2 r)(a - \varepsilon_2 p_2 + b_2 p_1) \\ \text{s.t.} p_2 \ge c_2 \end{cases} \tag{1}$$

Where, π_i represents the profit of enterprise i, c_i represents the total unit cost, q_i represents the actual demand, and a represents the basic demand; ε_i is the sensitivity of demand to pricing p_i; b_i is the service substitution coefficient between two enterprises, that is, the sensitivity of demand to the pricing of competitive enterprises. Li [5] once proposed that the demand function must satisfy $\varepsilon_i > b_i$, otherwise the relationship between pricing and substitution coefficient will be reversed [6].

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f_i represents the unit cost at a certain basic demand, v_i represents the cost increase when adding a unit demand, and r represents the change in basic demand. If the basic demand increases, enterprises will increase the investment in facilities and personnel to meet the demand. Then the cost increase accordingly.

Bertrand model has the following characteristics: 1) the model considers cost, demand and competition factors; 2) this model is applied to express delivery firms with direct competition; 3) this model adopt expectation to quantify the basic demand, without considering the demand volatility. In real life, customers' demand is affected by consumption habits, promotional activities and so on. When the deviation is particularly large, the expected value alone cannot accurately describe the characteristics of random variables. In the following paragraphs, we will introduce the effect mean to improve Bertrand model and discuss pricing in the case of uncertain demand.

3. Generalized Bertrand Pricing Model based on Effect Mean(GBPM-EM)

3.1 Effect Mean.

The value of random variable varies with the actual event. Before the occurrence, we can obtain the probability of each result according to the occurrence of previous events, not its accurate value. In general, the mathematical expectation is used to describe the random variable. For example, when express firms are building warehouses, they will rent warehouses and buy infrastructure according to the local market demand, which is quantified by expectation.

Table 1. Monthly express business volume in 2017 (million pieces)

January	February	March	April	May	June
13.48	13.64	16.14	13.96	14.78	16.15
July	August	September	October	November	December
14.63	17.79	18.38	19.04	23.68	21.62

As can be seen from the above table, the express business volume fluctuates greatly in a year, with an expectation of 16.94 million pieces and a variance of 9.79 million pieces. If the warehouse is rented according to the expected inventory level, the gap between monthly volume and the expectation in most months is more than 3 million pieces. In January and February, the warehouse will be empty and resources will be wasted. In November, December, there will be a burst situation. In the case that the demand deviation is particularly large, we cannot use expectation to reflect the demand volatility. So we must consider the proportion of different demands and the variance, which is the deviation degree between the actual value and the mathematical expectation. It is more reliable to describe the random variable by the way of the comprehensive quantization of mathematical expectation and variance. This model is called effect mean.

$$E_G(\xi) = E(\xi) + \alpha\sqrt{D(\xi)} \tag{2}$$

Where, ξ is random variable, α is the satisfaction coefficient, $E(\xi)$ is the expectation, and $D(\xi)$ is the variance. The satisfaction coefficient reflects the acceptance to variance of decision makers. In different situations, α is different. When facing someone's income, the higher the income, the higher satisfaction degree, $\alpha > 0$. When facing deterioration and loss of some products, the lower consumption, the higher satisfaction, $\alpha < 0$. When $\alpha = 0$, $E_G(\xi) = E(\xi)$. In the specific value, the greater the absolute value of the satisfaction coefficient, the higher the satisfaction degree of the decision-maker with the variance, and the value range generally $[0,1]$, $\alpha = 1$ indicates the most satisfied with the deviation. When the variance is large, it means that the fluctuation of random variable is large. When the variance is particularly small, the effect mean is not far from the mathematical expectation. In summary, we adopt the compound quantization of expectation and variance to deal with random variables, which is more in line with the actual situation. We adopt satisfaction coefficient, making decisions more credible.

3.2 GBPM-EM Model.

The pricing model after using the effect mean is as follows:

$$\begin{cases} \max z_1 = (p_1 - c_1)(E(\xi) + \alpha\sqrt{D(\xi)} + b_1 p_2 - \varepsilon_1 p_1) = (p_1 - f_1 - v_1 r)(E(\xi) + \alpha\sqrt{D(\xi)} + b_1 p_2 - \varepsilon_1 p_1) \\ \text{s.t. } p_1 \geq f_1 + v_1 r \\ \max z_2 = (p_2 - c_2)(E(\xi) + \alpha\sqrt{D(\xi)} + b_2 p_1 - \varepsilon_2 p_2) = (p_2 - f_2 - v_2 r)(E(\xi) + \alpha\sqrt{D(\xi)} + b_2 p_1 - \varepsilon_2 p_2) \\ \text{s.t. } p_2 \geq f_2 + v_2 r \end{cases} \tag{3}$$

Where, z_i represents the profit of enterprises i; ξ represents the basic demand and is a random variable. Model (3) mainly has the following characteristics: 1) the model is suitable for pricing under the demand uncertainty. In pricing, the satisfaction degree of deviation is taken into account, which can better reflect the deviation acceptance degree of enterprises. 2) when α=0, the model is the extension of Bertrand pricing model; 3) the model only considers the constraint of cost, making the model easier to solve.

3.3 Solution of GBPM-EM Model.

In the objective function of enterprise 1, p_1 is only the decision variable and p_2 is a constant; In the objective function of enterprise 2, p_2 is only the decision variable and p_1 is a constant, so the profit function is equivalent to the quadratic function of one variable. When the partial derivative is zero, the optimal price of the two enterprises can be obtained. The pricing of the express service products of the two logistics enterprises is as follows:

$$\begin{aligned} p_1 &= \frac{b_2\varepsilon_2(f_2 + v_2 r) + 2\varepsilon_1\varepsilon_2(f_1 + v_1 r) + \left(E(\xi) + \alpha\sqrt{D(\xi)}\right)(2\varepsilon_2 + b_2)}{4\varepsilon_1\varepsilon_2 - b_1 b_2} \\ p_2 &= \frac{b_1\varepsilon_1(f_1 + v_1 r) + 2\varepsilon_1\varepsilon_2(f_2 + v_2 r) + \left(E(\xi) + \alpha\sqrt{D(\xi)}\right)(2\varepsilon_1 + b_1)}{4\varepsilon_1\varepsilon_2 - b_1 b_2} \end{aligned} \tag{4}$$

If the substitutability between enterprises is considered, the pricing strategy is as follows:

$$\begin{aligned} p_1 &= \frac{\xi + c_1\varepsilon_1}{2\varepsilon_1} = \frac{\left(E(\xi) + \alpha\sqrt{D(\xi)}\right) + (f_1 + v_1 r)\varepsilon_1}{2\varepsilon_1} \\ p_2 &= \frac{\xi + c_2\varepsilon_2}{2\varepsilon_2} = \frac{\left(E(\xi) + \alpha\sqrt{D(\xi)}\right) + (f_2 + v_2 r)\varepsilon_2}{2\varepsilon_2} \end{aligned} \tag{5}$$

In this case, the service level of the two enterprises is quite different, the service market of the two enterprises is different, or the business scope is different. Then, the pricing will not affect each other, but will only be affected by their own express cost and demand sensitivity coefficient.

4. Case Analysis

For express enterprises 1 and 2 in the region market. Data analysis shows that the enterprise gains most when $\alpha = 0.85$. Below, we take $\varepsilon_2 = 4$、$\varepsilon_1 > b_1 = 2$, analyze the influence of $\varepsilon_1 = [2.5, 5.5]$ on the pricing, and substitute $E(\xi) = 16.94$、$D(\xi) = 9.79$、$f_1 = 3.2$、$f_2 = 2.5$、$v_1 = 0.21$、$v_2 = 0.16$ into the model to obtain the optimal price and profit. The following is a comparative analysis of Bertrand model and GBPM-EM model. We will show the pricing strategies and demand with different values in figure 1 and the profits obtained by the two pricing strategies in different pricing models in table 2.

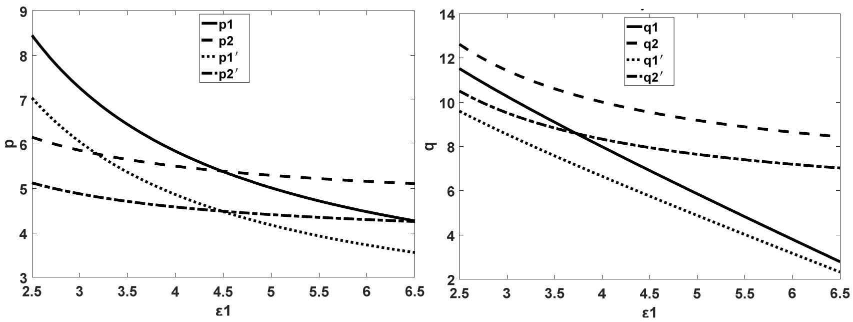

Fig. 1 Pricing strategies and demand with different values of ε_1

Table 2. Profit of enterprises in different pricing models (million yuan)

ε_1	Bertrand model				GBPM-EM model			
	G_p		B_p		G_p		B_p	
	z_1	z_2	z_1'	z_2'	z_1	z_2	z_1'	z_2'
2.5	42.38	33.21	36.85	27.61	48.61	36.32	38.63	27.48
3	27.78	26.72	24.37	22.66	31.73	29.68	24.18	22.40
3.5	18.44	22.62	16.41	19.52	21.03	25.48	15.03	19.16
4	12.12	19.82	11.07	17.36	13.90	22.60	8.97	16.94
4.5	7.69	17.80	7.37	15.80	9.00	20.51	4.85	15.33
5	4.52	16.27	4.77	14.62	5.62	18.94	2.04	14.11
5.5	2.23	15.08	2.94	13.70	3.28	17.71	0.15	13.15
Average	16.45	21.65	14.82	18.75	19.03	24.46	13.41	18.37

From figure 1, we find the trend of the pricing and demand of the two pricing models is consistent, indicating that GBPM-EM model conforms to the actual law. Specifically, enterprise 1 has a higher initial price due to its better service quality, while customers prefer enterprise with a lower price. With the increase of price elasticity coefficient, consumers become more sensitive to price, and enterprise 1 begins to reduce price. However, since the price of enterprise 2 is relatively stable, the demand of enterprise 2 is always slightly greater than that of enterprise 1. It can be seen from table 3 that the profit obtained by the pricing strategy of the GBPM-EM model is mostly larger than that obtained by Bertrand model. To sum up, the GBPM-EM model is applicable to express service pricing, which can solve the problem of express pricing when demand is uncertain.

5. Summary

Bertrand model is widely applied in competitive product pricing game. This paper first analyzes the features of Bertrand model; then introduce the effect mean to improve the Bertrand model and establish GBPM-EM model. The model has certain practical value that it can help enterprises reduce the basic demand uncertainty and obtain greater benefits.

Acknowledgments

This work is supported by the National Natural Science Foundation of China (71771078, 71371064).

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