Analysis on the Production and Marketing Strategies of Oligopoly Companies Based on Cournot Model and Stackelberg Model

Xueyi Zhang *

Beijing Normal University Business School, Beijing, China, 100875

Abstract—By comparing Cournot model and Stackelberg model under complete information market and Cournot model under incomplete information market, this paper analyzes the impact that manufacturer choose simultaneous or sequential games when determining the amount of output as well as the production and marketing strategy to maximize the profit of the manufacturers in the oligopoly market. A specific analysis is also conducted according to Gree air-conditioning manufacturer's data.

1 INTRODUCTION

In 2019, both the export scale of the air-conditioning market and the demand of domestic market decreased. The market scale was 19.12 billion yuan, which is a year-on-year growth of -3.4% over last year, and the export amount was 72.1 billion yuan, the same as last year. On November 11, 2019, Gree Electric launched a profit-sharing activity, starting the third obvious price war in the air-conditioning market [6].

In 2020, due to the impact of COVID-19, the number of consumers is further reduced, and as a non-essential goods, the selling scale of air conditioners are significantly suppressed. In addition, the rise of new sales forms such as live-streaming and social influencer marketing also bring down the price of air-conditioning market. The air-conditioning market, therefore, falls into a price war again and the leading companies seize the opportunity to grab market share by using their brand influence. Therefore, this paper will discuss how to gain greater market share and more sales profits in the air-conditioning market which has gradually formed a duopoly market of Gree and Midea.

2 LITERATURE REVIEW

There are many documents that have conducted research on the competition strategy of oligopoly market in order to find various factors that affect the competitiveness of those oligopoly enterprises.

Zhang Ya ming and Su Yanqi used the extended Hotelling model to analyze the market equilibrium and manufacturer profits when duopoly firms choose single or discriminatory pricing strategies, respectively. They discussed the impact of network externalities, the

marginal cost and the willingness of consumers to pay for their brand loyalty on manufacturers' pricing strategies [11]. Luo Qin (2008) studied the optimal decision-making of companies facing different profit margins based on the classic Cournot model. She established a discrete dynamic system model based on the game theory of resource oligarchs and found out the Nash equilibrium points of each manufacturer under cooperating and non-cooperating situation [4].

Mou Bojiao, Chen Jian, and Xiao Yongbo (2009) used the MNL model to conduct research and found that the equilibrium price of products in the oligopoly market goes up with the increase of costs, production's value and the cost of competitive products. In general, the equilibrium behavior of oligopoly firms is to provide product lines [5]. Liu Feng, Li Yaguang, and Wang Hongxing put forward by establishing a four-oligarch price game model that oligopoly manufacturers, with the goal of maximizing their own interests, will constantly adjust their product prices and ignore the external effects of product price changes, so as to make their own profits decline eventually due to market chaos. Therefore, product manufacturers should sell at lower prices to maximize their own interests and avoid changing prices frequently [3].

Yu Lin believes that oligopoly manufacturers can gain a certain oligopolistic advantage by continuously lowering the prices of their products, but at the same time, industry competition has intensified and the overall profit of the industry has declined. Therefore, manufacturers should focus on product differentiation in order to capture market share and avoid low-price competition [9].

Based on the Cournot model and the Stackelberg model, this article will discuss the production and marketing strategies of manufacturers in the oligopoly market and use Gree air-conditioning manufacturers as an example to conduct specific data analysis.

* Corresponding author: zzxueyizz@qq.com

3 MODEL CONSTRUCTION

3.1 Cournot Model Under Complete Information Market

The Cournot model assumes that in a duopoly market, two firms try to make decisions about how much to produce at the same time. Each firm makes a reasonable prediction of the output of the other firm in order to determine their own output that maximizes its profits. The model derives their respective reaction functions based on the predictions made by the two manufacturers, thereby obtaining the predicted equilibrium. In traditional Cournot model, two firms are assumed to have same marginal costs. However, in reality, the marginal production costs of oligarchs are not completely the same. Therefore, the model in this article assumes that different firms have different marginal production costs.

It is assumed that the output of firm 1 and firm 2 are determined as q_1 and q_2 , respectively, and the total supply of commodity in the market is $Q = q_1 + q_2$ (1). P represents the price of a unit commodity and a is the highest willingness to pay in this market. Therefore, the inverse demand function is $P = a - Q = a - (q_1 + q_2)$ (2). Assuming that the fixed costs of the two firms are both 0, the marginal cost of firm 1 is c_1 , and the marginal cost of firm 2 is c_2 , and the goal of each firm is to maximize their own profit. Therefore, the profit function of firm i is $\pi_i = q_i * (a - q_1 - q_2 - c_i)$, $i=1,2$. (3)

By finding the first-order condition of the profit functions of two firms, the reaction function of firm 1 is

$$q_1^* = \frac{a - c_1 - q_2}{2} \quad (4), \text{ the reaction function of firm 2 is}$$

$$q_2^* = \frac{a - c_2 - q_1}{2} \quad (5). \text{ By combining the reflection functions of the two firms, the equilibrium point in the}$$

$$\text{model is obtained as } \frac{a - 2c_1 + c_2}{3}, \quad q_2^* = \frac{a - 2c_2 + c_1}{3} \quad (6),$$

$$(7). \text{ The price of commodities in the market is } P = a - (q_1 + q_2) = \frac{a + c_1 + c_2}{3} \quad (8) \text{ and the profits of}$$

$$\text{the two firms are } \pi_1 = \frac{(a - 2c_1 + c_2)^2}{9} \quad (9),$$

$$\pi_2 = \frac{(a - 2c_2 + c_1)^2}{9} \quad (10), \text{ respectively.}$$

3.2 Cournot Model Under Incomplete Information Market

The assumption of the Cournot model not only requires two firms to have a fixed marginal cost and homogenization of their products, but also requires that the market information is completely symmetrical, that is, both firms know each other's marginal costs. However, in the real market, the marginal cost of some companies is not completely open to competitors. Therefore, the Cournot model under incomplete information market is also need to be introduced.

Assuming that the output of firm 1 and firm 2 are respectively determined as q_1 and q_2 , the total supply in the market is $Q = q_1 + q_2$ (1), P is the price of a unit

commodity, and a is the highest willingness to pay in the market, then the inverse demand function is $P = a - Q = a - (q_1 + q_2)$ (2). Assuming that the fixed costs of the two firms are both 0 and the marginal cost of firm 1 is c_1 . The marginal cost of firm 2 is not completely certain to firm 1. The probability that its marginal cost is c_H is θ and the probability that it is c_L is $1 - \theta$. Therefore, the profit function of firm i is $\pi_i = q_i * (a - q_1 - q_2 - c_i)$, $i=1,2$. (3)

By seeking the first-order conditions for those two profit functions, the reaction function of firm 1 can be conducted which is

$$q_1^* = \frac{\theta[a - q_2^*(c_H) - c_1] + (1 - \theta)[a - q_2^*(c_L) - c_1]}{2} \quad (11). \text{ If}$$

$$\text{firm 1 is a high-cost firm, then its reaction function is } q_2^*(c_H) = \frac{a - q_1^* - c_H}{2} \quad (12), \text{ whereas if firm 1 is a}$$

$$\text{low-cost firm, its response function is } q_2^*(c_L) = \frac{a - q_1^* - c_L}{2} \quad (13). \text{ Combining the reaction}$$

functions of the two firms we can get the equilibrium point in the model which is

$$q_1^* = \frac{a - 2c_1 + \theta c_H + (1 - \theta)c_L}{3} \quad (14),$$

$$q_2^*(c_H) = \frac{a - 2c_H + c_1}{3} + \frac{1 - \theta}{6}(c_H - c_L) \quad (15),$$

$$q_2^*(c_L) = \frac{a - 2c_L + c_1}{3} + \frac{\theta}{6}(c_H - c_L) \quad (16).$$

Therefore, the profit of firm 1 is $\pi_1 = \frac{[2a - 4c_1 + 3\theta c_H - \theta c_L - (1 - \theta)c_L] * [a - 2c_1 + \theta c_H + (1 - \theta)c_L]}{18}$ (17) and the profit of firm 2 is

$$\pi_2 = \frac{[2a + 2c_1 - 3\theta c_H - \theta c_L - (1 - \theta)c_L] * [2a - 4c_H + 2c_1 + (1 - \theta)(c_H - c_L)]}{36} \quad (18)$$

$$\text{when firm 2 is a high-cost firm, the profit firm 1 is } \pi_1 = \frac{[2a - 4c_1 - 3\theta c_H + 2c_L + 3\theta c_L] * [a - 2c_1 + \theta c_H + (1 - \theta)c_L]}{18} \quad (19)$$

$$\text{and the profit of firm 2 is } \pi_2 = \frac{[2a + 2c_1 - 3\theta c_H - 4c_L + 3\theta c_L] * [2a - 4c_L + 2c_1 + \theta(c_H - c_L)]}{36} \quad (20)$$

$$\text{when firm 2 is a low-cost firm.}$$

3.3 Stackelberg Model

In actual production, in addition to the possibility that two oligarchs are required to determine production amount at the same time, there is also a situation in which two firms make decisions on their own outputs successively. Therefore, the Stackelberg model needs to be introduced in this paper. In this model, it is assumed that a firm determines its amount of output as a natural leader and then another firm, as a follower, adjusts its output according to the leader's decision.

Assuming that firm 1 is the leader in the market and firm 2 is the follower. The output of those two firms are q_1 and q_2 respectively. Then the total supply of goods in the market is $Q = q_1 + q_2$. (1) P is the price of a unit commodity and a is consumer's highest willingness to pay in this market. Therefore, the inverse demand function of this product is $P = a - Q = a - (q_1 + q_2)$. (2) Assuming that the marginal cost of firm 2 is c_2 , then the profit of firm 2 is $\pi_2 = q_2 * (P - c_2) = (a - q_1 - q_2 - c_2)q_2$

(21) and the reaction function of firm 2, by seeking a first-order condition on its profit function, is obtained as $q_2^* = \frac{a-c_2-q_1}{2}$ (22).

Firm 1's profit is $\pi_1(q_1, q_2^*) = q_1 * (P - c_1) = \frac{q_1 * (a - 2c_1 + c_2 - q_1)}{2}$ (22). By seeking a first-order condition on this profit function, firm 1's optimal output can also be obtained as $q_1^* = \frac{a - 2c_1 + c_2}{2}$ (23). Substituting this into the reaction function of firm 2 and its optimal output can be calculated, which is $q_2^* = \frac{a - 2c_2 + c_1}{4}$ (24). The price of the commodity in the market is $P = \frac{a + 3c_1}{4}$ (25). Therefore, the profit of firm 1 is $\pi_1 = (P - c_1) * q_1 = \frac{(a - c_1) * (a - 2c_1 + c_2)}{8}$ (26) and the profit of firm 2 is $\pi_2 = (P - c_2) * q_2 = \frac{(a + 3c_1 - 4c_2) * (a - 2c_1 + c_2)}{16}$ (27).

TABLE 1. PRODUCTION COST OF AIR CONDITIONER [8]

Unit: yuan	Compressor	Production of external parts (evaporator, condenser) and motor controller, etc.	Manufacturing costs	Sales costs	Marginal costs
Gree KFR-26GW/ (26556) FNDc-3	500	810	33.43	357	1700.43
Other air conditioners	515	831.75	31.44	370	1748.19

Since the offline market share of Gree and Midea air conditioner in 2019 were 45.9% and 27.2% respectively and the sales volume of air conditioner far exceeded that of Haier air conditioner which ranked third, which means the air conditioning market has gradually formed a n oligopoly in recent years, this paper assumes that there are only two firms, Gree and Midea, manufacturing and competing with each other in the air-conditioning market.

The commodities with the biggest demand are the air conditioners with a price of 2000-3000 yuan, and the second most demanded price ranges from 3000 to 4000 yuan. Only about 30% of consumers are willing to pay more than 4000 yuan for an air conditioner. Therefore, it is assumed that the highest willingness to pay in the air-conditioning market is 5000 yuan.

In the Cournot model under complete information market, $c_1 = 1700.43$ yuan and $c_2 = 1748.19$ yuan. In equilibrium, the production quantities of the two firms are $q_1^* = 1116$ and $q_2^* = 1068$ respectively. Under that situation, the average price of air conditioners in the market is 2816.21 yuan. Therefore, Gree Air Conditioning's profit was 1,244,957.57 yuan and Midea Air Conditioning's profit was 1,140,659.60 yuan.

In the Stackelberg model, $c_1 = 1700.43$ yuan and $c_2 = 1748.19$ yuan. In equilibrium, the production quantities of the two manufacturers are $q_1^* = 1116$ and $q_2^* = 1068$ respectively. Under that condition, the average price of air conditioners in the market is 2525.32 yuan. Therefore, the profit of Gree air conditioning firm is 1,380,593.71 yuan, and the profit of Midea air conditioning firm is 650,329.73 yuan.

A. Analysis of Gree Air Conditioning

In recent years, the global economic climate has become worse and the economic growth of major economies such as the United States, the European Union and Japan has shown a significant slowdown. In 2019, the gross domestic product (GDP) of China increased by 6.1% year-on-year which is the lowest growth rate in 20 years. Domestic market sluggishness has become a common phenomenon in many industries. Therefore, how to give full play to their advantages and suppress their competitors in a sluggish market is critical. The following will take Gree air conditioner as an example, using the Cournot model for analysis.

In the air-conditioning market, according to the investigation, the cost of a commodity with a market quotation of about 2500 yuan is roughly as follows:

Since 2004, Gree has cooperated with Baosteel, which enabled Gree to obtain air-conditioning manufacturing materials at preferential prices. In 2005, Gree introduced the most advanced compressor production equipment in Zhuhai Douden and since then, it has invested in the construction of a motor manufacturing factory. The improvement of these industrial chains brought a significant reduction of the production costs for Gree air-conditioning. Therefore, in this paper, it is assumed that the marginal production cost of Gree air-conditioning may decrease by 30% on the original basis and the probability is 50%.

That is, in the Cournot model under incomplete information market, Midea's marginal production cost is $c_1 = 1748.19$ yuan while Gree's marginal production cost is $c_H = 1700.43$ yuan, $c_L = 1190.30$ yuan and $\theta = 0.5$. The production quantities of the two firms in equilibrium are $q_1^* = 983$, $q_2^*(c_H) = 1158$, $q_2^*(c_L) = 1498$. Therefore, when Gree is a high-cost firm, Gree air-conditioning profit is 1,341,629.93 yuan and Midea air-conditioning profit is 1,091,642.98 yuan whereas when Gree is a low-cost firm, Gree air-conditioning profit is 1,990,336.61 yuan and Midea air-conditioning profit is 1,128,528.89 yuan.

From the results above, it can be seen that in the complete information market, Gree Air Conditioning's profit as a leader in the Stackelberg model is higher than the profit obtained in the Cournot model while in the Cournot model with incomplete information, the lower the marginal production cost of air conditioners is, the higher the output is, and the lower the equilibrium price of

products in the market is, which means the profit of the firm is directly proportional to the output and inversely proportional to the market equilibrium price.

4 CONCLUSION

When the oligopoly market is a complete information market, firms should use their brand influence to become the leader of the market as much as possible and decide their own amount of output before other firms. When the oligopoly market is an incomplete information market, firms should reduce their marginal production costs as much as possible to expand their own scale of production and seize more market share. At the same time, they should also control the rate of change in amount of output and price within a reasonable range to avoid loss of profits caused by excessive decline in product prices.

ACKNOWLEDGEMENT

Thanks to the professors and students who helped in the creation of this paper. It was they who enabled me to learn more relevant knowledge and concepts. The completion of this paper was inseparable from their help.

REFERENCES

1. Hanif D. S herail, Al len L . S oyster, Frederic H. Murphy, Stackelberg-Nash-Cournot Equilibria: Characterizations and Computations[J], Operations Research, 1983, 31(2): 253-276.
2. Koji Okuguchi, Cournot and Stackelberg Duopolies Revisited[J], Japanese Economic Review, 2002, 50(3): 363-367.
3. Liu F., Li Y. G., Wang H. X., Price Game Model of Four Oligopoly and Its Complex Characteristics under Nonlinear Demand[J], Journal of System Engineering, 2016, 31(6): 719-728+839.
4. Luo Q., Research on Oligopoly Game of Renewable Natural Resources Based on Bounded Rationality[D], Jiangsu University, 2008.
5. Mou B. J., Cheng J., Xiao Y. B., Research on the Competitive Structure of the Product Line of Oligopoly Companies—Based on the Discrete Choice Behavior of Customers[J], Journal of Tsinghua University (Philosophy and Social Sciences Edition), 2009, 24(1): 21-26.
6. National Household Appliance Industry Information Center, China Home Appliance Industry Annual Report (2019) [EB/OL], 2020, <http://d.wanfangdata.com.cn/periodical/jydq202003008>.
7. Simon P . Anderson, Maxim Engers Stackelberg versus Cournot oligopoly equilibrium [J], International Journal of Industrial Organization, 1992, 10(1): 127-135.
8. Sun Y. R., price analysis of Gree air conditioner[D]. Zhengzhou: Zhengzhou University of Light Industry, 2016: 4-6.
9. Yu L., Game Analysis and Countermeasures of Price Competition in Oligopoly Market[J], Market Modernization, 2006, (8): 44-45.
10. Zhang, Y. -B, Luo, X. -J, Zhou, X. -S, Xu, J. -Y, Generation market power and the influence of bilateral trade on it[J], Proceedings of the Chinese Society of Electrical Engineering, 2004, 24: 18-23.
11. Zhang Y. M., Su Y. Q., Hotelling Pricing Model in Two-stage Duopoly Market[J], Practice and Understanding of Mathematics, 2017, 47(4): 25-34.