Research on the Pricing Strategy of New Energy Medium-sized Vehicles Based on Game Theory: Taking Tesla and BYD as Examples

Yingqi Chen[1, †] and Ruiyang Zhang[2,*,†]

[1] XiWai International school, Shanghai, 021-37727030, China

[2] College of Business, Nankai University, Tianjin, 300000, China

*Corresponding author: 2111647@mail.nankai.edu.cn

† These authors contributed equally.

Abstract: In recent years, the demand for new energy vehicles has been increasing. As foreign cars enter the Chinese market, the competition for new energy vehicles in China has become increasingly fierce; inevitably resulting in price wars, but blind price wars will only damage the interests of all parties. This paper uses a static game and a repeated game to analyze how firms can adopt pricing strategies to maximize their benefits. The results show that no matter what the situation is, if a company uses price cuts to capture the market, it may increase its own revenue in the short term, but in the long term, it will cause losses to itself and other companies. Finally, reasonable suggestions are made for new energy vehicle companies facing pricing problems. The research conducted in this paper on pricing can, to a certain extent, enable enterprises to carry out the correct pricing strategy, improve the interests of the enterprises as well as the whole enterprise, and thus promote the development of the new energy vehicle industry.

Keywords: Game theory; New energy; Mid-size cars; Pricing strategy.

1. Introduction

1.1 Research Background

At the current stage of rising oil resource consumption, the development of new energy vehicles is unstoppable, and people's demand for new energy vehicles is increasing. As foreign automobile enterprises continue to enter the Chinese market, the Chinese market is now an oligopoly market, in which the behavior of any automobile enterprise will be found, and it is difficult to avoid producing a price war, and in the price war, clearly formulating the corresponding strategy is very crucial, not only need the leader's self-decision more need theoretical support, game theory can be used as an effective theoretical tool to help develop the strategy [1,2].

In recent years, the manufacturers of new energy vehicles have been competing on price, but the result has not been an increase in their respective interests, but rather a decrease in revenue for the entire new energy vehicle industry, which is detrimental to the future development of the industry [3]. Tesla is a major international brand in the new energy vehicle industry and BYD is a very strong national brand. Tesla's model 3 and BYD's Han both belong to the new energy mid-size car, and the article takes these two cars as examples to analyze the price static game and repeat the game and put forward reasonable suggestions to maximize their interests.

The market entry game is a common basic game model in game theory, where the new company has two strategic choices: to enter or not to enter, and if it chooses to enter, the monopoly company also has two strategic choices in response to the entrant's choice: to fight and to acquiesce [4]. A monopoly company's strategy of struggle is to compete fiercely with the entrant, using various methods to combat the entrant, such as the common strategy of selling at a low price, selling the product at a price lower than its own cost, which in the short term will cause the company to lose money, but can effectively prevent the entrant from entering the market and continue to maintain its own monopoly position; the strategy of acquiescence is not to take measures to combat the entrant, acquiescing to the entrant to compete with itself. Although there are new entrants competing for the

market, resulting in a decrease in their own market share and profits, they can still make some profit. The outcome of the game is usually determined by the firms' expectations of profits as a result of their choice of strategy.

Assuming that both firms are not satisfied with their respective market shares and profits, it is possible that both firms will want to compete for a larger market share and more profits by reducing their prices. Suppose that both companies can each make a profit of A under their original "high price" strategy; if one company reduces its price alone, i.e. adopts a "low price" alone, then it can make a profit of B. At this point, the other company's profit will fall to C because it has lost market share to its rival. If the other company also reduces its price, both companies will only get a profit of D. If the other company also reduces its price, both companies will only get a profit of D.

1.2Literature Review

At present, there is a large amount of literature studying the pricing of new energy vehicle companies in imperfectly competitive markets and the price game problem. Tesla 'model 3' and BYD 'Han's pricing strategy is obtain low prices. Li et al. (2018) used a built analytical model based on game theory to quantitatively simulate the price of new energy vehicles under various scenarios to verify the efficacy of the new laws [5]. The profit distribution of each of the five supply chain members was solved by JingHua Zhao et al. in 2020 using the concepts and techniques of game theory. They also compared the various subsidy sales channel pricing, recycling channel pricing, changes in the profit range of each supply chain member, and changes in the profit distribution ratio of the closed-loop supply chain under different objects, which have an impact on the final pricing [6]. Rich configurations could counteract the impact of the price brand, according to Yao Xinwu, who used the DCM (Discrete Choice Modeling) model to study the best pricing practices used by corporate manufacturers [7]. In 2020, Lin Simeng will use the current market conditions for new energy vehicle products and pricing methods and strategies based on research, thorough consideration of the varied factors influencing the price of new energy vehicles, and existing pricing issues of new energy companies, including raw material procurement, processing, and production, as well as other costs incurred, targeted to give the corresponding improvement advice one by one. It is suggested to use a pricing game strategy based on the product life cycle and a product portfolio pricing game strategy [8]. This study employs two game models to assess the pricing strategy of oligopolistic new energy vehicle businesses based on the aforementioned research, and it offers some references for the best pricing strategy selection.

2. Tesla price change status

After the Tesla model 3 entered the Chinese market from 2019, the price has been adjusted for several rounds. According to statistics, the price of the standard range version of the model 3 has changed from 32.8-419,800 yuan in 2019.6 to 27.99-367,900 yuan in 2022.3, while the sales of the model 3 in China have gradually risen from 34,000 units in 2019 to In contrast, the price of the BYD Han, which has been described as the biggest competitor of the model 3, has changed from RMB 21.98-27.95 million in 2020 to RMB 21.48-31.98 million in 2022, and the sales of the BYD Han have increased from 40,000 in 2020 to 117,000 in 2021 to 117,000 units in 2021. Both models have undergone several rounds of price adjustments, but eventually prices tend to fall, and in this year the models will still expand production and reduce their prices, both of which have the effect of reducing prices more often and by a greater margin, and will lead to increased sales.

3. Model Analysis

3.1 Static game model

Both Tesla model 3 and BYD "Han" are electric cars of medium size, with a price ranging from 200k to 300k RMB. Both of their sales volumes are around 25k per month in China, which make them the top selling models of their brands. Besides, BYD has a price ranging from 100k to 300k while Tesla not only has top selling models priced at 200k to 400k but also has high end model

starting from 800k. Therefore, these two brands have competition only in the medium sized model which cost 200k to 300k.

In the game, both manufacturers pursue maximum profit. The two brands have dominant position in China's electric car market, which makes them oligarch manufacturers. At first, Tesla and BYD sell their medium sized models at a price from 200k to 300k, shortened as original price here. Before the drop of prices, the profit of Tesla and BYD are U1 and U2 respectively. When BYD maintain its original price but Tesla lower its price to enlarge its market share, Tesla may gain profit which far exceeds the loss of price drop, and the net increase of its profit is Ua. In this circumstance, BYD suffers from decrease of sales volume and the loss is Ub. When they both lower the price, none of them can monopolize the market and the net loss for them are both Uc ($U_c<U_b<U_a$).

Table 1. Payoff matrix

	BYD original price	BYD cut price
Tesla original price	U_1 , U_2	U_1-U_b , U_2+U_a
Tesla cut price	U_1+U_a , U_2-U_b	U_1-U_c,U_2-U_c

From the above payoff matrix, it can be known that when BYD's choice of maintaining its original price is given, Tesla can gain more profit by cutting price than sticking to its original price, i.e.

$$U_1+U_a>U_1. \quad (1)$$

Also, when BYD's choice of cutting its price is given, Tesla can gain more profit by cutting price than sticking to its original price, i.e.

$$U_1-U_c>U_1-U_b. \quad (2)$$

Accordingly, when the pricing strategy of BYD is given, Tesla can gain more profit by cutting price than sticking to original price, so cutting price is the manufacturer's best choice. Similarly, when the pricing strategy of Tesla is given, cutting price is the BYD's best choice. When Tesla's choice of maintaining its original price is given, BYD can gain more profit by cutting price than sticking to its original price, i.e.

$$U_2+U_a>U_2. \quad (3)$$

When Tesla's choice of cutting its price is given, BYD can gain more profit by cutting price than sticking to its original price, i.e.

$$U_2-U_c>U_2-U_b \quad (4)$$

Therefore, (price cut, price cut) is Nash equilibrium of this game. Manufacturer who cuts price first get the benefit of sales volume rising, making more profit in the short-term. But other manufacturer may also cut its price in order to fight back. Then the advantage of manufacturer who cuts price first may disappear and become disadvantage at last. In the long-term, the strategy of price cut may not work. To merely cut price will not help increase market share in the long-term, and may bring huge loss to the company. For the manufacturer who starts price war, the loss outweighs the gain ultimately. Besides, blindly lowering the price is harmful to the brand image and product positioning in customers' mind. This (cut price, cut price) equilibrium is based on the premise that products of these two brands' medium sized cars are just the same and are facing the same market. In other words, a manufacturer can only fight back the price cut of the other manufacturer by reducing the price due to homogenization of their products. However, there are significant difference between Tesla Model 3 and BYD Han in reality, regarding of their design, performance, cost of production and profit margin. As a result, the premise of (cut price, cut price) may not hold, and the result of their competition may not be a lose-lose situation. By improving quality and design of their products, manufacturers may get out of the prisoner dilemma of (cut price, cut price).

3.2 Repeated game model

Repeated game includes finitely repeated game and infinitely repeated game. Both Tesla and BYD regard China as a major market of their medium sized cars, so their sales in China will continue. Therefore, game of the two manufacturers on pricing strategy may be constantly repeated. Since it is not clear how long these two brands may exist, their games are defined as infinitely repeated games.

Introduce the discount factor k:

$$k=\frac{1}{1+r} \quad (5)$$

r is the market rate of a certain period) to the model. Players go through n stages of games, and in the equilibrium of each stage, they gain profit of U1, U2, U3, …, Un. Discounting and summing profit of each stage can get total profit of finitely repeated games i.e.

$$U'=U_1 + k * U_2 + k^2 * U_3 + \cdots \ldots + k^{n-1} * U_n \quad (6)$$

So the total profit of infinitely repeated games is

$$U=U_1 + k * U_2 + k^2 * U_3 + \cdots \ldots \quad (7)$$

If Tesla cut the price and BYD has not yet reacted, Tesla will gain all the profit of price reduction, so in the first stage it will earn a profit of $(U + U_a)$. Then BYD takes revenge by cutting its price continuously and Tesla has to cut price continuously in response to competition which makes its profit of each stage decrease to $(U - U_c)$. So, the total profit after discounting is

$$U'=(U + U_a) + \frac{(U-U_c)*k}{1-k} \quad (8)$$

If Tesla' price remains the same, its profit in each stage will be U, and total profit after discounting will be

$$U'=\frac{}{1-k} \quad (9)$$

Therefore, when

$$(U + U_a) + \frac{(U-U_c)*k}{1-k} < \frac{U}{1-k},$$

i.e.,

$$k > \frac{U_a}{U_a+U_c} \quad (10)$$

Tesla will stick to its original price, otherwise it will cut price. In the former situation, the discount factor k is relatively big, i.e. future market rate will be low, so Tesla may focus more on the long-term profit, avoiding to increase short-term profit by starting a price-war which will lead to revenge of BYD and cause damage to the company's long-term profit. In the later situation, discount factor k is relatively small i.e. future market rate will be high, so Tesla will put more emphasis on the short-term profit, adopting the price-cutting strategy regardless of the damage of long-term profit.

In the initial stage of this game, sticking to the original price is the best choice of both sides, and this (original price, original price) situation will continue until a player choose to cut price which will cause the other player take its revenge and turn this game into a (cut price, cut price) equilibrium, leading to a lose-lose situation. By contrast, if both parties are rational enough to maintain the (original price, original price) situation, they will both achieve the maximum profit.

In conclusion, regardless of whether the game is a finitely repeated game or an infinitely repeated one, if a manufacturer cut price of its products to seize market, it will be harmful not only to the profit of itself but also to other manufacturers.

4. Results and Discussion

This paper analyses the pricing problem of medium-sized new energy vehicles in the Chinese market, taking the Tesla model 3 and BYD Han as examples, and uses a static game model to explain the price reduction of the two products in order to capture the market. However, as the magnitude of k is constantly changing, it is possible that one of the parties will choose a price reduction strategy first, which will lead to the other party choosing a price reduction strategy as well, which will result in some damage to the long-term benefits. This leads to the following recommendations.

For foreign imports of new energy medium-sized vehicles, encourage the establishment of factories in China to achieve production within China, reduce taxes and fees and save costs to face the challenges posed by price reductions. For domestic independent brands of new energy medium-sized vehicles, the state can increase subsidies, expand the scale of production, form an orderly cooperation and competition model, and establish an orderly and reasonable market system [9].

Encourage the promotion of domestic brands to expand their international competitiveness. Every country should protect its own national brand, which is a practice that every country should have [10].

The difficulties faced by new energy vehicles are mainly due to the fact that the level of technology has not yet been perfected and the market mechanism is not yet mature. It should be noted that the government should be moderate in its protection of enterprises, so as to avoid the phenomenon that too little effort has no effect and too much effort hinders the development of enterprises.

Each company needs to have its own unique product. To this end, enterprises should strengthen their own research and development; strive to improve product quality and technology; make flexible use of foreign capital to resist the challenges posed by imported products; and establish a unique after-sales service system. There is still a gap between the key technology and quality level of China's new energy medium-sized vehicles and the big international brands. The realistic reason is the lack of its own unique technology in key areas lack of independent research technology, the need for enterprises to increase research and development efforts [11]. In the development process, try to reduce the confrontation with foreign companies. What needs to be done for big international brands like Tesla to enter the Chinese market is to make full use of China's policy towards foreign companies and to constantly update their core technology level?

Encourage and guide customer consumption, for new products and new consumer hotspots, need to be encouraged by the government, enterprises through advertising to attract consumers, can improve the demand, to reach a new balance between supply and demand, improve the oversupply situation, while improving economic growth to counteract the enterprise R & D products, to promote a virtuous circle to solve the price competition [12].

5. Conclusion

The development of new energy vehicles is unstoppable under the premise of increasing consumption of oil resources, and with foreign brands gradually entering the Chinese market; the Chinese new energy vehicle market has turned into an oligopoly market. In order to solve the problem of blind price wars, which lead to the loss of both sides, and to improve the revenue of enterprises, the paper uses a static game to conduct a high and low price game between two enterprises and the introduction of a discount factor k in the repetitive game to study the pricing aspects, and finds that if enterprises blindly use price reduction to seize the market, the revenue will not last long or even generate losses. The paper thus makes recommendations for companies and the government to make full use of government policies to reduce costs, increase revenues, increase investment in their own research, develop their own brand of unique products and achieve product differentiation to compete in the market. The government also needs to improve its policies for foreign and domestic companies and for consumers to purchase new energy vehicles in order to encourage consumer spending. These recommendations could bring more benefits to companies and the industry as a whole and address the side effects of price competition. However, there are still some shortcomings in this paper, as it is still a theoretical game analysis, and the game analysis is also using dummy variables, with less predictive game analysis of actual data.

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