Research on Co-opetition Strategy of New Energy Vehicle Companies Based on Stackelberg Game: Taking Tesla and BYD as Examples

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Abstract. With the support policies of various countries, new energy vehicles are developing rapidly. The promising prospect of new energy vehicle market also leads to the competition between oligopolistic companies intensify. Based on Stackelberg game model, this paper analyzes the problem of production and revenue between Tesla and BYD in the state of competition and cooperation. The research results of this paper show that: without considering the difference of entry cost and marginal cost between the two companies, the optimal strategy of both companies is to cooperate in making production decision and suggest the corresponding countermeasures in the cooperation mode. In order to maintain the leading edge of both parties in the industry, Tesla and BYD should combine resources to reduce entry cost and marginal cost, widen the cost gap with late entrants, and reduce competitive pressure. The research in this paper has important practical significance for the future development of new energy vehicles.

Keywords: Tesla; BYD; Co-opetition strategy; Stackelberg.

1. Introduction

1.1 Research Background

In the context of China's economic globalization and automobile industrial transformation and upgrading, China's new energy automobile industry is actively participating in the international market competition [1]. The proposed development strategy system of "industrial symbiosis" for new energy vehicles requires enterprises to pay attention to their own R&D innovation, and to integrate industrial resources and carry out collaborative innovation with a group-based global strategy. In some aspects, breakdowns have been reflected. Taking the development of new energy vehicle batteries as an example, it is necessary to deepen the cooperation and communication between enterprises and promote a win-win cooperation between upstream and downstream enterprises [2]. Effective cooperation and competition among enterprises requires them to establish long-term trust and cooperation for the overall benefit, but the limited rationality of economist makes enterprises may choose not to cooperate and obtain temporary betrayal benefits, and the essence of cooperation and competition among enterprises is to make the "cake" bigger through it. Based on the competition theory, this paper selects Tesla and BYD as the representatives of oligopolistic enterprises, establishing a Stackelberg game model between them to analyze the benefits that each party obtains under the following circumstances. BYD, as an industry follower, would observe the decision of Tesla, the industry leader, to decide its own output under the same entry cost and marginal cost. Faced with the competitive pressure of new energy vehicles, especially in the electric market, the need for cooperation among enterprises increases, and the relationship between oligopolistic enterprises will tend to achieve coexistence of competition and cooperation in the future.

1.2 Literature Review

Considering consumer demand for vehicle range and the ability of the industry chain to cooperate and innovate, Liu Yujie (2021) constructs three-game models of equity-holding cooperative R&D that include upstream battery suppliers and downstream vehicle manufacturers in the industry chain. By comparing non-cooperative R&D and equity-holding cooperative R&D strategies, the study shows that cooperative R&D is a more preferable option [3]. Moderate competition can act as a dynamic selection mechanism that determines the existence of various institutional forms. In such a selection mechanism, even if the actors are not considered rational, the evolutionary pressure from society (survival of the fittest) will motivate each actor to take the most appropriate action for its survival, thus making the evolutionary equilibrium reach Nash equilibrium [4]. China's new energy vehicle industry cooperation network from the perspective of industry chain innovation shows that the synergistic relationship between sub-networks is not significant, which lead to the relative lack of innovation in the whole industry chain [5]. Liang Shuai, Li haibo and Chen Na consider that cooperation and technology exchange between new energy vehicle enterprises is still based on the traditional automotive industry cooperation network, which is somewhat restrictive [6]. According to Bai Mei, although BYD ranks first in the world in terms of sales of new energy vehicles, its sales are far behind those of Tesla in terms of a single model, and there is the problem that a single model does not have economies of scale. Moreover, domestic car companies should learn from Tesla, strengthen the cultivation of technology research and development capabilities, and improve international operation capabilities [7].

These studies provide the basis for the theoretical and research methodology for this paper's study of competitive strategies. From the above literature review, it can be seen that competition and cooperation between enterprises are inevitable in the long-term development of new energy vehicles, and the competitive game has an important role to play in analyzing the development strategies of enterprises. The existing literature has yielded some results on the vertical competition strategies between upstream and downstream firms in the supply chain. This study aims to solve the Nash equilibrium with the objective of optimal returns for the double oligopoly, which is a practical guide for Tesla and BYD to further maintain and expand their competitive advantage in the future.

2. Theoretical Foundation

American scholars Brandenburger and Nalebuff in 1996 for the first time clearly put forward the concept of co-opetition. The capture and creation of value need to move from simple low-level bilateral confrontation to adapt to the trend of diversified cooperation [8]. Co-opetition is a new type of dynamic dependency relationship between enterprises based on partial alignment of interests. In the process of market operation, enterprises should curb low-priced vicious competition and establish a continuous dynamic cooperative relationship based on competition. Hence, the sum of benefits obtained by all competitive participants will be greater than the sum of their inputs, achieving the goal of win-win situation for all parties [9]. Simultaneously, the Stackelberg Leadership Model is a ponderable model used to analyze oligopolistic competition proposed by German economist H. Von Stackelberg in the 1930s. This model is a price leadership model in which oligopolistic enterprises producing homogeneous goods which are assumed costing equally (i.e. output is the decision variable of the model) and the game participants are divided into dominant and following firms according to the size of output [10].

3. Model Assumptions and Analysis

3.1 Model Assumption

In recent years, BYD sales have scored a substantial increase and the market share gap between BYD and Tesla has gradually decreased. According to the data published by CleanTechnica

(https://cleantechnica.com/), in the list of global new energy vehicle companies in Q1 2022, Tesla ranked first with 310,411 units, which has captured 15.5% of global market; BYD ranked second with 285,849 units, with a global share of 14.3%.These are also the only two companies with global shares of more than 10%. Thereupon this article considers Tesla as the leader of the new energy vehicle market and BYD as a follower.

First, the number of market competitors is 2, and Q represents the total output of the market. The output of the two competitors are Q_1 and Q_2 respectively, and the total output of the market is equation (1) ：

$$Q = q_1 + q_2 \tag{1}$$

Second, since entering the new energy vehicle industry requires a large amount of investment, the impact of production cost on its revenue should be taken into account when Stackelberg model is constructed, that is, production cost is composed of entry cost and marginal cost. Assuming that the entry cost of the i market competitor is F_i and the marginal cost is C_i, the production cost is shown in equation (2):

$$C_i(q_i) = F_i + c_i q_i \tag{2}$$

F_i， C_i are normal numbers，$(i = 1,2 \ldots)$.The market price is determined by the total output Q as the independent variable and the market price p as the dependent variable. The inverse demand function is:

$$p(Q) = a - bQ \tag{3}$$

where $a > 0$ and $b > 0$; then the market price of each competitive participant is expressed in Equation (4).

$$p_i(q_i) = a - b\sum_{i=1}^{n} q_i \tag{4}$$

The revenue function of each competitor is as follows (5) and (6):

$$\pi_i(q_i) = q_i \tag{5}$$

$$(a - b\sum_{i=1}^{n} q_i) - F_i - c_i q_i \tag{6}$$

a, b are normal numbers，$(i = 1,2 \ldots)$. Due to the different market positions of Tesla and BYD at the present stage, according to the Stackelberg model analysis, Tesla is regarded as the leading enterprise, with the output q_1, and BYD as a follower setting its own output q_2.

3.2 Analysis of Stackelberg game model under competitive state

Both of them are rational, aiming at profit maximization when making sequential production decisions. Now it is assumed that the two car companies have the same scale when they enter the market, and the difference of entry cost and marginal cost between them is not considered. Assuming that the entry cost is F and the marginal cost is c, the revenue function of Tesla and BYD according to their different market shares is Equation (7):

$$\begin{cases} \pi_1(q_1, q_2) = q_1(a - b\sum_{i=1}^{2} q_i) - F - cq_1 \\ \pi_2(q_1, q_2) = q_2(a - b\sum_{i=1}^{2} q_i) - F - cq_2 \end{cases} \tag{7}$$

Assuming that q_i^*,π_i^* represent the optimal yield and optimal yield of Tesla and BYD in a competitive state, respectively, where i=1,2. For this Stackelberg game with multiple stages, backward induction is used to solve its sub-game refined Nash equilibrium.

First of all, when Tesla selects the output q_1, the conditions for BYD to obtain the maximum income in the second stage are as follows (8):

$$\frac{\partial \pi_2}{\partial q_2} = a - bq_1 - 2bq_2 - c = 0 \tag{8}$$

Equation (9) is solved as follows:

$$q_2^* = \frac{a - bq_1 - c}{2b} \tag{9}$$

q_2^* is the reaction function of BYD to Tesla's output.Then Tesla predicts BYD's output q_2^*, so its maximum revenue condition in the first stage is: $\frac{\partial \pi_1}{\partial q_1} = 0$. By substituting q_2^* into Equation (5) and taking its partial derivative, Equation (10) can be obtained:

$$q_1^* = \frac{a - c}{2b} \tag{10}$$

Substituting Equation (10) into Equation (11), it can be obtained

$$q_2^* = \frac{a - c}{4b} \tag{11}$$

Therefore, in the competitive state, the subgame refined Nash equilibrium of the Stackelberg game model when Tesla and BYD successively select output is ($\frac{a-c}{2b}$, $\frac{a-c}{4b}$). In this case, the total market output is: $Q^* = \frac{3a-3c}{4b}$, and the respective returns of Tesla and BYD are shown in Equation (12):

$$\begin{cases} {\pi_1}^* = \frac{(a-c)^2}{8b} - F \\ {\pi_2}^* = \frac{(a-c)^2}{16b} - F \end{cases} \tag{12}$$

At this time, the total market return is shown in Equation (13):

$${\pi_{Total}}^* = \frac{3(a-c)^2}{16b} - 2F \tag{13}$$

3.3 Analysis of Stackelberg game model analysis under cooperative state

In this case, Tesla and BYD decide to adopt a cooperative strategy to jointly decide the total production of cars Q , and promise to only produce half of the decided output, that is, only get half of the total market revenue. According to this hypothesis, the total revenue model of enterprises participating in cooperative decision-making is as follows:

$$\max \pi(Q) = (a - bQ)Q - 2F - CQ \tag{14}$$

When taking the first and the second order partial derivatives, it is easy to conclude that the two companies always yields the highest total output for the

$$Q^{**} = \frac{a-c}{2b} \tag{15}$$

The expression for total revenue is

$$\pi_{Total}{}^{**} = \pi(Q^{**}) = \frac{(a-c)^2}{4b} - 2F \tag{16}$$

The case, both corporate earnings are for

$$\pi(q_1^*, q_2^*) = \frac{(a-c)^2}{8b} - F \tag{17}$$

Their productions are

$$q_1^{**} = q_2^{**} = \frac{a-c}{4b} \tag{18}$$

By comparing equation (16) with equation (13), it is found that $\pi_i{}^{**} > \pi_i{}^*(i = 1,\ 2)$. The Stackelberg model is used to analyze the income of two oligopolistic enterprises in the new energy vehicle market. When the entry cost and marginal cost are the same, the cooperation income is always greater than the competition income.

4. Results and Discussion

The parameters involved in the study for both competition and cooperation states along with the results are shown in Table 1. The following conclusive results are obtained: Through preliminary assumptions on cost-related parameters, firstly, the results of the yield decisions of both parties that maximize the revenue under two states are studied under the idea of controlling variables, while the magnitude of gains is compared. Further, the impact of cost-related variables on both parties in the long run is considered.

Table 1. Parameters and results under different states

Parameters	Competition State	Cooperation State
$\mathrm{F_i}$	F	F
c_i	c	c
C_i	C	C
q_1^*	$\frac{a-c}{2b}$	$\frac{a-c}{4b}$
q_2^*	$\frac{a-c}{4b}$	$\frac{a-c}{4b}$
$\pi_1{}^*$	$\frac{(\mathrm{a}-\mathrm{c})^2}{8b} - F$	$\frac{(\mathrm{a}-\mathrm{c})^2}{8b} - F$
$\pi_2{}^*$	$\frac{(\mathrm{a}-\mathrm{c})^2}{16b} - F$	$\frac{(\mathrm{a}-\mathrm{c})^2}{8b} - F$
$\pi_{\mathrm{Total}}{}^*$	$\frac{3(\mathrm{a}-\mathrm{c})^2}{16b} - 2F$	$\frac{(\mathrm{a}-\mathrm{c})^2}{4b} - 2F$

On the one hand, differences in entry cost and marginal cost of the two firms are not considered. In the output Nash equilibrium derived by both firms in competition to achieve optimal returns, the

respective benefits of both firms are greater than or equal to the competitive benefits when they choose to cooperate in the output decision:

$$\pi_1{}^{*} = \pi_1{}^{**} = \frac{(a-c)^2}{8b} - F \tag{19}$$

$$\pi_2{}^{**} = \frac{(a-c)^2}{8b} - F > \pi_2{}^{*} = \frac{(a-c)^2}{16b} - F \tag{20}$$

In total, the benefits of cooperation are greater than the benefits of competition：

$$\pi_{Total}{}^{**} = \frac{(a-c)^2}{4b} - 2F > \pi_{Total}{}^{*} = \frac{3(a-c)^2}{16b} - 2F \tag{21}$$

Therefore both parties should prioritize the cooperation strategy.

On the other hand, the entry cost F and marginal cost c of Tesla and BYD are directly related to the revenue of both parties and are negatively correlated, both in the competitive state and in the cooperative state. Under the condition of maximum revenue, it can be intuitively concluded that each cost reduction is beneficial to the market share capture and benefit acquisition. Furthermore, in the state of full cooperation, if the two sides reach cooperation in technology R&D level, can effectively reduce the entry cost F of both sides. At this time, $2F$ in the state of cooperation will be much smaller than the sum of high F of both sides in the state of competition. The advantage of cooperation is further expanded.

The rapid development and transformation of a company is inseparable from the collaboration with other companies. At present, Tesla and BYD have occupied most of the Chinese market, and even a large number of international markets. In the era of rapid development, how to maintain the monopoly position of these two enterprises in the long term is a very critical issue. With BYD's rich accumulation in core technology, combined with Tesla's resources and other aspects of profitability, to achieve a state of rational competition and cooperative coexistence. By making production decisions together, we can reduce production pressure and lower total costs while reaping more profits. Shifting the focus of development toward further integration of the industrial chain is the only way to mutually benefit.

5. Conclusion

With the increasingly tense global energy and the deteriorating ecological environment, the development and application of new energy vehicles has become the focus of active exploration by the auto industry in various countries. Auto products will move forward in the direction of safety, energy saving and environmental protection. The goal of research and development has also become a research hotspot. The promising prospect of new energy vehicle market will lead to the competition between oligopolistic companies intensify. In the context of the "industrial symbiosis" development strategy, China's new energy vehicles are facing an important opportunity to emphasize their own R&D innovation. Re-integration of industrial resources and collaborative innovation has become a new way to break through the technological bottleneck from a global strategic perspective. This paper analyzes the benefits of this industrial symbiosis model in the new energy vehicle market by using the Stackelberg model to analyze the game between Tesla and BYD in a competitive and cooperative state from the perspective of each competitive participant's limited production. By virtue of long-term competitive strategy, counting on manufacturing to reduce marginal costs will not fundamentally solve the problem. In response to the entry cost, the integration of resources and a comprehensive cooperation model from R&D to the production decision-making can significantly magnify profits, which help maintain the leading edge of both sides in the industry, pull away the cost gap with the late entrants, so as to slow down the competitive pressure. Therefore, this paper provides a reference

basis for how the double oligarchs in the new energy vehicle industry can consolidate their position and cooperate rationally in future competition. With respect to how to integrate resources, further specific analysis is needed.

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