Research on the influence of new energy vehicle enterprise operation decision under the background of sharing economy

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Abstract. At present, China's energy structure is mainly based on fossil fuels, which has brought serious problems such as environmental pollution, low energy efficiency and poor development quality. In the automotive industry, in order to save energy and protect the environment, many countries are actively promoting the production of new energy vehicles, optimizing the use of resources and benefits, and achieving green development. Based on the idea of sharing economy, this paper constructs a two-stage model. Considering the different quality of new energy vehicles in the two stages, optimization theory, game theory and other methods are used to study the influence of sharing behavior on enterprise operation decisions, and the following conclusions are drawn. First, in the presence of product sharing, product quality is negatively correlated with the optimal profit of the enterprise. Second, there is a negative correlation between the charging rate of the third-party platform and the optimal profit of the enterprise, and with the increase of the charging rate of the platform, the decline of the optimal profit of the enterprise is less and less. Third, when product sharing exists, the ratio of product quality in the two stages is positively correlated with the optimal profit of the enterprise.

1. Introduction

In recent years, urban traffic congestion, environmental pollution, parking difficulties and other problems are becoming more and more serious in our country. In addition to the lag of urban traffic infrastructure and the lack of predictability in planning, public transport construction can not meet the travel demand, which also leads to the continuous growth of private car ownership. In order to effectively alleviate this problem, the domestic and foreign automobile industry began to produce new energy vehicles, and the country also actively made policy advocacy to increase the supply of new energy vehicles and guide the transfer of automobile consumption to new energy vehicles.

With the rapid development of the Internet, the sharing economy has gradually entered public life. As for China, by the end of 2019, the market turnover of the sharing economy reached 3,282.8 billion yuan, and the number of people participating in the sharing economy exceeded 800 million. It is predicted that the growth rate of the sharing economy will continue to rise in the next few years. To some extent, the sharing economy not only alleviates overcapacity, but also conforms to the implementation of the policy of mass innovation and entrepreneurship. Sharing economy is widely used as a way to integrate offline idle resources and reduce transaction costs. Compared with traditional cars, new energy vehicles have relatively high prices, short mileage and less comfortable driving experience, which makes the development of new energy vehicles in China into a bottleneck. In the face of
development difficulties, the sharing economy model brings new development opportunities for new energy vehicles. Consumption mode is no longer limited to buyers and sellers, but with the help of a third-party platform for new energy vehicle rental services, which can not only effectively eliminate consumers' concerns about product performance, but also realize the efficient use of resources and promote the development of circular economy.

The origin of the idea of sharing economy can be traced back to a long time ago. Felson and Spaeth [1] first proposed the concept of collaborative consumption, which is defined as the event that many people consume goods or services in the joint participation activities. With the development of the market, the concept of sharing economy is gradually derived. Botsman [2] defined the sharing economy as "an economic model of sharing space, skills, goods and other idle resources for monetary or non-monetary benefits". Belk [3] pointed out that sharing economy is the pursuit of return. He defined sharing economy as "people's resource acquisition and distribution for money or other benefits". As an emerging economic activity, sharing economy has gradually been recognized by the public and has become a hot issue for scholars at home and abroad. In addition, with the exponential growth of China's energy demand, the increasing exhaustion of fossil energy and the continuous improvement of environmental protection awareness, the combination of sharing economy concept and automobile industry has become a new research idea. Shi et al. [4] took the reasonable layout of shared rental network as the theme, modeled and analyzed the extended characteristics of shared electric vehicle rental network, and proposed the corresponding layout algorithm accordingly. Ji et al. [5] believe that the factors affecting the profitability of new energy sharing vehicles include operators' coordination ability, enterprise scale, network infrastructure construction and product and service, etc. The biggest concern of new energy vehicles in sharing is to solve the problem of battery life and charging. Based on this problem, Zhang et al. [6] proposed a space-time power flow model of a new type of vehicle power battery. From the perspective of policy, Zhang et al. [7-8] improved the development policies of the car timeshare rental industry from the perspectives of demand, supply and environment to promote the healthy development of the industry.

Through combing, we find that most of the existing studies focus on the planning and development of shared cars and profit model, and discuss the optimization problem [9]. The research on the impact of sharing behavior among consumers on enterprise decision-making is not full. Therefore, this paper will study and discuss from this point of view, through the establishment of the model to analyze the impact of automobile sharing behavior among consumers on the operation decision-making of automobile enterprises under the sharing economy [10], and try to draw relevant conclusions from the analysis results of the model.

2. Product sharing decision model among consumers

2.1. Model establishment and parameter description
When there is no sharing market, in order to use new energy vehicles, consumers can only choose to buy from suppliers, while when there is sharing market, consumers can choose to rent in order to use new energy vehicles. Considering that consumers have different use values at different stages of use, consumers can choose to rent new energy vehicles with the help of a third-party platform when their use value is low, so as to obtain additional benefits. At the same time, potential consumers can also obtain this service by renting through a third-party platform. This paper simplifies the multi-stage sharing of new energy vehicles into two stages. In each sharing stage, consumers can choose to rent products in the first stage or the second stage because of the different utility of products used in each stage. If the quality of products is different in different stages, the rental price will be different in different stages.

For enterprises, they will face competition from consumers in the sharing market. When consumers with new energy vehicles choose to share their products with other consumers, what is the impact of this situation on enterprises and how enterprises will deal with it? This paper will build a model to analyze and solve the above problems. Symbols used herein are described in Table 1.
Table 1. symbols and their meanings

| Variable | Meaning |
|----------|---------|
| $p$      | Product sales price |
| $p_n$    | Stage $n$ shares the rental price of the product in the market, $n = 1, 2$ |
| $V_{sn}$ | The use value of consumer $x$ to the product in the $n$ stage |
| $m$      | Product quality |
| $\tau$   | Residual value of products owned by product owners |
| $c$      | Unit cost of product |
| $\sigma$ | Consumers' willingness to pay |
| $U$      | Consumer utility |
| $\alpha$ | Charging rates for third-party sharing platforms |
| $\xi$    | The ratio of the selling price of the product in two stages |
| $\beta$  | The quality ratio of the two stages of the product |
| $\varepsilon$ | Residual value of products |
| $\pi$    | Profits of enterprises |

2.2. Problem description and hypothesis

We know that consumers can share products in a flexible time unit, but considering the pricing and cost issues, enterprises will not change the price or quality frequently to cope with consumers' sharing at each stage. Therefore, we assume that in each stage of product sharing, the product price of the enterprise is fixed, that is, the price of the consumer's product is fixed. At the same time, let's assume that there is only one firm in the market, offering consumers a product of quality $p$ and unit cost $m$ at a price $c$. In addition, the company does not participate in the sharing of product sharing market, but in real life, in the face of the emergence of the sharing market and the significant impact on it, the enterprise has to transform, at present, some enterprises have also started to get involved in this part. For the sake of generalization, let's assume for the moment that the enterprise does not participate in the sharing market.

Suppose the consumer is a rational person, and the consumer has different use value of the product at different stages. Suppose the use value of the product at each stage of consumer $x$ is $V_{sn}$, here $n = 1, 2$.

Meanwhile, the factors influencing the value of $V_{sn}$ are product quality and consumers' willingness to pay, $V_{sn} = m\sigma_{sn}$. Let $\sigma_{sn}$ be the uniform distribution between 0 and 1.

According to the different use values of the product rented by consumers in different stages, we simplify the multi-stage into two stages. Consumers can decide to rent or rent the product at the beginning of the multi-stage, but they can only decide whether to buy the product at the beginning. For the convenience of the model, assume that the residual value of the goods owned by the product owner is $\tau = 0$.

On the basis of the existing new energy vehicle sharing market, we have joined the third-party sharing platform. Enterprises sell products to consumers at price $p$, and consumers will decide whether to buy or lease products according to their use value of the products in the two stages, the price of the products and the rental price of the products. In the two-stage model, consumers who buy products can choose to rent their products through third-party platforms to obtain rental income at the stage when their use value is low. In the process of leasing products, the third-party platform will charge a certain percentage of intermediate service fees, and the fee rate of the third-party sharing platform is $\alpha$. If consumers who do not purchase products choose to rent products at a certain stage, they will pay the rental fee $p_n$. Meanwhile, the third-party sharing platform will get the service fee $\alpha p_n$, while consumers who rent
products will get the rental income \((1 - \alpha)P_n\). For the convenience of calculation, we assume that the third-party sharing platform's fee rate \(\alpha\) is fixed.

The profit function of the enterprise is \(\pi(p, m) = (p - c)Q(p, m)\), where \(Q(p, m)\) is the demand function faced by the enterprise. When \(c \geq 2m\), the enterprise cannot provide products and will choose to quit or not enter the market. When \(p \geq 2m\), consumers are also unable to buy the product, so we will only discuss \(c \in [0, 2m)\) and the situation of \(p \in [0, 2m)\).

\[
Q(p, m) = \begin{cases} 
\frac{1 - p^2}{2m^2} & 0 \leq p \leq m \\
\frac{2 - p^2}{m^2} & m \leq p \leq 2m 
\end{cases}
\] (1)

2.3. Decision-making process and decision-making of consumers and enterprises

In the two-stage model, the decision-making process of enterprises and consumers is as follows:

The enterprise sets the retail price \(p\) of the product. The retail price is fixed in the two stages of this model, but in the initial stage, the enterprise can choose the price strategically.

At the beginning of the two stages, consumers can decide whether to buy the product or not according to the price of the product and their consumption utility.

In the use stage of the product, consumers who have purchased the product can decide whether to use or rent the product according to the utility of the product, while consumers who have not purchased the product can decide whether to rent the product.

From the discussion of the preceding hypotheses, we can see that any consumer has eight choices to make and makes the optimal decision based on utility.

Here are eight alternative decisions that consumers can make:

1. Consumers purchase the product and use it all by themselves in both stages.
   \[U_{(1)} = V_{x1} + V_{x2} - p\] (2)

2. The consumer buys the product, uses it in the first stage, rents it out in the second stage.
   \[U_{(2)} = V_{x1} + (1 - \alpha)p_1 - p\] (3)

3. The consumer buys the product and rents it out in the first stage.
   \[U_{(3)} = V_{x2} + (1 - \alpha)p_2 - p\] (4)

4. Consumers do not buy products and lease them all in two phases.
   \[U_{(4)} = V_{x1} - p_1 + V_{x2} - p_2\] (5)

5. The consumer doesn't buy the product, but only leases the product in the first phase.
   \[U_{(5)} = V_{x1} - p_1\] (6)

6. The consumer doesn't buy the product, but only leases the product in the second phase.
   \[U_{(6)} = V_{x2} - p_2\] (7)

7. The consumer buys the product and rents it out in two phases.
   \[U_{(7)} = (1 - \alpha)p_1 + (1 - \alpha)p_2 - p\] (8)

8. Consumers don't buy products, they don't rent products.
   \[U_{(8)} = 0\] (9)

2.4. Conditions for product sharing among consumers

In addition to the basic constraint conditions, product sharing will occur among consumers in the following situations: First, the total income of consumers who buy products in the sharing market is
higher than the use value of their products at this stage. Second, the total utility of consumers renting and using products in the sharing market is higher than the total utility of buying and using products. That is to say, when the use value of consumers is higher than the income obtained from renting products, consumers will not choose to share their products on the sharing platform, and there will be no sharing market. When the rental price in the sharing market is higher than the use value of consumers, consumers will not choose to rent products, so there will be no product sharing in the market.

Assuming that the charging rate of the third-party platform is $0 < \alpha < 1$, consumers will choose to rent the product when the value in use is less than the income of the leased product. When the rental cost of consumers is higher than the use value of products, consumers will not choose to rent products in the sharing market, so there will be no sharing market. So we get the following theorem:

Theorem 1: Suppose the retail price of an enterprise, if there is a sharing transaction in the product sharing market equilibrium, then $p_1 = \beta p_2$, and $(1-\alpha)p_1 + p_2 = p$.

Certification process: Considering that consumers have eight choices, let's assume $(1-\alpha)p_1 + p_2 > p$ first, then $V_{x_1} + (1-\alpha)p_2 - p > V_{x_1} - p_1$, so decision (2) is better than decision (5), consumers choose to buy products. In the same way, $V_{x_2} + (1-\alpha)p_1 - p > V_{x_2} - p_2$, so decision (3) is better than decision (6), consumers choose to buy products. From $(1-\alpha)p_1 + p_2 > p$, obviously there is $V_{x_1} + V_{x_2} - p > V_{x_1} - p_1 + V_{x_2} - p_2$, so decision (1) is better than decision (4), and consumers choose to buy products. To sum up, consumers choose to buy products better than not to buy, so there will be no product sharing market in the market, so hypothesis $(1-\alpha)p_1 + p_2 > p$ does not hold.

Similarly, under the assumption of $(1-\alpha)p_1 + p_2 < p$, consumers choose not to buy products better than to buy, and there is no product sharing market in the market. Therefore, if there is transaction in product sharing market, there must be $(1-\alpha)p_1 + p_2 = p$.

The utility of consumers in area 1 is as follows:

$U_{(1)} = V_{x_1} - (1-\alpha)p_1 + V_{x_2} - p_2 > 0$ \hspace{1cm} (10)

$U_{(2)} = V_{x_1} - 1 - \alpha p_1 - \alpha p_2 < U_{(1)}$ \hspace{1cm} (11)

$U_{(3)} = V_{x_2} - p_2 < U_{(1)}$ \hspace{1cm} (12)

$U_{(4)} = V_{x_1} - p_1 + V_{x_2} - p_2 < U_{(1)}$ \hspace{1cm} (13)

$U_{(5)} = V_{x_1} - p_1 < U_{(1)}$ \hspace{1cm} (14)

$U_{(6)} = V_{x_2} - p_2 < U_{(1)}$ \hspace{1cm} (15)

$U_{(7)} = (1-\alpha)p_1 + (1-\alpha)p_2 - p < U_{(1)}$ \hspace{1cm} (16)

$U_{(8)} = 0 < U_{(1)}$ \hspace{1cm} (17)

To sum up, the consumer choice decision (1) in a. Similarly, it is concluded that the optimal decision of consumers in region A is decision (1), that is, consumers purchase products and use them in two stages. For consumers in region B, the optimal decision is decision (2), that is, consumers buy products and use them in the first stage and rent them in the second stage. In region C, the choice of consumers is not unique, that is, some consumers will choose to buy products and rent them in the first stage for their own use in the second stage; some consumers will not buy products but rent them in the second stage; in region D, consumers will not choose to buy or rent products in any stage.

The products in the sharing market ultimately come from enterprises. Under the condition of market equilibrium, the demand and supply in each stage of the product sharing market should be equal. Therefore, all consumers in region B will choose to buy products, while half of consumers in region C will choose to buy products, and the other half will choose to rent products in the product sharing market.

To sum up, the total demand of consumers for products will be calculated by adding all the consumers:
$Q(p, m) = \frac{m_1 - p_1(m_2 - p_2)}{m_1 m_2} + \frac{\alpha p_2(m_1 - p_1)}{m_1 m_2} + \frac{\alpha p_1(m_2 - p_2)}{m_1 m_2} + \frac{\alpha^2 p_1 p_2}{2 m_1 m_2} + \frac{m_2 - p_2(1 - \alpha) p_1}{2 m_1 m_2}$ \hspace{1cm} (18)

$p_2 = \frac{\xi}{\xi + 1} p_1$ \hspace{1cm} (19)

$m_2 = \beta m_1$ \hspace{1cm} (20)

$(1 - \alpha) p_1 + p_2 = p$ \hspace{1cm} (21)

$(1 - \alpha) p_1 + \xi p_2 = p$ \hspace{1cm} (22)

$Q(p, m_2) = \frac{(2 - 4\alpha - 2\xi - \beta + 2\alpha^2 - 2\alpha^2 \xi - \alpha^2 \beta + 2\alpha^2 \beta - \beta \xi + \alpha \beta \xi) m_2^2 - (\alpha^2 - 3\alpha + 1) \beta \xi p^2}{2(1 - \alpha + \xi)^2 m_2^2}$ \hspace{1cm} (23)

$A = \frac{(2 - 4\alpha - 2\xi - \beta + 2\alpha^2 - 2\alpha^2 \xi - \alpha^2 \beta + 2\alpha^2 \beta - \beta \xi + \alpha \beta \xi) p^2}{2(1 - \alpha + \xi)^2}$ \hspace{1cm} (24)

$B = \frac{(\alpha^2 - 3\alpha + 1) \beta \xi p^2}{2(1 - \alpha + \xi)^2}$ \hspace{1cm} (25)

Obtained from the above list:

$Q(p, m_2) = A - \frac{Bp^2}{m_2^2}$ \hspace{1cm} (26)

2.5. Optimal price decision of the enterprise

According to the enterprise profit maximization:

$\pi(p, m_2) = (p - c)Q(p, m_2) = Ap - B \cdot \frac{p^3}{m_2^2} - Ac + Bc \cdot \frac{p^2}{m_2^2}$ \hspace{1cm} (27)

$Q^* = A - \frac{Am_2^2 + 2Bc}{3m_2^2}$ \hspace{1cm} (28)

$p^* = \sqrt{\frac{Am_2^2 + 2Bc}{3B}}$ \hspace{1cm} (29)

$\pi^* = (p^* - c) \cdot Q^* = \left(\frac{Am_2^2 + 2Bc}{3B} - c\right) \cdot (A - \frac{Am_2^2 + 2Bc}{3m_2^2})$ \hspace{1cm} (30)

Theorem 2: In summary, $p^*$ monotonically increases with respect to $c$, and $Q^*, \pi^*$ monotonically decreases with respect to $c$.

3. Conclusion

The results show that product sharing market has an impact on enterprise decision-making. In the presence of product sharing, the charging rate of the third-party platform has a negative relationship with the optimal profit of the enterprise. In the sharing market, the ratio $\beta$ of product quality in two stages has a positive change relation with the optimal profit of the enterprise. Therefore, in order to make the enterprise obtain higher profit when product sharing exists, the product quality in two stages should be as close as possible, that is, the ratio of product quality in two stages should tend to 1. The leasing price of two-stage products in the sharing market has a positive change relationship with the optimal profit of the enterprise. Therefore, in order to achieve higher profit of the enterprise, the leasing price of two-stage products should be as close as possible, that is, the two-stage leasing price tends to 1, so that the enterprise can obtain higher profit.
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