Pricing Strategy for Green Products Based on Disparities in Energy Consumption

Tao Zhang, Yingchi Qu, and Gang He

***Abstract*—The energy consumption disparity is an important factor affecting product pricing. The risk and the cost of new energy products are generally higher than those of traditional energy products, which results in conflicting pricing strategies between manufacturers and retailers. Applying the concepts from dynamic cooperative game theory, such as improved Shapley value, in this paper, we have studied the optimal pricing strategies of manufacturers and retailers in a cooperative and a noncooperative game. Based on policies and market conditions in China, we have used a logistic regression model to determine the impact of product sales, devised pricing strategies affected by the relevant government tax, and subsidy policy. The results show that, first, under the basic condition in which the manufacturer obtains profit, the optimal pricing of the retailer in a noncooperative game is more than that in a cooperative game. Second, the differential coefficient of the energy consumption of the two products in the cooperative game is greater than that in the noncooperative game. Third, the cooperative game not only plays an incentivizing role for retailers in setting reasonable prices of new energy products but also encourages manufacturers, producing a greater difference of energy consumption between traditional energy products and new energy products, which further reduces the consumption of new energy products. Finally, the strategies of sharing the green marketing costs by manufacturers and retailers can improve the total profits of the supply chain in addition to their own.**

***Index Terms*—Cooperative game, energy consumption difference, improved Shapley value, logistic regression.**

I. Introduction

GREEN products are characterized as environmentally friendly, energy saving, water saving, recycling, low-carbon or renewable throughout the lifecycle, including products such as recyclable PET plastic soft drink bottles [1], electric vehicles, solar products, etc. Green products are able to enhance environmental quality and enterprise competitiveness [2], green products have become a consensus for contemporary manufacturers against the backdrop of the vigorous development of the low-carbon economy in China, and retailing is paying more attention to the sales of green products as well [3]. The State Council issued the 13th Five-Year Plan for Energy Conservation and Emission Reduction to emphasize the necessity to establish a green manufacturing system [4] to advance the development of the new energy industry and to promote energy. Environmental issues have become a substantial barrier that restrict the economic development of China, and energy-saving methods such as green technology progress can mitigate environmental problems [5]. It may be remarked that industries need to transform to green and low-carbon schemes, however, manufacturers need to analyze market demand for green products, and retailers need reasonable pricing schemes in order to obtain profits, with differentiated pricing strategies for new energy and traditional energy products. However, the main factors influencing pricing strategy include energy consumption disparity, which is mainly manifested in carbon emissions, energy utilization types, and average energy usage costs among products.

The paper on pricing strategies for green products mainly focuses on the factors affecting the pricing of manufacturers and retailers, including green marketing, the degree of greenness of various products, environmental legislation, manufacturer and retailer cooperation, government subsidies [6], [7], and consumers' energy preferences. Green marketing, government environmental protection policies, and cooperation between manufacturers and retailers are the factors that influence the market competitiveness of manufacturers and retailers and the green attributes of their products [8]. The incorporation of green attributes results in higher research and development, production, and marketing costs relative to the costs of producing ordinary products; the greenness of a product is correlated with its price [9], [10], and manufacturers and retailers adopt a higher price strategy for the sake of earning reasonable profits. Therefore, green product subsidies from the government can decrease actual prices, preventing the loss of potential consumers who prefer green products that might have resulted from high prices [11]. Through their impact on the sales of energy consumption differentiated products, consumers' energy preferences influence pricing strategies indirectly; meanwhile, some scholars have found that the main factors that affect consumers' preferences are prices and income, using discrete or continuous dualistic logistic models to analyze household energy consumption [12].

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Considering the factors that influence pricing, game theory is used to study the pricing strategies of manufacturers and retailers under various competitive schemes. In the competitive environment of the simple supply chain, suppliers of green products can engage in price competition and "green competition," and the price competition at the retailer level can proactively promote green balance [13]. Under the dual-channel supply chain, which includes retail and internet channels, where the green product is produced by one manufacturer and the nongreen product is made by the second manufacturer, there are two competing modes of centralization and decentralization. In the decentralized scenario, Stackelberg competition between retailers and manufacturers is considered, where manufacturers are the leaders and retailers are the followers; each player in the centralized scenario is integrated [14]. The leader–follower mode enables us to research interactive behavior among manufacturers, retailers, and the government, and we find that the government promotes the implementation of energy-saving policies and cooperation, allocating additional profits in the supply chain by Shapley value in the interim [15]. Therefore, it is necessary to consider the supervision system and the policy of the government when discussing the pricing strategies for energy consumption differentiated products [16]. In addition, the related literature also studies the impact of cooperative and noncooperative game structures on the pricing of manufacturers and retailers. Under the noncooperative scheme, retailers have not achieved their optimal selling prices and profits in Stackelberg competition. In the cooperative game of the two-stage supply chain with vertical and horizontal channels, vertical cooperation between retailers and manufacturers contributes to the reduction of energy consumption and selling prices, but the cooperation between the manufacturers will damage the retailers' profits and consumers' welfare [17]. The members of the green supply chain form a revenue-sharing contract to coordinate profit distribution, improving its performance [18]: Tsao and Sheen [19] analyzed the impact of promotion cost sharing on cooperation, showing that cost sharing can act as a coordination mechanism.

The existing literature has mainly focused on games between enterprises and the government in low-carbon supply chains, as in Wang *et al*. [20], as well as on collaborative emissions reduction, as in Wang *et al*. [21] and Wu *et al*. [22]. As a major factor influencing product pricing, green marketing has matured over the past several years [23]; however, the impact of consumers on energy consumption differentiated products and the role of green marketing costs in cooperation between manufacturers and retailers have not been well studied.

This paper studies the pricing strategies of two types of products (traditional energy products and new energy products) and the impact of energy consumption disparity for products of the same brand on pricing strategies in a situation where a retailer and a manufacturer act either in cooperation or noncooperation. In the cooperative scenario, the Shapley value algorithm is amended to determine the profit distribution; different degrees of green marketing cost sharing between the two sides of the supply chain are considered, and a modification factor is introduced to achieve a more equitable allocation. At the same time, this paper considers the influence of consumer behavior on market scale and the final sales of these two kinds of products. Finally, the sharing of green marketing costs as a cooperation strategy is considered in order to study its impact on the distribution of benefits in the cooperation game with a practical example. This example proves the feasibility of the model by using data from different brands and types, as in the exercise from Wang and Sun [24].

The rest of this paper is organized as follows. Section II introduces relative parameters and three basic hypotheses in this paper and describes the game order. Section III presents the establishment, solution, and the analysis of the model, which determines the pricing strategies and profits allocation. Section IV uses the data collected from different car brands in order to show the effectiveness of the conclusions. Section V concludes this paper.

II. Relative Parameters and Basic Hypotheses

Our model is based on a two-echelon supply chain structure, which is composed of a manufacturer and a retailer influenced by government subsidies or tax policy, as shown in Fig. 1. The manufacturer produces two products of the same brand: the traditional energy product T and the new energy product R. We assume that the traditional energy product refers to a product that consumes fossil fuels during use, and the new energy product refers to a product that consumes clean or mixed energy during its use. The manufacturer supplies two kinds of products to retailers at wholesale prices, and then, the retailers sell them to the consumers. The government, as the maker of macroeconomic policies, only participates in the entire supply chain by issuing fiscal policies.

The relative parameters are described as follows.

1) π_{r1} represents units of new energy product profit for the manufacturer, π_{t1} denotes units of traditional energy product profit for the manufacturer, π_{r2} denotes units of new energy product profit for the retailer, and π_{t2} represents units of traditional energy product profit for the retailer.
2) c_r denotes the manufacturing cost of the new energy product (including all general taxes), c_t represents the manufacturing cost of traditional energy product (including all general taxes), and c_g denotes the green marketing cost of new energy product.
3) w_r is the wholesale price of the new energy product, whereas w_t is the wholesale price of the traditional energy product.
4) s_r is the nominal selling price of the new energy product, whereas s_t is the nominal selling price of the traditional energy product.
5) m_r is the market scale of the new energy product, and m_t is the market scale of the traditional energy product.
6) a represents units of the government subsidy for the new energy product.
7) t denotes the high carbon tax on units of the traditional energy product, whereas f is the tax deduction for units of the traditional energy product due to environmental protection.

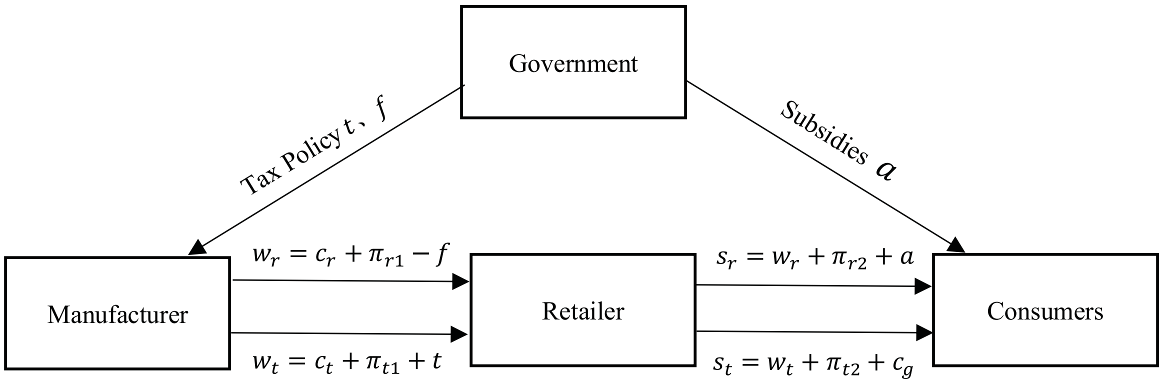

Fig. 1. Simple two-stage supply chain model.

The game sequence for pricing in the noncooperative environment assumes that the manufacturer can completely observe the retailers' pricing strategy and develop its own pricing strategies based on that of the retailers. In the cooperative environment, the retailer and the manufacturer jointly determine the cooperation measures, set the selling price to maximize the profit of the supply chain, then distribute the profits according to the improved Shapley value algorithm and finally the manufacturer decides on the wholesale price.

Hypothesis 1: The game between manufacturers and retailers is based on complete information. Under complete information, the manufacturer is able to obtain the retailer's response function accurately.

Hypothesis 2: Both products are in the balanced production-marketing state. To simplify the model, we assume that the potential inventory cost and product loss are zero.

Hypothesis 3: Green marketing cost is entirely undertaken by the retailer in the noncooperative game.

III. Model Analysis

A. Modeling

Based on the research of Lu and Liu [25], the normalized energy consumption difference coefficient θ of two kinds of products is introduced, where $\theta = |d_t - d_r|/(d_t + d_r)$, $\theta \in [0, 1)$, and d_t, d_r express the average energy consumption of the traditional energy product and the new energy product, respectively. The sum of the average energy consumption of the two products is considered to be constant. Therefore, the degree of differentiation in energy consumption is linearly related to the coefficient θ. The consumer preferences coefficient λ indicates how much consumers like new energy products, $\lambda \in (0, 1]$.

The market demands for the traditional energy product and the new energy product, which can be substituted for each other, are given by

$$Q_t = m_t - \lambda b_1/\theta s_t + c\,(s_r - a) \tag{1}$$

$$Q_r = m_r + cs_t - (1 - \lambda)\, b_2\theta\,(s_r - a)\,. \tag{2}$$

Here, the selling prices of the two kinds of products, denoted by s_r,s_t are variables in (1) and (2), the relations among variable coefficients are: $\lambda b_1/\theta > c > 0,\ (1 - \lambda)b_2\theta > c > 0$. Equation (1) shows that the sale volume of the traditional energy product is negatively related to its selling price and positively related to the new energy product's selling price, but the relation $\lambda b_1/\theta > c > 0$ stipulates that the price of the traditional energy product has a greater impact on its sales. Equation (2) shows that the sale volume of the new energy product is negatively related to its selling price and positively related to the traditional energy product's selling price, but the relation $(1 - \lambda)b_2\theta > c > 0$ stipulates that the price of the new energy product has a greater impact on its sales. When the degree of differentiation in energy consumption between these two products decreases (so that the value of θ from infinitely close to 1 tends to 0), it can reflect market laws to some extent, where the new energy product sales decline and the traditional energy product sales increase simultaneously.

The market size of the energy consumption differentiated products is determined by a logistic model. The logistic model is defined as

$$g\,(x) = w_0 + \sum_{i=1}^{2} w_i x_i \tag{3}$$

$$f\,(x) = \frac{1}{1 + e^{-g(x)}} \tag{4}$$

$$(p_r = f\,(x) = P\,(y = 1\,|x)\,. \tag{5}$$

In equation (3), x_i represents the quantifiable factors affecting the purchase of energy consumption differentiated products, including the product price, the cost of average energy consumption, whereas ω_i represents the weight of each influencing factor and ω_0 is a constant. According to equations (4) and (5), the probability of purchasing the new energy product R is given by p_r and the probability of buying the traditional energy product is given by $p_t = 1 - p_r$, with the market scale of the new energy product given by $m_r = p_r\ m$, and the market scale of the traditional energy product given by $m_{\mathrm{t}} = p_t\ m$.

B. Pricing Strategy and Benefit Distribution of Cooperative Game

The manufacturer may spend more in terms of research and development costs and testing costs when producing the new energy product than it would spend on the traditional energy product. It also faces the risk of returning the product to the factory due to imperfect technology, and may spend more on green marketing to promote the sale of the new energy product, so the selling price of the new energy product will exceed the price traditional energy product. At the same time, in reality, the market scale of the new energy product is relatively smaller, the production and marketing investments are unbalanced, and each enterprise has faces its own demand, all of which probably create the pricing conflict between retailers and manufacturers [26].

To reduce conflict, collaboration is a better choice for both sides. If the manufacturer and the retailer reach a cooperation agreement, they will sign a copayment contract for the green marketing cost, where $c_g = c_{g1} + c_{g2}$. The green marketing cost of the manufacturer's expenditure accounted for *k*, so the gross profit π of the supply chain can be expressed as

$$\begin{aligned}\pi = {} & (s_t - w_t)\ Q_t + (s_r - w_r - c_{g1})\, Q_r \\ & + (f + w_r - c_r - c_{g2})\, Q_r + (w_t - c_t - t)\, Q_t. \end{aligned} \tag{6}$$

The interests of both sides to reach a cooperation agreement are satisfied by maximizing the gross profit of the supply chain, which is denoted by $\mathrm{Max}\pi$. Taking the partial derivative for π, we can obtain the following equation:

$$\begin{cases} \frac{\partial \pi}{\partial s_t} = -2\lambda b_1/\theta s_t + c\,(2s_r + f - a - c_g - c_r) \\ \qquad +b_1/\theta\,(c_t + t) + m_t \\ \frac{\partial \pi}{\partial s_r} = -2\,(1-\lambda)\, b_2\, \theta s_r + (a + c_g + c_r - f)\, b_2\theta \\ \qquad + (2s_t - c_t - t)\, c + m_r. \end{cases} \tag{7}$$

Here, $\frac{\partial^2 \pi}{\partial {s_t}^2} = -2\lambda b_1/\theta < 0$, $\frac{\partial^2 \pi}{\partial {s_r}^2} = -2(1-\lambda)b_2\,\theta < 0$, and the second derivatives are less than 0, so π is a convex function. Setting $\frac{\partial \pi}{\partial s_t} = 0$, $\frac{\partial \pi}{\partial s_r} = 0$, here is the optimal pricing formula for the retailer

$$\begin{cases} s_t' = \frac{c_t + t}{2} - \frac{cm_r + (1-\lambda) b_2 \theta m_t}{2(c^2 - b_1 b_2)} \\ s_r' = \frac{c_r + a + c_g - f}{2} - \frac{cm_t + \lambda b_1/\theta m_r}{2(c^2 - b_1 b_2)}. \end{cases} \tag{8}$$

The gross profit $\pi_{\max}$ of the supply chain can be determined by substituting into (6) the prices from formula (8).

The improved Shapley value algorithm is used to allocate the profit according to the profit distribution between both sides. First, the Shapley value algorithm can be written as follows:

$$\phi_i\ (v) = \sum_{s \subseteq N} w\,(|s|)\,[v\,(s) - v\,(s\,|i\,)]. \tag{9}$$

Here, *N* denotes a set of members (which consists of the retailer and the manufacturer), its subset is $s \subseteq N$, $v(s)$ represents a profit function on a member subset class, and $|s|$ indicates the number of members in the subset. The profit that the retailer and manufacturer obtained by assignment is defined as $\phi_i(v)(i = 1, 2)$, and formula (9) shows each member's profit according to the traditional Shapley value algorithm.

In addition, $w|s|$ represents the weight of profit distribution, and can be defined as

$$w\ (|s|) = \frac{(|s| - 1)!\,(n - |s|)!}{n!}. \tag{10}$$

The distribution of benefits is based on the superadditivity of cooperative games for coalitions. Therefore, if collaboration is to be achieved by both sides, the profit gained from a cooperative game must satisfy the following relationship:$\phi_i(v) \geq \mathrm{v(s)}$.

The profit calculated by the traditional Shapley value algorithm is displayed in Table I, but the traditional method has its limitations; in particular, it does not consider the different degrees of green-marketing cost sharing between both sides.

The improved Shapley value algorithm was developed by introducing a modification factor $r_i = c_{gi}/c_g$, which changes the distribution of profit into the one given by formula (11). The modification factor indirectly changes the distribution's weight and influences each member's benefit. By optimizing the profit distribution, the initiative of the manufacturer to participate in the marketing of the new energy product has been improved, yielding a scheme of benefit allocation that is more satisfactory to both sides

$$\phi_i\ (v) = \sum_{s \subseteq N} w\,(|s|)\,\left[r_i v\,(s) - r_{(s|i)} v\,(s\,|i\,)\right]. \tag{11}$$

After the satisfactory profit allocation scheme is reached, the manufacturer decides its optimal pricing strategy on the basis of the relationship between profit and cost, which is given by

$$\begin{cases} w_t = \frac{\phi_2(v) + (c_r + c_{g2} - f)Q_r + (c_t + t)Q_t}{Q_t + (1+h)Q_r} \\ w_r = (1+h)\, w_t. \end{cases} \tag{12}$$

In these equations, h denotes the ratio of the wholesale price difference to the wholesale price of the traditional energy product. k represents the green marketing cost proportion of manufacturer expenditure

C. Optimal Pricing Strategy in the Noncooperative Game

In noncooperative situations, the information sets of the retailer and the manufacturer are independent of each other, and each agent expects to maximize their respective benefits. The green marketing cost is fully undertaken by retailer itself, and its profit can be written as

$$\pi_1 = (s_t - w_t)\ Q_t + (s_r - w_r - c_g)\, Q_r. \tag{13}$$

The manufacturer obtains operating income from the wholesale of goods to the retailer, whereas the government issues a tax relief policy on the new energy product and imposes additional taxes on the traditional energy product, e.g., carbon taxes. The retailer can observe the manufacturer's profit under the assumption of complete information, and its profit can be expressed as

$$\pi_2 = (f + w_r - c_r)\ Q_r + (w_t - c_t - t)\, Q_t. \tag{14}$$

In the noncooperative scenario, the manufacturer first observes the optimal pricing strategy made by the retailer when

TABLE I
PROFIT DISTRIBUTION UNDER THE COOPERATIVE GAME

	$\phi_i(v)$ before modification	$\phi_i(v)$ after modification
Retailer	$\frac{1}{2}\pi_1^* + \frac{1}{2}(\pi_{\max} - \pi_2^*)$	$\frac{1-k}{2}\pi_1^* + \frac{1}{2}[\pi_{\max} - k\pi_2^*]$
Manufacturer	$\frac{1}{2}\pi_2^* + \frac{1}{2}(\pi_{\max} - \pi_1^*)$	$\frac{k}{2}\pi_2^* + \frac{1}{2}[\pi_{\max} - (1-k)\pi_1^*]$

the retailer tries to achieve its maximum profit $\mathrm{Max}\pi_1$. Taking the partial derivative for π_1, we obtain the following equation:

$$\begin{cases} \frac{\partial \pi_1}{\partial s_t} = -2\lambda b_1/\theta s_t + 2cs_r - (a + c_g + w_r)\,c \\ \qquad +\lambda b_1/\theta w_t + m_t \\ \frac{\partial \pi_2}{\partial s_r} = -2\,(1-\lambda)\,b_2\,\theta s_r + (a + c_g + w_r)\,b_2\theta. \\ \qquad +2cs_t - w_t c + m_r \end{cases} \tag{15}$$

Here, $\frac{\partial^2 \pi_1}{\partial {s_t}^2} = -2\lambda b_1/\theta < 0,\ \frac{\partial^2 \pi_1}{\partial {s_r}^2} = -2(1-\lambda)b_2\ \ \theta < 0$, and the second derivatives are less than zero, so π_1 is a convex function. Setting $\frac{\partial \pi_1}{\partial s_r} = 0,\ \frac{\partial \pi_1}{\partial s_t} = 0$ yields the optimal pricing formula for the retailer

$$\begin{cases} s_t^* = \frac{1}{2}\ w_t - \frac{cm_r + (1-\lambda)b_2\theta m_t}{2(c^2 - b_1 b_2)} \\ s_r^* = \frac{a + c_g + w_r}{2} - \frac{cm_t + \lambda b_1/\theta m_r}{2(c^2 - b_1 b_2)} \end{cases}. \tag{16}$$

The manufacturer also determines its pricing strategy according to its maximized profit $\mathrm{Max}\pi_2$. Finding the partial derivative for π_2 yields (17), where $\frac{\partial^2 \pi_2}{\partial {w_t}^2} = -\frac{\lambda b_1/\theta}{2} < 0,\ \frac{\partial^2 \pi_2}{\partial {w_r}^2} = -\frac{(1-\lambda)b_2\theta}{2} < 0$, and the second derivatives are less than zero, so π_2 is a convex function. Setting $\frac{\partial \pi_2}{\partial w_r} = 0,\ \frac{\partial \pi_2}{\partial w_t} = 0$, the optimal pricing formula for a retailer is given by

$$\begin{cases} w_t^* = \frac{c_t + t}{2} - \frac{cm_r + (1-\lambda)b_2\theta m_t}{2(c^2 - b_1 b_2)} \\ w_r^* = \frac{c_r + a + c_g - f}{2} - \frac{cm_t + \lambda b_1/\theta m_r}{2(c^2 - b_1 b_2)}. \end{cases} \tag{17}$$

$$\begin{cases} \frac{\partial \pi_1}{\partial w_t} = -\lambda b_1/\theta s_t + \frac{c}{2}\,(w_r - c_r) - \frac{\lambda b_1/\theta}{2}\,(w_t - c_t - t) \\ \qquad +c\,(s_r - a) + m_t \\ \frac{\partial \pi_2}{\partial w_r} = -\,(1-\lambda)\,b_2\,\theta\,(s_r - a) + \frac{c}{2}\,(w_r - c_t - t) \\ \qquad -\frac{(1-\lambda)b_2\theta}{2}\,(w_r + f - c_r) + cs_t + m_r \end{cases}. \tag{18}$$

In this case, the profits of the retailer and the manufacturer are defined as ${\pi_1}^*$ and ${\pi_2}^*$, respectively.

D. Pricing Analysis of Energy Consumption Differentiated Products

There are four hypothetical lines in Fig. 2 that indicate the relationships between the price of the traditional energy products (hst), the price of the new energy products (hsr), traditional energy products (fst), new energy products (fsr), and the disparity in energy consumption.

The price and the different degree of energy consumption of the new energy product under the cooperative and noncooperative scenarios exhibit an approximately inversely proportional relationship, whereas the price and energy consumption of the traditional energy product are linearly related. Based on the comparative analysis of the dependent variables, the following conclusions are drawn.

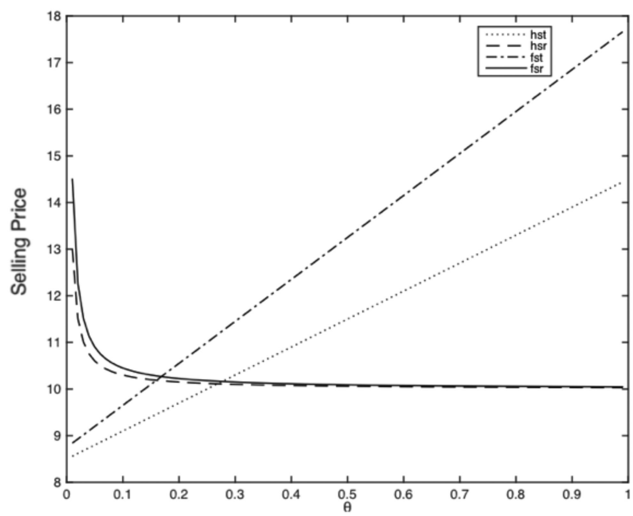

Fig. 2. Relationship between energy consumption differentiation and selling price.

1) When the manufacturer's wholesale price is greater than the total cost of production (including general taxes), the noncooperative price is higher than the cooperative price. Noting that $s_t^* - w_t^* = (w_t - c_t - t)/2,\ \ s_r^* - w_r^* = (w_r - c_r + f)/2$, and that when the wholesale price is greater than the total cost of production, $w_t > c_t + t$, $w_r > c_r - f$, means that $s_t^* - w_t^* > 0,\ s_r^* - w_r^* > 0$. Moreover, ${s_t}' = w_t^*,\ {s_r}' = w_r^*$, so that under the basic condition in which the manufacturer obtains a profit, the noncooperative price is higher than its cooperative counterpart.
2) The impact of changing θ on the price of the new energy product and the traditional energy product varies greatly. The slope (β_1) of the traditional energy product's price under noncooperation is greater than its analog (β_2) under cooperation, and both are constants that are greater than zero. The slope (β_3) of the new energy product's price before the inflection point is large, negative, and its absolute value is greater than the slope for the traditional energy product. On the pricing curve after the inflection point, the slope (β_4) of the pricing curve for the new energy product is relatively small, and its absolute value is smaller than the slope of the curve for the traditional energy product. Overall, $\beta_3 > \beta_1 > \beta_2 > \beta_4$, which indicates that a change in

θ has a significant impact on the selling prices of the new energy product and the traditional energy product. That is, the degree of energy consumption disparity has a different effect on the selling prices of these two kinds of products.

3) The cooperative game has a positive incentive effect on the pricing of new energy products.

It is assumed that the equilibrium points in the cooperative and noncooperative games are (θ_h, s_h), (θ_f, s_f), respectively, where θ_h, θ_f refer to the degree of energy consumption differentiation when the price of the new energy product is equal to the price of the traditional energy product. When the energy consumption disparity coefficient is between 0 and θ_h (θ_f), the new energy product price is higher than the price of the traditional energy product. This shows that the demand for the new energy product is relatively large, and the high price can be fixed. When the energy consumption disparity coefficient is between θ_h (θ_f) and 1, the price of the traditional energy product is greater than that of the new energy product, and consumers' demand for the new energy product is relatively low, so that low prices must be set to stimulate demand. It can be inferred that a further increase in cost and the energy consumption disparity for the manufacturer will not play a positive role in stimulating consumers' demand for the new energy product and result in a relatively high price for the new energy product when the energy consumption disparity of the product exceeds the equilibrium point. This is because the production cost, selling cost, and risk of new energy product are higher than they are for the traditional energy product.

According to Fig. 2, the value of the independent variable θ_h corresponding to the equilibrium price point under cooperation is greater than the value of the independent variable θ_f under noncooperation. Then, when the retailer and the manufacturer choose to collaborate with each other, the new energy product, which has a greater disparity, can be assigned a higher price. High price has a positive impact on new energy product pricing while it plays a positive role in reducing energy consumption and carbon emissions.

4) Tax policies enable the government to promote the purchase and use of new energy products.

Fig. 3 illustrates the relationship between the tax t and the proportion of manufacturing costs c_t, including two hypothetical lines. The selling price will increase with tax growth when the government imposes a carbon tax on the traditional energy product, and the market demand Q_t is also falling. Fig. 4 reflects the relationship between the tax reduction f and the proportion of manufacturing costs c_r, including two hypothetical lines. The selling price will decline with a higher tax exemption when the government reduces the tax on the new energy product, and market demand Q_t is also increasing. This proves that the tax policy implemented by the government to influence the demand for these two products is effective, which is conducive to the promotion and use of new energy products and helps to protect and control the ecological environment.

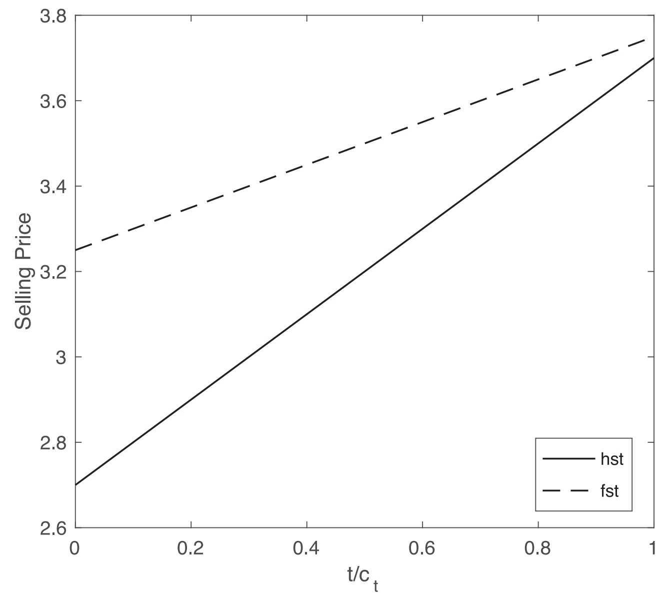

Fig. 3. Relationship between tax policy and selling price of the traditional energy product.

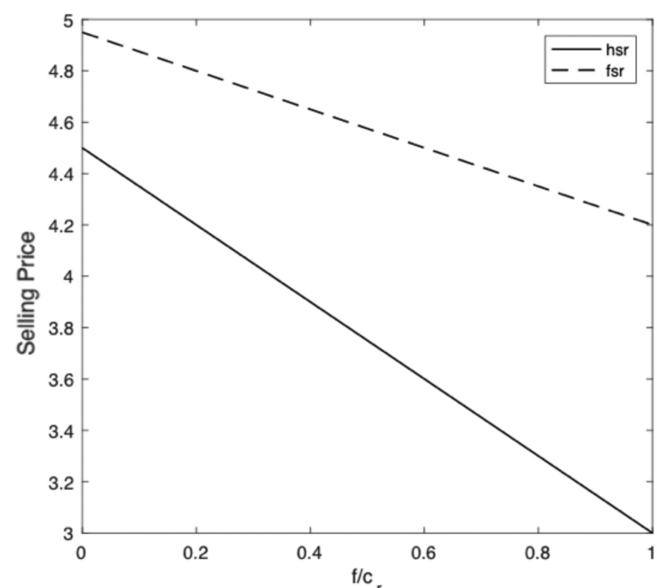

Fig. 4. Relationship between tax policy and selling price of the new energy product.

IV. Case Study

In the current Chinese market, the application of new energy technologies has been emerging in the automobile industry. Taking this industry as an example, data samples were collected from BMW, Audi, Lexus, Ferrari, Volkswagen, BYD, Chevrolet, Cadillac, Volvo, Honda, Toyota, Hyundai, Mitsubishi, and other car brands as a case study (Table II). At present, the production and sales of new energy vehicles in the Chinese market are unbalanced, and the market sales volume is far less than it is for the traditional energy vehicles market, but the growth rate is much higher than that of the traditional energy vehicles, and there are future development prospects, so the disparity between

TABLE II
SUMMARY OF MARKET PRICES

	Price(yuan)
Min.	113800
1st Qu.	214650
Median	358900
Mean	448479
3rd Qu.	532100
Max.	1408000

TABLE III
LOGISTIC REGRESSION RESULT

	Estimate	Std.Error	z value	Pr(>|z|)
ω_0	7.51739	4.12554	1.822	0.0684
ω_1	0.06537	0.02939	2.225	0.0261
ω_2	-0.29321	0.13362	-2.194	0.0282

TABLE IV
MODEL PARAMETER SELECTION

Parameters	Value selection	Parameters	Value selection
c	1	c_g	25560
b_1	3.1	t	46840
b_2	0.62	f	25560
a	40896	m_t	94037
c_r	398736	m_r	447963
c_t	351300		

manufacturers and retailers is inevitable. Analyzing the pricing strategies of both sides helps to ease conflicts and reach mutual benefit.

A. *Determining the Weight of the Influence Factors of Market Demand*

To determine the weight of factors affecting the market demand for energy consumption differentiated products, the product price is first quantified and standardized, and average energy consumption cost and product quality are included in the logistic regression model. The average price per 100 km of the product is used as a quantitative indicator for the average price. (It is assumed that a total of 1 million kilometers of motor vehicles will be used.) The product quality is measured in terms of the acceleration time of 100 km/h, and the average cost of energy used is based on the domestic average price of 93 # gasoline (6.97 yuan/liter). While the electric new energy vehicles do not have comprehensive fuel consumption indices, the battery capacity, cruising range, and unit energy price (0.5383 yuan/kWh) are used as parameters for calculation. The weight ω_i is shown in Table III.

The average energy cost of new energy vehicles is 19.27 yuan/100 km, and the cost of plug-in hybrid vehicles is greater than the cost of electric vehicles, whereas the average cost of energy use for traditional cars is 49.17 yuan/100 km, which is more than twice the cost of new energy vehicles.

The mature development of China's automobile market has laid the foundation for the diversity of consumer choice. Consumers will select the most satisfactory one among the different models in the same price range after considering their own economic conditions.

B. *Case Calculation*

A sample of medium- to high-end automobile brands was selected for analysis where the overall probability of a sample was calculated based on the weights ω_1, ω_2, where $p_r = 0.1735$, $p_t = 0.8265$. The energy consumption disparity coefficient of this brand is calculated by the average use of energy consumption cost, yielding $\theta = 0.4586$. The government was exempt from the vehicle purchase tax before 2020, so a was approximately equal to $8\% s_r$. If $m = 542\,000$, suppose $c_t = 78\%$, $c_r = 75\% s_r$, $c_g = 5\% s_r$, h = 5%. The values of the parameters are described in Table IV.

TABLE V
RESULTS OF NONCOOPERATIVE GAME

λ	w_t	w_r	s_t	s_r	q_t	q_r	π^*
0.36	457940	481867	487840	502985	174089	11385	16802589885
0.37	454672	482568	482937	504036	190332	26266	18905436347
0.38	451404	483269	478035	505088	206457	41077	20863618886
0.39	448135	483970	473133	506139	222466	55820	22678643528
0.40	444867	484671	468231	507191	238357	70493	24352016300
0.41	441599	485372	463329	508242	254131	85097	25885243228
0.42	438331	486073	458427	509293	269788	99633	27279830337
0.43	435063	486774	453525	510345	285328	114099	28537283654
0.44	431795	487475	448623	511396	300751	128496	29659109205
0.45	428527	488176	443721	512448	316056	142824	30646813016
0.46	425259	488877	438818	513499	331244	157084	31501901112
0.47	421991	489578	433916	514551	346315	171274	32225879521
0.48	418723	490279	429014	515602	361269	185395	32820254268
0.49	415455	490980	424112	516653	376105	199447	33286531379
0.50	412187	491681	419210	517705	390824	213430	33626216881
0.51	408919	492382	414308	518756	405426	227344	33840816799
0.52	405651	493083	409406	519808	419911	241189	33931837159
0.53	402382	493783	404504	520859	434279	254965	33900783988
0.54	399114	494484	399602	521911	448529	268672	33749163312
0.55	395846	495185	394699	522962	462663	282310	33478481156
0.56	392578	495886	389797	524013	476679	295879	33090243547
0.57	389310	496587	384895	525065	490577	309379	32585956510
0.58	386042	497288	379993	526116	504359	322810	31967126073
0.59	382774	497989	375091	527168	518023	336172	31235258260
0.60	379506	498690	370189	528219	531570	349465	30391859099
0.61	376238	499391	365287	529271	545000	362689	29438434615
0.62	372970	500092	360385	530322	558313	375844	28376490833
0.63	369702	500793	355483	531373	571509	388930	27207533782
0.64	366434	501494	350580	532425	584587	401946	25933069485
0.65	363166	502195	345678	533476	597548	414894	24554603970
0.66	359897	502896	340776	534528	610392	427773	23073643262
0.67	356629	503597	335874	535579	623119	440583	21491693388
0.68	353361	504298	330972	536631	635728	453323	19810260374
0.69	350093	504999	326070	537682	648220	465995	18030850245
0.70	346825	505700	321168	538733	660595	478598	16154969028
0.71	343557	506401	316266	539785	672853	491131	14184122749
0.72	340289	507102	311364	540836	684994	503596	12119817434
0.73	337021	507803	306461	541888	697017	515992	9963559109
0.74	333753	508503	301559	542939	708923	528318	7716853800
0.75	330485	509204	296657	543991	720712	540576	5381207533

w_t −wholesale price of traditional energy products, w_r −wholesale price of new energy products
s_t − selling price of traditional energy products, s_r −selling price of new energy products
q_t − sales of traditional energy products, q_t − sales of new energy products

TABLE VI
RESULTS OF COOPERATIVE GAME

λ	s_t	s_r	q_t	q_r	π_{max}
0.36	457940	481867	193468	20030	13746419601
0.37	454672	482568	207497	33112	15352301684
0.38	451404	483269	221448	46147	16875598986
0.39	448135	483970	235321	59137	18316980851
0.40	444867	484671	249115	72080	19677116623
0.41	441599	485372	262832	84978	20956675648
0.42	438331	486073	276470	97829	22156327270
0.43	435063	486774	290030	110635	23276740835
0.44	431795	487475	303512	123394	24318585688
0.45	428527	488176	316916	136108	25282531173
0.46	425259	488877	330242	148775	26169246635
0.47	421991	489578	343490	161397	26979401419
0.48	418723	490279	356659	173972	27713664871
0.49	415455	490980	369750	186502	28372706335
0.50	412187	491681	382764	198985	28957195155
0.51	408919	492382	395699	211422	29467800678
0.52	405651	493083	408556	223814	29905192247
0.53	402382	493783	421335	236159	30270039208
0.54	399114	494484	434035	248458	30563010906
0.55	395846	495185	446658	260712	30784776686
0.56	392578	495886	459202	272919	30936005892
0.57	389310	496587	471668	285080	31017367869
0.58	386042	497288	484056	297196	31029531963
0.59	382774	497989	496366	309265	30973167518
0.60	379506	498690	508598	321288	30848943879
0.61	376238	499391	520752	333265	30657530391
0.62	372970	500092	532827	345197	30399596400
0.63	369702	500793	544825	357082	30075811249
0.64	366434	501494	556744	368921	29686844285
0.65	363166	502195	568585	380714	29233364851
0.66	359897	502896	580348	392461	28716042293
0.67	356629	503597	592033	404162	28135545955
0.68	353361	504298	603640	415818	27492545183
0.69	350093	504999	615168	427427	26787709322
0.7	346825	505700	626619	438990	26021707716
0.71	343557	506401	637991	450507	25195209710
0.72	340289	507102	649285	461978	24308884650
0.73	337021	507803	660501	473403	23363401880
0.74	333753	508503	671639	484782	22359430745
0.75	330485	509204	682698	496115	21297640590

w_t −wholesale price of traditional energy products, w_r −wholesale price of new energy products
s_t − selling price of traditional energy products, s_r −selling price of new energy products
q_t − sales of traditional energy products, q_t − sales of new energy products

TABLE VII
PROFIT AND WHOLESALE PRICES UNDER COOPERATION

λ	Retailer's profit(yuan)	Manufacturer's profit(yuan)	w_t(yuan)	w_r(yuan)
0.60	13641664568-15195929549k	17207279311+15195929549k	397224+27671k	417085+29054k
0.61	13127918885-14719217307k	17529611506+14719217307k	396043+26689k	415845+28023k
0.62	12564178972-14188245417k	17835417427+14188245417k	394873+25703k	414616+26988k
0.63	11951030506-13603766891k	18124780744+13603766891k	393713+24714k	413399+25949k
0.64	11289059162-12966534743k	18397785123+12966534743k	392564+23722k	412192+24908k
0.65	10578850618-12277301985k	18654514233+12277301985k	391423+22728k	410994+23864k
0.66	9820990550-11536821631k	18895051743+11536821631k	390291+21733k	409806+22819k
0.67	9016064636-10745846694k	19119481319+10745846694k	389168+20736k	408626+21773k
0.68	8164658551-9905130187k	19327886632+9905130187k	388053+19739k	407455+20726k
0.69	7267357974-9015425123k	19520351348+9015425123k	386944+18742k	406292+19679k
0.70	6324748581-8077484514k	19696959135+8077484514k	385843+17744k	405136+18632k
0.71	5337416048-7092061375k	19857793662+7092061375k	384749+16748k	403987+17585k
0.72	4305946052-6059908717k	20002938598+6059908717k	383662+15752k	402845+16539k
0.73	3230924271-4981779554k	20132477609+4981779554k	382581+14757k	401710+15495k
0.74	2112936381-3858426900k	20246494364+3858426900k	381505+13763k	400581+14451k
0.75	952568058-2690603767k	20345072532+2690603767k	380436+12771k	399458+13409k

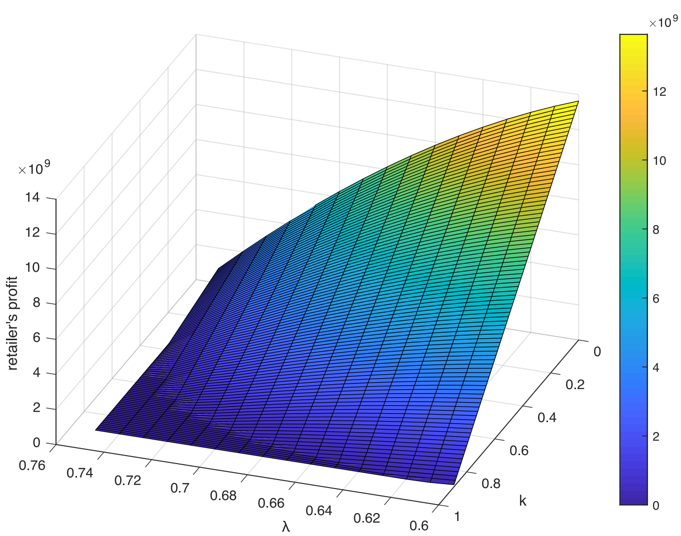

Fig. 5. **λ**-*k*-retailer's profit.

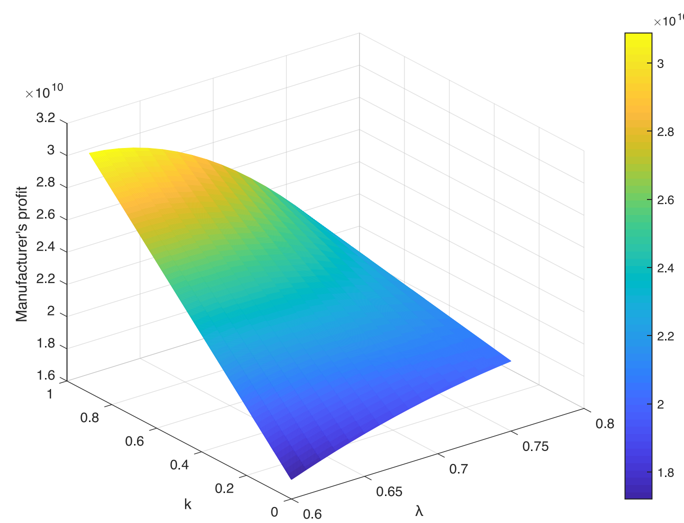

Fig. 6. *k*-**λ**-manufacturer's profit.

The optimal pricing, sales, and profits of the retailer and the manufacturer, respectively, can be calculated in the cooperative and noncooperative scenarios (Table VII).

Under cooperation, the total profit of the supply chain is greater than that in the noncooperative environment, which proves that manufacturers and retailers should actively cooperate in order to obtain more profit.

When the manufacturer cooperates with the retailer, the pricing is lower than it is under noncooperation, and the sales of automobiles increased nearly twofold. The demand price elasticities of the traditional energy vehicles and new energy vehicles are $E_t = -15.43$, $E_r = -18.11$, The new energy vehicle has greater demand price elasticity, which suggests that the government's relevant tax and subsidy policies can reduce the prices of new energy vehicles, stimulate market demand, and achieve the purpose of encouraging environmental protection.

Observing Tables V and VI, we can find when $\lambda \in [0.36, 0.59]$, $\pi_{\max} > \pi^*$. In this situation, the retailer and manufacturer will not cooperation. Conversely, when $\lambda \in [0.60, 0.75]$, the retailer and manufacturer will cooperate with each other.

TABLE VIII
RANGE OF *K*.

λ	k range	λ	k range
0.60	(0,0.897718334608749]	0.68	(0,0.824285839501008]
0.61	(0,0.891889739196614]	0.69	(0,0.806102638030176]
0.62	(0,0.885534370420797]	0.7	(0,0.783009682004713]
0.63	(0,0.878508916068445]	0.71	(0,0.752590222499247]
0.64	(0,0.870630387065866]	0.72	(0,0.710562857197666]
0.65	(0,0.861659233483922]	0.73	(0,0.64854822169895]
0.66	(0,0.851273501832758]	0.74	(0,0.547616019516171]
0.67	(0,0.83902784883301]	0.75	(0,0.354035057034218]

Besides, λ refers to how much consumers like new energy products, we can infer that only when consumers are more inclined to new energy products will they cooperate.

To meet the condition of $\phi_1(v) \geq {\pi_1}^*, \ \ \phi_2(v) \geq {\pi_2}^*$, Table VIII shows the range of *k*.

When k and λ changes within the range, the profits of the retailer and the manufacturer change, as shown in Figs. 5 and 6.

Manufacturers in the upstream of the supply chain can actively participate in consumer-oriented green marketing as a feasible way to expand their own profits. For retailers, cooperating with manufacturers to bear the green-marketing cost can reduce some risks and increase profits. Therefore, sharing the green-marketing cost is a positive way to achieve mutual benefits for both sides of the supply chain.

V. CONCLUSION

This paper studied the pricing strategies between the retailer and the manufacturer for products with energy consumption disparities based on policies and market conditions in China. This analysis classified the products into two categories: traditional energy product and new energy product, and used game theory and a logistic regression model to study the cooperation strategies of the manufacturer and the retailer in the two-stage supply chain. Finally, through actual data analysis, several suggestions were offered, which are as follows.

1) For manufacturers, one of the important factors affecting consumers' purchases is the average cost of energy use. Therefore, the energy consumption disparity is one of the most important characteristics of product, and the average energy consumption cost of new energy products is much lower than that of traditional energy products.
2) For retailers, new energy products have greater price elasticity of demand compared with traditional energy products, and government subsidy policies have a positive effect. Retailers should make differential prices for the two products based on the relevant policies and consumer demand.
3) Cooperation plays a positive role in the pricing of new energy products. It can improve the energy consumption disparity at the equilibrium point and help assign a reasonable high price to the new energy products, whereas collaboration also has a positive impact on energy consumption and carbon emissions reduction.
4) Cooperation is the best way to address the conflict between the two sides of the supply chain about the new energy products. The profit from cooperation is greater than that from noncooperation, and it is feasible to adopt the cooperative strategy of sharing the green-marketing cost.

However, the following are several limitations that remain in this paper.

1) In this analysis, complete information was assumed when considering supply chain cooperation. Under actual circumstances, if the retailers or manufacturers conceal their actual costs, the optimal pricing strategies of both sides would be different, even leading to a reduction in the likelihood of cooperation.
2) To simplify the model, the problem of an imbalance between production and marketing has been ignored. When the output is larger than the sales volume, the cost increases because the inventory backlog will have an impact on profits.

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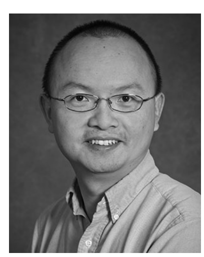

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