

Study on the Selection of Credits Disposal Strategies of Automobile Companies Considering the Level of R&D Investment

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Abstract:

Considering the “dual-credit” policy and R&D factors, this paper constructs three strategic models of NEV credits selling, carryover and hybrid for an automobile enterprise that produces both traditional fuel vehicles and new energy vehicles, to study the optimal disposal strategy of surplus credits. Results show that: (1) With the increase of R&D investment, automobile enterprise should reduce the prices of the vehicles, and increase the output to realize the capital recovery. (2) Automobile enterprise should pay attention to the price of credits and adjust their strategies to the price. If the credit price is lower, the carryover strategy should be chose; on the contrary, the selling strategy is better. (3) To expand the proportion of selling credits, enterprise should lower the prices of fuel vehicles and increase their production; similarly, the price of fuel vehicles should be increased to reduce the total amount of CAFC negative credits.

Keywords:

Dual-Credit Policy, R&D Investment Level, Credit Disposal Strategy, New Energy Vehicles, Credits Price

1. Introduction

To improve energy efficiency and reduce fuel consumption, the Ministry of Industry and Information Technology issued the dual-credit policy to promote the development of new energy vehicles. Enterprises need to calculate average fuel consumption credits (CAFC credits for short) and new energy vehicle credits (NEV credits for short) every year. If the negative credits are not paid, the enterprise will face the penalty of discontinuing some fuel models. In response to the dual-credit policy, fuel enterprises have joined the ranks of new energy vehicle production and R&D vehicles to expand market size. To further adjust the supply and demand of credits, the government stipulates that enterprises can carryover the positive NEV credits generated in the current year. According to data released by the Ministry of Industry and Information Technology, the proportion of auto enterprises with excess

NEV credits in 2021 is about 48.84%; the proportion of auto enterprises that meet the government's requirements for NEV credits carryover accounts for about 26.36%. It can be seen that in recent years, the proportion of enterprises with NEV excess credits has gradually increased. Therefore, to reduce credit waste, we need solve the dispose of excess credits.

The relevant researches are mainly reflected in three aspects: the production pricing research under the dual-credit policy, the impact of credits price on the decision-making of automobile enterprises, and the impact of R&D investment on automakers' decision-making. In terms of the impact of dual-credit policy on the production pricing of automobile enterprises, Cheng and Fan [1] found that in the unstable credits market, cooperation strategy is the best strategy. Gu et al. [2] studied the optimal pricing strategy of manufacturers and remanufacturers under the closed-loop supply chain of battery recycling and reuse. Li et al. [3] found that the dual integration policy increased the profits of the supply chain of new energy vehicles. Fan et al. [4] studied the optimal selling prices of batteries and electric vehicles of two brands under three strategies. Yu et al. [5] found that optimal production and pricing strategies can be formulated according to average fuel consumption credits. The relevant research shows that the change of the price of credits will affect the production decision of enterprises. Cheng et al. [6] found that manufacturers tend to adjust the price or production of new energy vehicles to cope with the interference of the price of credits. Yang et al. [7] obtained that the efficiency could be improved by conducting credit trading through market mechanism. Meng et al. [8] found that suppliers should choose to share the cost with manufacturers. Wu et al. [9] found that the increase in the price of credits promoted the adoption of electric vehicles. He et al. [10] found that the dual-credit policy could improve the capacity utilization rate. Li et al. [11] find that when automobile technology level is low, automobile enterprises will choose procurement strategies. In terms of the impact of R&D investment on the decision-making of automobile enterprises, Wu et al. [12] found that there is a positive correlation between the technological capability of enterprises and the performance of ecological innovation. Lu et al. [13] found that the impact of enterprises R&D input was far greater than that of government subsidies.

The existing literature has made certain contributions to the research on dual-credit policy, but there are still the following limitations: First, the research subjects mainly produce a single type of vehicles; Second, few researches on NEV credits carryover. Therefore, this paper considers the level of R&D investment to construct decision-making models of two-vehicle enterprises under three strategies. By studying the three strategy models, provides optimal decision-making guidance for automobile enterprises.

2. Strategy and Assumptions

Considering a car company that produces new energy vehicles and fuel vehicles at the same time, and sells them to consumers at prices of p_1 and p_2 respectively, the automobile market demand is q_1 and q_2 respectively. If the positive NEV credits obtained by the car company are greater than the negative credits, there will be surplus credits. At this stage, the surplus credits disposal strategies are mainly divided into selling all surplus credits this year to the credits market (referred to as the selling strategy), carrying forward the credits to the next year (referred to as the carryover

strategy), and selling partial credits to the market and carrying part of it to the next year (referred to as hybrid strategy).

Hypothesis 1: According to the current model quotation in the market, the price of new energy vehicles is usually higher than that of fuel vehicles, so this paper assumes $p_1 > p_2$.

Hypothesis 2: Considering the different preferences of heterogeneous consumers for vehicles, the utility functions of consumers buying new energy vehicles and fuel vehicles can be obtained as follows:

$$\mu_1 = (1 + \eta) v - p_1 + \sigma x_1 \quad (1)$$

$$\mu_2 = \tau x_2 + v - p_2 \quad (2)$$

Three, v is to obey $[0,1]$ the basic utility of uniformly distributed consumers buying cars, η is the environmental awareness of consumers, $0 < \eta < 1$. σ is the improvement coefficient of consumer preference after the research of new energy vehicles, we measure new energy vehicles' by $(1 + \eta) v + \sigma x_1$. τ represents the improvement coefficient of consumer preference after the development of fuel vehicles, and measure fuel vehicles' by $\tau x_2 + v$.

The demand functions of new energy vehicles and traditional vehicles are as follows:

$$q_1 = \int_{\frac{\tau x_2 - \sigma x_1 + p_1 - p_2}{\eta}}^1 1 dv \quad (3)$$

$$q_2 = \int_{-\tau x_2 + p_2}^{\frac{\tau x_2 - \sigma x_1 + p_1 - p_2}{\eta}} 1 dv \quad (4)$$

Hypothesis 3: Suppose γ_1 is the credit coefficient of new energy vehicles, ω_1 is the credit coefficient of R&D investment of new energy vehicles, then automobile enterprises can obtain $(\gamma_1 + \omega_1 x_1) q_1$ NEV credits for producing new energy vehicles. γ_2 is fuel vehicle credits coefficient, ω_2 is the credit coefficient of R&D input on fuel vehicles, the NEV credits of $(\gamma_2 - \omega_2 x_2) q_2$ is offset by the automobile enterprise's production of fuel vehicles.

Hypothesis 4: In order to make the disposal strategy of NEV surplus credits valid, we let $(\gamma_1 + \omega_1 x_1) q_1 > (\gamma_2 - \omega_2 x_2) q_2$. Please see Table 1 for detailed symbols.

Table 1. Symbol meaning.

Parameter	Interpretation	Parameter	Interpretation
p_1	Prices of new energy vehicles	x_1	New energy vehicles R&D level
p_2	Price of fuel vehicles	x_2	Fuel vehicles R&D level
q_1	Production of new energy vehicles	π_s	Selling strategy off enterprise profit
q_2	Production of fuel vehicles	π_c	Carryover strategy off enterprise profit
c_1	Cost of new energy vehicles	π_h	Hybrid strategy off enterprise profit
c_2	Cost of fuel vehicles	α	Carry-over ratio
p_d	Credit price	β	Discount factor

u_1	The utility of new energy vehicles	θ	Percentage of credits sold
u_2	The utility of fuel vehicles		

2.1. Selling strategy

$$\pi_s = (p_1 - c_1)q_1 + p_d[(\gamma_1 + \omega_1 x_1)q_1 - (\gamma_2 - \omega_2 x_2)q_2] + (p_2 - c_2)q_2 - \frac{1}{2}x_1^2 - \frac{1}{2}x_2^2 \quad (5)$$

Under the selling strategy, the car company chooses to sell all the NEV surplus credits this year, the revenue is the revenue of automobile revenue, sales credits and the R&D input. Regarding the price and output of new energy vehicles and fuel vehicles, the optimal profit is detailed in Table 2.

Proposition 1: Under the selling strategy, The level of investment in new energy vehicles is inversely proportional to their prices. unrelated to the price of fuel vehicles and inversely proportional to its output. The level of R&D investment in fuel vehicles is not related to the price of new energy vehicles, is inversely proportional to its sales, is inversely proportional to the price of fuel vehicles, and is proportional to the output.

$$\frac{\partial}{\partial x_1}(p_{s1}) < 0, \frac{\partial}{\partial x_1}(p_{s2}) = 0, \frac{\partial}{\partial x_1}(q_{s1}) > 0, \frac{\partial}{\partial x_1}(q_{s2}) < 0, \frac{\partial}{\partial x_2}(p_{s1}) = 0, \frac{\partial}{\partial x_2}(p_{s2}) < 0, \frac{\partial}{\partial x_2}(q_{s1}) < 0, \frac{\partial}{\partial x_2}(q_{s2}) > 0$$

However, it is worth noting that the price of fuel vehicles is not affected by the level of investment in new energy vehicles, but the output will decline as the level of R&D increases. Because the market size is certain, and with the improvement of the R&D level of new energy vehicles, the new energy vehicles production has risen, which will affect the decline in the output of fuel vehicles.

2.2. Carryover strategy

$$\pi_c = (p_1 - c_1)q_1 + p_d\alpha\beta[(\gamma_1 + \omega_1 x_1)q_1 - (\gamma_2 - \omega_2 x_2)q_2] + (p_2 - c_2)q_2 - \frac{1}{2}x_1^2 - \frac{1}{2}x_2^2 \quad (6)$$

Under this strategy, car company chooses to carry forward the current year's NEV surplus credits to the next year according to the carryover ratio specified by the government for use in the next year. the profits of automobile enterprise are composed of the profit from selling vehicles, the value of credits and research and development costs.

Proposition 2: Under the carryover strategy, the new energy vehicle price is negatively correlated with the credit price, while the output is positively correlated with the credit price; The credit price is positively correlated with the price of fuel vehicles, and negatively correlated with the output.

$$\frac{\partial}{\partial p_d}(p_{c1}) < 0, \frac{\partial}{\partial p_d}(p_{c2}) > 0, \frac{\partial}{\partial p_d}(q_{c1}) > 0, \frac{\partial}{\partial p_d}(q_{c2}) < 0.$$

It can be seen from proposition 2 that when an automobile enterprise chooses to carryover surplus credits, with the increase of credits transaction price, the enterprise will consider the increased cost to be borne in case of insufficient credits in the second year, so it can obtain more NEV credits by reducing the prices of new energy vehicles and increasing their output to reduce the risk of insufficient credits in the second year.

2.3. Hybrid strategy

Under this strategy, car company can choose to sell part of surplus credits directly on the market, and the remaining part will be carried forward to the next year in proportion for use in the next year. the profits of automobile enterprise are composed of vehicle sales revenue, credits sales revenue, credits value and research and development costs.

$$\pi_H = (p_1 - c_1)q_1 + p_d \left[(\gamma_1 + \omega_1 x_1)q_1 - (\gamma_2 - \omega_2 x_2)q_2 \right] \left[\theta + (1-\theta)\alpha\beta \right] + (p_2 - c_2)q_2 - \frac{1}{2}x_1^2 - \frac{1}{2}x_2^2 \quad (7)$$

Proposition 3: The proportion of NEV credits sold is negatively correlated with new energy vehicles price, positively correlated with its output. It is positively correlated with fuel vehicle price and negatively correlated with output.

$$\frac{\partial}{\partial \theta} (p_{H1}) < 0, \frac{\partial}{\partial \theta} (p_{H2}) > 0, \frac{\partial}{\partial \theta} (q_{H1}) > 0, \frac{\partial}{\partial \theta} (q_{H2}) < 0.$$

Proposition 3 shows that enterprises should consider the influence of credits price, vehicle R&D investment level, credits carryover ratio and second-year production plan. If enterprise expands the proportion of credits sales, the price of credits should be reduced. Increase production of new energy vehicles to obtain more NEV credits. At the same time, increase the price of fuel vehicles, reduce production, reduce CAFC negative credits, and prepare for the production plan for the second year.

Table 2. Optimal decision and profit.

	Selling strategy	Carryover strategy	Hybrid strategy
p_1	$\frac{-Ap_d + \eta + \sigma x_1 + c_1 + 1}{2}$	$\frac{-\alpha\beta Ap_d + \sigma x_1 + \eta + c_1 + 1}{2}$	$\frac{-ACp_d + \sigma x_1 + \eta + c_1 + 1}{2}$
p_2	$\frac{Bp_d + \tau x_2 + c_2 + 1}{2}$	$\frac{\tau x_2 + \alpha\beta Bp_d + c_2 + 1}{2}$	$\frac{\tau x_2 + BCp_d + c_2 + 1}{2}$
q_1	$\frac{(A+B)p_d - \tau x_2 + \sigma x_1 + \eta - c_1 + c_2}{2\eta}$	$\frac{\alpha\beta(A+B)p_d - \tau x_2 + \sigma x_1 + \eta - c_1 + c_2}{2\eta}$	$\frac{(A+B)Cp_d + \sigma x_1 - \tau x_2 + \eta - c_1 + c_2}{2\eta}$
q_2	$\frac{\tau(1+\eta)x_2 - (Bp_d + c_2)\eta - (A+B)p_d}{2\eta} + \frac{-\sigma x_1 + c_1 - c_2}{2\eta}$	$\frac{\tau(1+\eta)x_2 - (\alpha\beta Bp_d + c_2)\eta - \alpha\beta(A+B)p_d}{2\eta} + \frac{-\sigma x_1 + c_1 - c_2}{2\eta}$	$\frac{\tau(1+\eta)x_2 - (BCp_d + c_2)\eta - (A+B)Cp_d}{2\eta} + \frac{-\sigma x_1 + c_1 - c_2}{2\eta}$
π	$\frac{(Ap_d + \eta + \sigma x_1 - c_1 + 1)D}{4\eta} - \frac{x_1^2}{2} - \frac{x_2^2}{2} + \frac{(-Bp_d + \tau x_2 - c_2 + 1)E}{4\eta}$	$\frac{(A\alpha\beta p_d + \eta + \sigma x_1 - c_1 + 1)D}{4\eta} - \frac{x_1^2}{2} - \frac{x_2^2}{2} + \frac{(-B\alpha\beta p_d + \tau x_2 - c_2 + 1)E}{4\eta}$	$\frac{(ACp_d + \eta + \sigma x_1 - c_1 + 1)D}{4\eta} - \frac{x_1^2}{2} - \frac{x_2^2}{2} + \frac{(-BCp_d + \tau x_2 - c_2 + 1)E}{4\eta}$

$$A = \gamma_1 + \omega_1 x_1, B = \gamma_2 - \omega_2 x_2, C = \theta + (1-\theta)\alpha\beta, D = (A+B)p_d - \tau x_2 + \sigma x_1 + \eta - c_1 + c_2,$$

$$E = \tau(1+\eta)x_2 - (Bp_d + c_2)\eta - (A+B)p_d - \sigma x_1 + c_1 - c_2$$

2.4. Model comparison

Proposition 4: Prices of new energy vehicles: $p_{S1} < p_{H1} < p_{C1}$;

Prices of fuel vehicles: $p_{C2} < p_{H2} < p_{S2}$;

Production of new energy vehicles: $p_{C1} < q_{H1} < q_{S1}$;

Production of fuel vehicles: $q_{S2} < q_{H2} < q_{C2}$.

Under the selling strategy, automobile enterprise will reduce the price of new energy vehicles to increase production, and then increase corporate profits. Under the carryover strategy, automobile enterprise should consider carryover the credits to the next year, so fuel vehicles price will be reduced, R&D funds will be quickly returned.

3. Numerical Analysis

Assuming $\eta = 0.4$, $\gamma_2 \approx 1$, $\gamma_1 = 3$, $\sigma = 0.2$, $\tau = 0.1$, $\omega_1 = 1$, $\omega_2 = 0.3$, $\theta = 0.2$, $\alpha = 0.5$, $\beta = 0.98$. The impact of R&D input levels on vehicles price and production is shown in Figure 1.

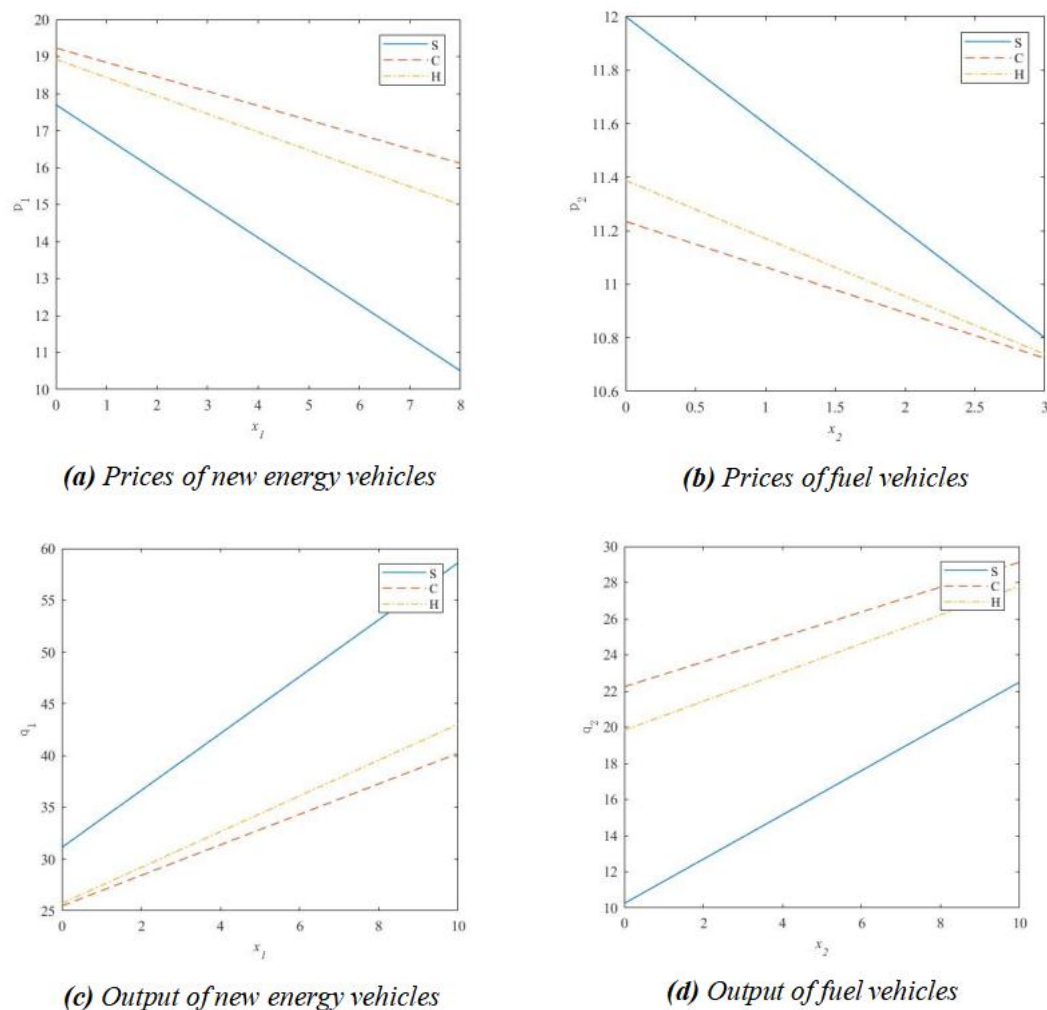


Figure 1. The impact of R&D investment levels on automobile production and prices.

As can be seen in Figure 1, we can see that the price of new energy vehicles under the carryover strategy is the highest, and finally the selling strategy; the output of new energy vehicles under the selling strategy is the highest, followed by the hybrid strategy, and finally It is carryover strategy. The prices of fuel vehicles are selling strategy, hybrid strategy and carryover strategy in order; the output of fuel vehicles is the highest under the carryover strategy, the hybrid strategy follows, finally the selling strategy.

As can be seen from Figure 2, the profit under the selling strategy decreases first and then increases; The profit under the hybrid strategy is always between the selling strategy and carryover strategy. Profit under the carryover strategy always tends to rise slowly. Therefore, when NEV credits price is low, enterprises can choose to carryover the surplus credits to make more profits. As the price of credits rises, the profit obtained by the selling strategy is significantly higher than that of the carryover strategy, and managers should timely sell the NEV surplus credits.

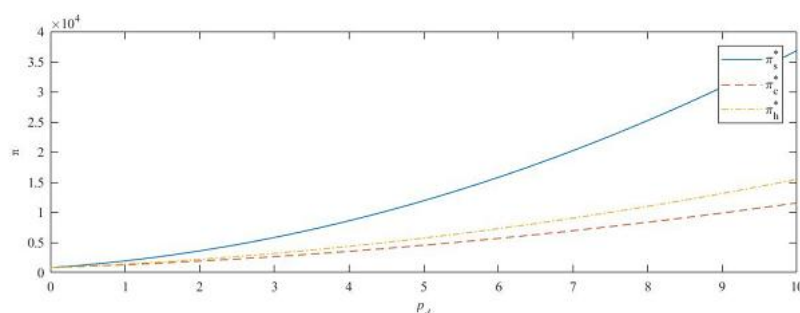


Figure 2. Optimal profit of the three strategies.

4. Conclusions

In this paper, for an automobile enterprise, three strategic models of NEV surplus credits selling, carryover and hybrid are constructed. The results are as follows: (1) As R&D investment levels increase, automobile enterprises should reduce the price of automobiles and increase production to increase the profits of automobile enterprises. (2) Enterprises should adjust the production plan to changes in credits price. When the credit price is high, automobile enterprise can choose to appropriately reduce new energy vehicles price to increase sales, obtain more NEV credits, and increase profits. (3) When car companies choose to carry forward surplus credits, they will lower the price of new energy vehicles and obtain more NEV credits to reduce the company's risk of insufficient credits in the second year; or they will increase the price of fuel vehicles to reduce the demand for credits. To a certain extent, it has suppressed the sales of fuel vehicles and promoted the development of new energy vehicles, thus proving the effectiveness of the dual-credit policy. (4) The credit coefficient will affect the total amount of CAFC credits and NEV credits in the market and the relationship between supply and demand, and indirectly affect the credit price. Therefore, the government should consider the interaction between various factors and set a more reasonable and perfect credit coefficient value.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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