Study on the Disposal Strategy of Automobile Enterprise Credits Considering 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, New energy vehicles, Credits disposal strategy

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.

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2. LITERATURE REVIEW

The relevant literatures mainly include three aspects: Related research shows that consumer preferences will affect car sales and upgrades. Lim M K et al.[1] found that the level of resale anxiety will affect the use value of electric vehicles, so the higher the resale anxiety, the business model of leasing electric vehicle batteries will incentivize car companies to choose to adopt higher levels of adoption and emission reductions. Langbroek et al.[2] found that people's trust in electric vehicles as effective and convenient transportation can increase their desire to purchase electric vehicles. Hardmand S et al.[3] found that incentive measures at the time of consumer purchase are the best way to promote electric vehicles with low energy consumption and long range. Incentive measures for publicity should be reduced. Judging from the impact of the dual-credit policy on production pricing of car companies Fan et al.[4] studied the optimal selling prices of batteries and electric vehicles under three strategies. Yu et al.[5] found that optimal production and pricing strategies could be formulated according to CAFC credits. The relevant research showed that the change of the credits' price affected the production decision of enterprises. Meng et al.[6] found that suppliers should choose to share the cost with manufacturers. Wu et al.[7] found that increase in credit price promotes the promotion of new energy vehicles. Lu et al.[8] found that the impact of enterprises R&D input was far greater than that of government subsidies.

Existing literature has made some contributions to the research on the dual-credit policy, but there are still the following limitations: first, the research object mainly produces a single vehicle model; second, few studies involve the issue of NEV credits carryover. Therefore, this paper constructs three strategy models for an automobile enterprise's credits disposal under the secondary car supply chain to provide optimal decision-making guidance for automobile enterprise.

3. PROBLEM DESCRIPTION

Considering the secondary supply chain composed of car companies and consumers. To expand market share, automobile enterprise sell developed vehicles to consumers. According to the current model quotation in the market, the prices of new energy vehicles is usually higher than that of traditional vehicles, so assumes $p_1 > p_2$. Automobile enterprise will get credits for selling cars, suppose γ_1 is the NEV credits coefficient, ω_1 is the credit coefficient of R&D investment of new energy vehicles, then automobile enterprises can obtain $\left(\gamma_1 + \omega_1 x_1\right) q_1$ 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 $\left(\gamma_2 - \omega_2 x_2\right) q_2$ is offset by the automobile enterprise's production of fuel vehicles. To make the disposal strategy of NEV excess credits valid, we let $\left(\gamma_1 + \omega_1 x_1\right) q_1 > \left(\gamma_2 - \omega_2 x_2\right) q_2$. For all the excess credits, the enterprise can sell all to market (referred to as the sales strategy), or carryover them to the next year based on the proportion stipulated (referred to as the carryover strategy), or sell part of credits to market, and carryover part to the next year (referred to as hybrid strategy), the specific symbols are shown in Table 1.

Considering the different preferences of heterogeneous consumers for vehicles, and references [3], the utility of consumers purchasing vehicles can be obtained as follows:

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

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

Here, v represents the basic utility of consumers buying vehicles, η is the environmental awareness of consumers, 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 fuel vehicles are as follows:

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

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

Table 1. Symbolic meaning

Parameter	Meaning	Parameter	Meaning
p_1	Prices of new energy vehicles	x_2	Fuel vehicles R&D level
p_2	Prices of fuel vehicles	π_S	Enterprise profit under selling strategy
q_1	Output of new energy vehicles	π_C	Enterprise profit under carryover strategy
q_2	Output of fuel vehicles	π_H	Enterprise profit under hybrid strategy
c_1	Cost of new energy vehicles	α	Carryover ratio
c_2	Cost of fuel vehicles	β	Discount factor
p_d	Credit price	θ	Percentage of credits sold
x_1	New energy vehicles R&D level		

3.1 Selling strategy

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

Under the selling strategy, the profit is the vehicles sales revenue, sales credits, and the R&D input. For the price and output of new energy vehicles and fuel vehicles, the optimal profit is shown 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.

3.2 Carryover strategy

$$\pi_C=(p_1-c_1)q_1+p_d\alpha\beta\left[(\gamma_1+\omega_1x_1)q_1-(\gamma_2-\omega_2x_2)q_2\right]+(p_2-c_2)q_2-\frac{1}{2}x_1^2-\frac{1}{2}x_2^2 \tag{6}$$

Under this strategy, 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.

3.3 Hybrid strategy

Under this strategy, the profits of automobile enterprise are composed of vehicle sales revenue, credits sales revenue, credits value and research and development costs.

$$\pi_H=(p_1-c_1)q_1+p_d\left[(\gamma_1+\omega_1x_1)q_1-(\gamma_2-\omega_2x_2)q_2\right]\left[\theta+(1-\theta)\alpha\beta\right]+(p_2-c_2)q_2-\frac{1}{2}x_1^2-\frac{1}{2}x_2^2 \tag{7}$$

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	$\frac{(Ap_d+\eta+\sigma x_1-c_1+1)D}{4\eta}-\frac{x_1^2}{2}-\frac{x_2^2}{2}+\frac{(-Bp_d+\tau x_2-c_2+1)E}{4\eta}$	$\frac{(A\alpha\beta p_d+\eta+\sigma x_1-c_1+1)D}{4\eta}-\frac{x_1^2}{2}-\frac{x_2^2}{2}+\frac{(-B\alpha\beta p_d+\tau x_2-c_2+1)E}{4\eta}$	$\frac{(ACp_d+\eta+\sigma x_1-c_1+1)D}{4\eta}-\frac{x_1^2}{2}-\frac{x_2^2}{2}+\frac{(-BCp_d+\tau x_2-c_2+1)E}{4\eta}$

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

3.4 Model comparison

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

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

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

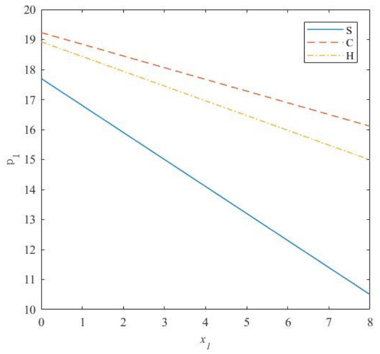
Output of fuel vehicles: $q_{S2}<q_{H2}<q_{C2}$

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.

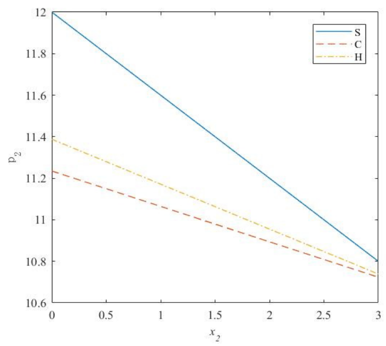
4. NUMERICAL ANALYSIS

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

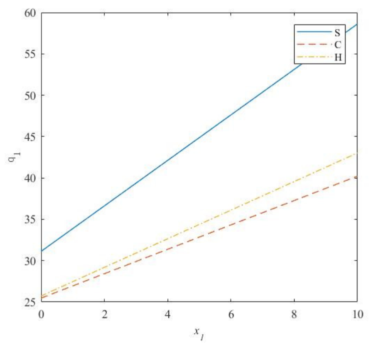
As can be seen in Figure 1, we can see that the price of new energy vehicles under the carryover strategy is the highest, and finally the selling strategy; the output of new energy vehicles under the selling strategy is the highest, followed by the hybrid strategy, and finally It is carryover strategy.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



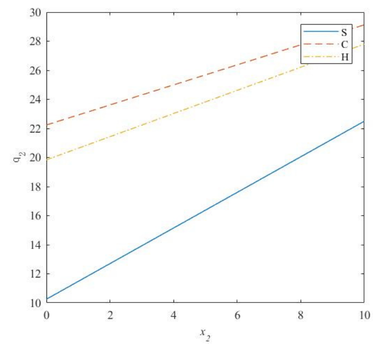
(a)Prices of new energy vehicles



(b) Prices of fuel vehicles



(c)Output of new energy vehicles



(d) Output of fuel vehicles

Figure 1. Prices and output of vehicles

Under the three strategies, the optimal profit of the enterprise changes with the point price, as shown in Figure 2.

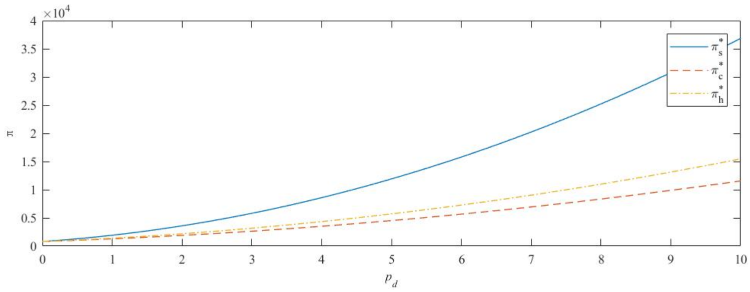


Figure 2. Optimal profit of the three strategies.

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.

5. CONCLUSION

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.

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