Pricing Strategies for Vehicle Production Under the Corporate Average Fuel Consumption and New Energy Vehicle Credit Policy

Jiawei Zhang, Jiayu She, Shaoqi Zhang and Xiaoyu Gu
School of Economics and Management, Nanjing University of Science and Technology, Nanjing, China.

Keywords: CAFC and NEV Credit Policy; Electric and Gasoline Vehicle.

Abstract: China has a clear strategic positioning and phased development goals for electric vehicles, and has been guaranteed through fiscal and tax encouragement and a series of policies. Based on the reality of the industry, the operation and decision-making of traditional Gasoline vehicle and Electric vehicle is a common problem for enterprises. Aiming at the important index of credit, this paper constructs a new automobile supply chain model composed of electric / gasoline vehicle manufacturers, government, and customers, in order to study the Corporate Average Fuel Consumption and New Energy Vehicle credit policy. On the other hand, the government's regulation and control of gasoline consumption and other key indicators and market demand factors affect the pricing decisions of enterprises. When the profit of the whole society reaches the maximum value, the maximum profit, optimal sales price, and credit value of every agent in the supply chain are given. This study puts forward management suggestions for the pricing decisions of automobile enterprises and government implementation policies, which will contribute to the rapid development of the electric vehicle industry.

1 INTRODUCTION

The CAFC (Corporate Average Fuel Consumption) and NEV (New Energy Vehicle) credit policy has an important influence on the coexistence of Gasoline vehicle (GV, driven by the gasoline) and Electric vehicle (EV, driven by the electricity as the new energy vehicle) which is used to develop the automobile market to promote the production and marketing of new energy vehicle (Yin, 2021). With this policy, how to make production pricing and decision-making has become a hot issue of concern to automobile enterprises and the government.

At present, there have been several related research on CAFC and NEV credit policy of automobile enterprises (Yin, 2021). Liu et al. (2018) analysed the future development of electric vehicle under policy incentives by setting four scenarios and establishing a system dynamics model, and concluded that large-scale market penetration requires strong policy support. Yang et al. (2022) used optimization theory to compare the government pricing model and the market pricing model of the CAFC and NEV credit, and discussed the effectiveness of the pricing method for electric vehicle production. Diwu et al. (2016) proposed a dual channel supply chain model considering government subsidies to study the optimal promotion strategy of new energy vehicle. On the basis of game theory and credit market equilibrium, Li et al. (2019) established a model of market analysis quantify the influence of CAFC and NEV credit on the purchase and sale mechanism of the automobile industry. Through the method of game theory, Ma et al. (2022) studied the improvement level and production situation of fuel economy of traditional internal combustion engine vehicle and electric vehicle, established the optimization model of traditional automobile supply chain, and produced new management opinions on the specific action plan. According to the credit value, Wang et al. (2022) studied the profit and loss of automobile manufacturers based on different technology combinations and summarized the most cost-effective compliance strategies of these automobile manufacturers. From the perspective of coexistence of electric vehicle and Gasoline vehicle, Xu et al. (2021) constructed a dynamic game model composed of retailers, manufacturers and the government, and considered the supply chain pricing strategy under the Stackelberg game modelled by manufacturers to formulate the optimal pricing strategy. To sum up, scholars have achieved several research on

Zhang, J., She, J., Zhang, S. and Gu, X.
Pricing Strategies for Vehicle Production Under the Corporate Average Fuel Consumption and New Energy Vehicle Credit Policy.
DOI: 10.5220/0011906200003536
In *Proceedings of the 3rd International Symposium on Water, Ecology and Environment (ISWEE 2022)*, pages 83-89
ISBN: 978-989-758-639-2; ISSN: 2975-9439

automobile industry with CAFC and NEV credit.

The innovation of this paper is to discuss the optimal pricing and decision-making of GV and EV produced by automobile enterprises in credit form, and to establish an equilibrium model, which is solved by optimization theory and method, and studies the influence of credit coefficient, oil price and electricity price on the total social profit, and analyses how the CAFC and NEV credit affects the operation decision of the enterprise. Especially aiming at the checks and balances between the policy measures and market factors of EV, this paper analyses the policy-oriented decision-making behaviour of enterprises.

The structure of this paper is as follows. In the second section, a three-level supply chain model composed of EV/GV manufacturers, governments and customers is constructed, and the optimal decision-making problem of automobile enterprises under CAFC and NEV credit is explained. In the third section, the conclusion analysis is carried out based on the model, that is, taking the given variable as an example, the numerical results of the model are given, and the influence of electricity price, oil price and credit coefficient on the total profit is analysed by the combination of numbers and shapes. Finally, the paper summarizes the research conclusions of this paper in the fourth section and provides a reference for the development of the industry. In order to fill the gap in the vehicle industry area, especially the sustainable development of EVs, this paper focuses on the impact of the optimal pricing of the overall policy on enterprise pricing by using the equilibrium theory of game theory. Finally, the average profit level of auto industry enterprises is affected by pricing.

2 MODEL DESTRIBUTION

The model includes a tripartite relationship between vehicle manufacturers, consumers and government, as shown in Figure 1 below.

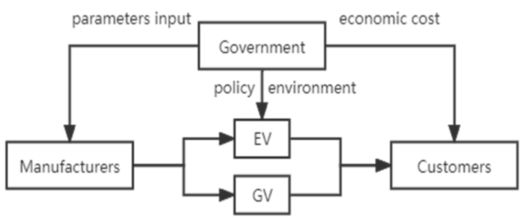

Figure 1: Model structure.

All the parameters and notations used in this paper are shown in the table below.

Table 1: Parameters and notations

$Symbol$	Meaning
k	Customer's willingness to buy a car $0 < k < 1$
L	Vehicle's lifecycle (year)
M_L	Average driven mileage per year (km/year)
$p_{\text{fuel}}/p_{\text{elec}}$	Price of fuel(£/L)/electricity (£/kWh)
$e_{\text{fuel}}/e_{\text{elec}}$	Mileage per fuel unit (km/L)/electricity unit (km/kWh)
v_t	Time value (£/h)
$H_{\text{refuel}}/H_{\text{recharging}}$	Time cost in each fuel refilling(h)/electricity recharging (h)
$V_{\text{gv}}/V_{\text{ev}}$	Gasoline tank volume (L)/ Battery volume (kWh)
$\pi_{\text{gv}}/\pi_{\text{ev}}$	GV/EV driving experience utility (£)
$C_{\text{gv}}/C_{\text{ev}}$	The total cost in GV/EV's full life cycle
$\theta_{\text{gv}}, \theta_{\text{ev}}$	Environmental protection awareness level for GV/EV user (£)
C_n/C_p	Negative Credits (Credits deducted for one fuel car)/Positive Credits (Credits added by one electric vehicle)
$p_{\text{Mgv}}/p_{\text{Mev}}$	GV/EV manufacturer cost (£)
$p_{\text{Cgv}}/p_{\text{Cev}}$	GV/EV price paid to the manufacturer (£)
$P_{\text{gv}}/P_{\text{ev}}$	The probability of buying a GV/EV
m_n/m_p	Money awarded for one unit of Negative Credits / Positive Credits
b_n/b_p	Regulation factor
C_{envir}	Annual treatment cost for carbon dioxide treatment
$\pi_{\text{Mgv}}/\pi_{\text{Mev}}$	Profit for GV/EV manufacturer (£)
π_{gov}	The social entire profit

For model simplification, we assume that k satisfies $0 \leq k \leq 1$, where $k = 0$ means customer will not buy a car and $k = 1$ means customer will buy a car.

Over the life cycle of a vehicle, costs include the cost of fuel or electricity and the cost of time, expressed by the equation:

$$C_{\mathrm{gv}} = \frac{Lp_{\mathrm{fuel}}M_L}{e_{\mathrm{fuel}}} + \frac{LH_{\mathrm{refuel}}M_L v_t}{e_{\mathrm{fuel}}V_{\mathrm{gv}}} \quad (1)$$

$$C_{\mathrm{ev}} = \frac{Lp_{\mathrm{elec}}M_L}{e_{\mathrm{elec}}} + \frac{LH_{\mathrm{recharging}}M_L v_t}{V_{\mathrm{ev}}} \quad (2)$$

We define the utility functions for fuel and electric vehicle customers as:

$$U_{\mathrm{Cgv}} = \left(-C_{\mathrm{gv}} + \theta_{\mathrm{gv}} + \pi_{\mathrm{gv}}\right)k - p_{\mathrm{Cgv}} = v_{\mathrm{gv}}k - p_{\mathrm{Cgv}} \quad (3)$$

$$U_{\mathrm{Cev}} = \left(-C_{\mathrm{ev}} + \theta_{\mathrm{ev}} + \pi_{\mathrm{ev}}\right)k - p_{\mathrm{Cev}} = v_{\mathrm{ev}}k - p_{\mathrm{Cev}} \quad (4)$$

Moreover, we have following assumptions of this model:

(1) User's profit of GV and EV is unequal which means $v_{gv} > v_{\mathrm{ev}}$;

(2) According to Gu et al. (2016), customers are rational, so they will choose those with a high utility function, i.e., good value for money.

Table 2 indicates the probability of people buying an electric and fuel car.

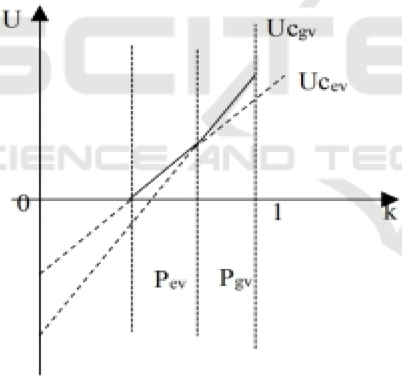

Figure 2: GV/EV usage utility with different purchase intention in EV early development stage.

It is easy to find that the probability of buying a GV is

$$P_{\mathrm{gv}} = 1 - \frac{p_{\mathrm{Cgv}} - p_{\mathrm{Cev}}}{v_{\mathrm{gv}} - v_{\mathrm{ev}}} \quad (5)$$

The probability of purchasing an EV is

$$P_{\mathrm{ev}} = \frac{p_{\mathrm{Cgv}} - p_{\mathrm{Cev}}}{v_{\mathrm{gv}} - v_{\mathrm{ev}}} - \frac{p_{\mathrm{Cev}}}{v_{\mathrm{ev}}} \quad (6)$$

For credits, we require the positive credits minus the negative credits to be greater than 0.

$$b_p C_p - b_n C_n = R \quad (\mathrm{R}>0) \quad (7)$$

So, the profit for a car manufacturer to produce a fuel car is

$$\pi_{\mathrm{Mgv}} = P_{\mathrm{gv}}\left(p_{\mathrm{Cgv}} - p_{\mathrm{Mgv}} - C_n m_n\right) \quad (8)$$

And the profit from the production of an electric vehicle is

$$\pi_{\mathrm{Mev}} = P_{\mathrm{ev}}\left(p_{\mathrm{Cev}} - p_{\mathrm{Mev}}C_p m_p\right) \quad (9)$$

Based on lemma 1, we can work out the best price:

$$p_{\mathrm{Cgv}} = A_2 C_n + A_1 C_p + (A_3 + A_4) \quad (10)$$

$$p_{\mathrm{Cev}} = \begin{pmatrix} A_6 C_n + A_5 C_p \\ +(A_7 + A_8 + A_9 + A_{10} + A_{11}) \end{pmatrix} \quad (11)$$

(To simplify the expressions and highlight the focus of the study, we replace all the coefficients before C_p and C_n with a new variable, such as A1, A2 in table2, in order to subsequently visualize the relationship between total social profit and the key study variables).

Therefore, the probability about purchasing an GV is

$$P_{\mathrm{gv}} = B_2 C_n + B_1 C_p + B_3 \quad (12)$$

And the possibility of buying an EV is

$$P_{\mathrm{ev}} = B_5 C_n + B_4 C_p + B_6 \quad (13)$$

In turn, we can find the profits of car manufacturers producing fuel and electric vehicles:

$$\pi_{\mathrm{Mgv}} = \left(B_2 C_n + B_1 C_p + B_3\right)\left(A_2 C_n + A_1 C_p + (A_3 + A_4) - C_n m_n - p_{\mathrm{Mgv}}\right) \quad (14)$$

$$\pi_{\mathrm{Mev}} = \left(B_5 C_n + B_4 C_p + B_6\right)\left(A_6 C_n + A_5 C_p + (A_7 + A_8 + A_9 + A_{10} + A_{11}) + C_p m_p - p_{\mathrm{Mev}}\right) \quad (15)$$

In order to optimize the total profit of the vehicle manufacturer, we define

$$\pi_{\mathrm{gov}} = \pi_{\mathrm{Mev}} + \pi_{\mathrm{Mgv}} - C_{envir} = T_5 C_n C_p + T_2 C_n^2 + T_4 C_n + T_1 C_p^2 + T_3 C_p + T_6 \quad (16)$$

All formulas mentioned above are expressed in Table 2 below.

Table 2: Simplifying expressions.

$A_1 = \dfrac{2m_n\left(C_{\mathrm{gv}} - \theta_{\mathrm{gv}} - \pi_{\mathrm{gv}}\right)}{-C_{\mathrm{ev}} + 4C_{\mathrm{gv}} + \theta_{\mathrm{ev}} + \pi_{\mathrm{ev}} - 4\theta_{\mathrm{gv}} - 4\pi_{\mathrm{gv}}}$
$A_2 = \dfrac{m_p\left(C_{\mathrm{gv}} - \theta_{\mathrm{gv}} - \pi_{\mathrm{gv}}\right)}{-C_{\mathrm{ev}} + 4C_{\mathrm{gv}} + \theta_{\mathrm{ev}} + \pi_{\mathrm{ev}} - 4\theta_{\mathrm{gv}} - 4\pi_{\mathrm{gv}}}$
$A_3 = \dfrac{\left(C_{\mathrm{gv}} - \theta_{\mathrm{gv}} - \pi_{\mathrm{gv}}\right)\left(2C_{\mathrm{ev}} - 2C_{\mathrm{gv}} + p_{\mathrm{Mev}}\right)}{-C_{\mathrm{ev}} + 4C_{\mathrm{gv}} + \theta_{\mathrm{ev}} + \pi_{\mathrm{ev}} - 4\theta_{\mathrm{gv}} - 4\pi_{\mathrm{gv}}}$
$A_4 = \dfrac{2A_3\left(-\theta_{\mathrm{ev}} - \pi_{\mathrm{ev}} + \theta_{\mathrm{gv}} + \pi_{\mathrm{gv}} + p_{\mathrm{Mgv}}\right)}{2C_{\mathrm{ev}} - 2C_{\mathrm{gv}} + p_{\mathrm{Mev}}}$
$A_5 = \dfrac{2m_p\left(C_{\mathrm{gv}} - \theta_{\mathrm{gv}} - \pi_{\mathrm{gv}}\right)}{-C_{\mathrm{ev}} + 4C_{\mathrm{gv}} + \theta_{\mathrm{ev}} + \pi_{\mathrm{ev}} - 4\theta_{\mathrm{gv}} - 4\pi_{\mathrm{gv}}}$

$$A_6=\frac{m_n(-C_{\mathrm{ev}}+\theta_{\mathrm{ev}}+\pi_{\mathrm{ev}})}{C_{\mathrm{ev}}-4C_{\mathrm{gv}}-\theta_{\mathrm{ev}}-\pi_{\mathrm{ev}}+4\theta_{\mathrm{gv}}+4\pi_{\mathrm{gv}}}$$

$$A_7=\frac{-C_{\mathrm{ev}}^2+\pi_{\mathrm{ev}}\pi_{\mathrm{gv}}+\pi_{\mathrm{ev}}p_{\mathrm{Mgv}}-\pi_{\mathrm{ev}}^2+2\pi_{\mathrm{gv}}p_{\mathrm{Mev}}}{C_{\mathrm{ev}}-4C_{\mathrm{gv}}-\theta_{\mathrm{ev}}-\pi_{\mathrm{ev}}+4\theta_{\mathrm{gv}}+4\pi_{\mathrm{gv}}}$$

$$A_8=\frac{\pi_{\mathrm{gv}}\theta_{\mathrm{ev}}-2\pi_{\mathrm{ev}}\theta_{\mathrm{ev}}+\theta_{\mathrm{ev}}p_{\mathrm{Mgv}}}{C_{\mathrm{ev}}-4C_{\mathrm{gv}}-\theta_{\mathrm{ev}}-\pi_{\mathrm{ev}}+4\theta_{\mathrm{gv}}+4\pi_{\mathrm{gv}}}$$

$$A_9=\frac{-C_{\mathrm{gv}}(\theta_{\mathrm{ev}}+\pi_{\mathrm{ev}}+2p_{\mathrm{Mev}})-\theta_{\mathrm{ev}}^2}{C_{\mathrm{ev}}-4C_{\mathrm{gv}}-\theta_{\mathrm{ev}}-\pi_{\mathrm{ev}}+4\theta_{\mathrm{gv}}+4\pi_{\mathrm{gv}}}$$

$$A_{10}=\frac{C_{\mathrm{ev}}\left(C_{\mathrm{gv}}+2\theta_{\mathrm{ev}}+2\pi_{\mathrm{ev}}-\theta_{\mathrm{gv}}-\pi_{\mathrm{gv}}-p_{\mathrm{Mgv}}\right)}{C_{\mathrm{ev}}-4C_{\mathrm{gv}}-\theta_{\mathrm{ev}}-\pi_{\mathrm{ev}}+4\theta_{\mathrm{gv}}+4\pi_{\mathrm{gv}}}$$

$$A_{11}=\frac{\pi_{\mathrm{ev}}\theta_{\mathrm{gv}}+\theta_{\mathrm{ev}}\theta_{\mathrm{gv}}+2\theta_{\mathrm{gv}}p_{\mathrm{Mev}}}{C_{\mathrm{ev}}-4C_{\mathrm{gv}}-\theta_{\mathrm{ev}}-\pi_{\mathrm{ev}}+4\theta_{\mathrm{gv}}+4\pi_{\mathrm{gv}}}$$

$$B_1=\frac{A_1-A_5}{v_{\mathrm{ev}}-v_{\mathrm{gv}}}$$

$$B_2=\frac{A_2-A_6}{v_{\mathrm{ev}}-v_{\mathrm{gv}}}$$

$$B_3=\frac{(A_3+A_4)-(A_7+A_8+A_9+A_{10}+A_{11})}{v_{\mathrm{ev}}-v_{\mathrm{gv}}}+1$$

$$B_4=\frac{A_5v_{\mathrm{gv}}-A_1v_{\mathrm{ev}}}{v_{\mathrm{ev}}\left(v_{\mathrm{ev}}-v_{\mathrm{gv}}\right)}$$

$$B_5=\frac{A_6v_{\mathrm{gv}}-A_2v_{\mathrm{ev}}}{v_{\mathrm{ev}}\left(v_{\mathrm{ev}}-v_{\mathrm{gv}}\right)}$$

$$B_6=\frac{(A_7+A_8+A_9+A_{10}+A_{11})v_{\mathrm{gv}}-(A_3+A_4)v_{\mathrm{ev}}}{v_{\mathrm{ev}}\left(v_{\mathrm{ev}}-v_{\mathrm{gv}}\right)}$$

$$T_1=B_4\left(A_5+m_p\right)+A_1B_1$$

$$T_2=B_2(A_2-m_n)+A_6B_5$$

$$T_3=\begin{pmatrix} B_6\left(A_5+m_p\right) \\ +B_4\left(\begin{pmatrix}A_7+A_8+A_9\\+A_{10}+A_{11}\end{pmatrix}-p_{\mathrm{Mev}}\right) \\ +B_1\left((A_3+A_4)-p_{\mathrm{Mgv}}\right)+A_1B_3 \end{pmatrix}$$

$$T_4=\begin{pmatrix} B_3(A_2-m_n)+B_5\left(\begin{pmatrix}A_7+A_8+A_9\\+A_{10}+A_{11}\end{pmatrix} \\ -p_{\mathrm{Mev}}\right) \\ +B_2\left((A_3+A_4)-p_{\mathrm{Mgv}}\right)+A_6B_6 \end{pmatrix}$$

$$T_5=B_1(A_2-m_n)+B_5\left(A_5+m_p\right)+A_1B_2+A_6B_4$$

$$T_6=B_6\left((A_7+A_8+A_9+A_{10}+A_{11})-p_{\mathrm{Mev}}\right)+B_3\left((A_3+A_4)-p_{\mathrm{Mgv}}\right)$$

3 NUMERICAL ANALYSIS AND DISCUSSION

In this section, we analyse the above model and analyse the parameters in the model based on mathematical examples

3.1 Numerical Example

The initial values for each variable are shown in Table 3 below.

Table 3: Value of initial variables:

$\boldsymbol{M_{\mathrm{L1}}=10000}$	$\boldsymbol{L=10}$	$\boldsymbol{p_{\mathrm{fuel}}=1}$
$\boldsymbol{p_{\mathrm{elec}}=0.5}$	$e_{\mathrm{fuel}}=10$	$e_{\mathrm{elec}}=6$
$\boldsymbol{v_t=8}$	$H_{\mathrm{refuel}}=0.15$	$H_{\mathrm{recharging}}=0.5$
$\boldsymbol{V_{\mathrm{gv}}=50}$	$V_{\mathrm{ev}}=400$	$\theta_{\mathrm{gv}}=3000$
$\boldsymbol{\theta_{\mathrm{ev}}=5000}$	$\pi_{\mathrm{gv}}=120000$	$\pi_{\mathrm{ev}}=105000$
$\boldsymbol{p_{\mathrm{Mgv}}=14000}$	$p_{\mathrm{Mev}}=15000$	$m_n=3000$
$\boldsymbol{m_p=4000}$ R=5	$b_n=3$ $C_{\mathrm{envir}}=50$	$b_p=4$

Through substituting initial values above into equation (16), we can find that equation (16) is a quadratic function on C_p, and in order to maximize profit, the optimal value of positive credits C_p and negative credits $C_n$of can be derived as.

$$C_p=1.4685 \tag{17}$$

$$C_n=0.2913 \tag{18}$$

And the total profit is:

$$\pi_{\mathrm{gov}}=\ 8055.14 \tag{19}$$

Specifically, these results means that the average production of an electric car will give the company 1.4685 CAFC Credits and the average production of a fuel car will give the company 0.2913 NEV credits, at which point the average production of an electric car and a fuel car will bring the company a profit of 8,055.14. The CAFC Credits factor is much larger than the NEV credits factor, which encourages enterprises to produce electric vehicles and reduce the number of fuel vehicles, which is conducive to the implementation of CAFC and NEV credit policy.

3.2 Analysis

Using the above values for C_p and C_n as reference values, we discuss the impact of each parameter in the model on total profit.

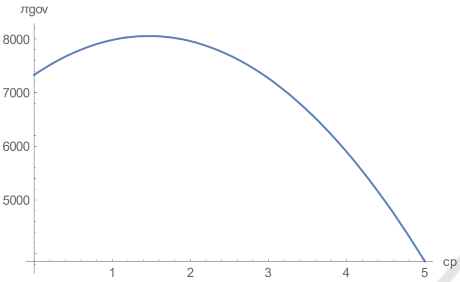

Figure 3: Impact of Positive Credits vs total profit.

Figure 3 indicates that there is an optimal value of C_p that maximizes the total profit, the value of C_p found in 3.1 section. There is an optimal value of C_p that maximizes total social profit. The reality behind is that the subsidies for electric vehicle enterprises should not be too high, too high policy subsidies will affect the profitability of fuel companies, but also lead to a decline in the competitiveness of electric vehicle enterprises themselves.

Moreover, as can be seen in Figure 4 below, the blue line indicates $C_n = 0$ (no penalty for fuel car producing enterprises) and the yellow line indicates $C_n \neq 0$ (penalty for fuel car producing enterprises). When the cost of environmental treatment is low, the total social profit of not penalizing fuel car producing enterprises is higher than that of penalizing fuel car producing enterprises; when the cost of environmental treatment is high, the total social profit of penalizing fuel car producing enterprises is higher than that of not penalizing fuel car producing enterprises.

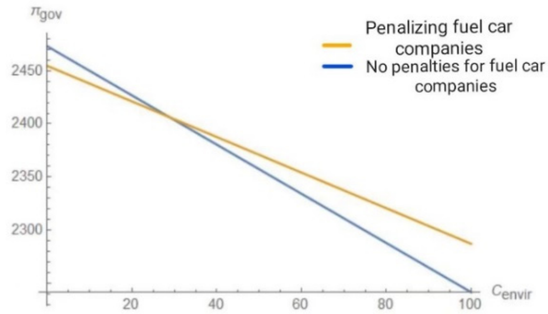

Figure 4: C_{envir}(Environmental treatment cost) vs total profit.

We find that the total profit as a function of m_n is a quadratic function with a downward opening when m_p is fixed. As m_p increases, the axis of symmetry and the maximum value of the total profit as a function of m_n become larger. The reverse is also true. And by doing the calculations, we can find the range of total profit.

$$5233.45 \le \pi_{gov} \le 11504. \ (0 < m_n < 8000, \quad 0 < m_p < 8000)$$

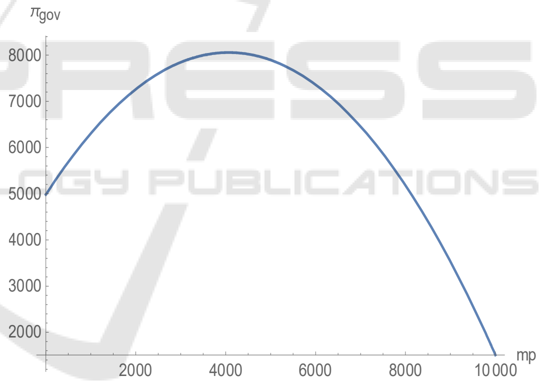

Figure 5: m_p (Money awarded for one unit of Negative Credits) vs total profit.

Then we then discuss the impact of oil and electricity prices on total profits. Figure 6 shows the image of total profit as a function of oil price at an electricity price of 0.5

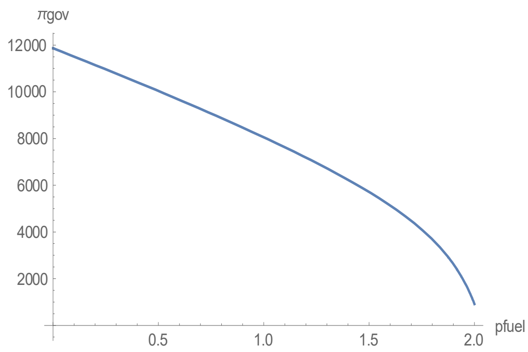

Figure 6: Oil price vs total profit.

Total profit decreases with increasing oil prices between approximately 0 and 2.

Figure 7 shows the image of total profit as a function of electricity price at an oil price of 1.

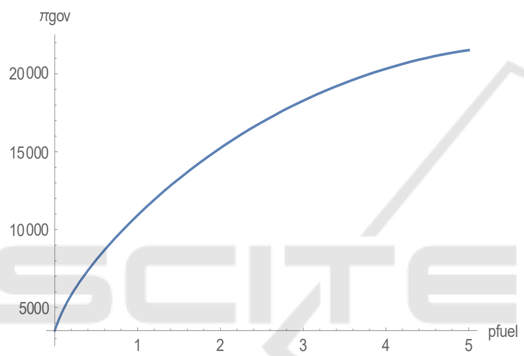

Figure 7: Electricity price vs total profit.

As can be seen, total profit increases with the price of electricity between approximately 0 and 5. Finally, we discuss the effect of the coefficients of C_n and C_p on total profit.

Figure 8 shows the effect of b_p on total profit when b_n is 3 while Figure 9 shows the effect of b_n on total profit when b_p is 4. (b_p is equal to 4 to ensure that the value of C_n is greater than 0).

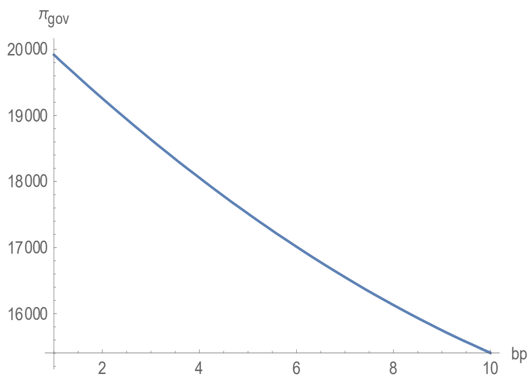

Figure 8: The effect of b_p on total profit when b_n is 3.

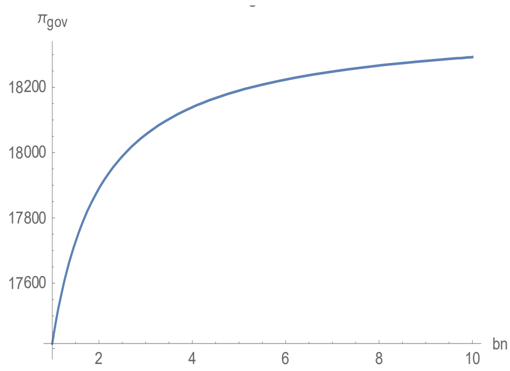

Figure 9: The effect of b_n on total profit when b_p is 4.

The larger the b_p(Factor to adjust the ratio of C_n to C_p), the larger theC_n, the greater the penalty for producing fuel cars, and the lower the total social profit. The larger the b_n(Factor to adjust the ratio of C_n to C_p), the smaller the C_n,the smaller the penalty for producing fuel cars, and the higher the total social profit. We can optimize the total social profit by appropriately adjusting the ratio of $C_p$to C_n.

4 CONCLUSION

This paper examines the profits of car manufacturers and the impact of each factor on total profits under the CAFC and NEV credit policy. We have the following conclusions:

(1) The effect of C_p and C_n on total profit is a quadratic function, there is an optimal value of C_p and C_n that maximises total profit. For the government, the policy of double points should be stipulated according to the market conditions to maximize the total social profit. In the examples in this paper, the optimal values for C_p and C_n are 1.4685 and 0.2913, the car manufacturer should deduct 0.2913 credits for the production of a fuel car and add 1.2865 credits for the production of an electric car.

(2) The effect of m_n and m_p on total profit is also a quadratic function. In order to increase the proportion of electric vehicles, we should improve the utility it brings to consumers, such as raising oil prices, reducing electricity charges or giving more incentives to C_p, which can better increase the proportion of electric vehicles.

(3) For the market, the specific pricing of $C_p$andC_n will be affected by the proportion of fuel vehicles and electric vehicles. This simplifies the quantitative relationship between them. In combination with the above discussion on oil price, electricity price and

annual environmental treatment cost to the total social profit, the current domestic oil price is generally too high, the electricity price is relatively cheap, and the annual environmental treatment cost is high. Therefore, it is necessary to support the development of electric vehicle enterprises and punish the fuel vehicle enterprises. In combination with the national carbon neutral policy and from the perspective of long-term development, it is necessary to punish electric vehicles. Although this punishment will affect the total social profit in the short term, it is necessary in the long term.

To summarise, this paper expands on the application of CAFC and NEV credit in the automotive sector and can provide a reference for those in this industry. We hope to complete the structural transformation of the automobile industry, promote the development of new energy vehicles, help achieve carbon neutrality and achieve sustainable social development by implementing CAFC and new energy automobile credit. In the future, we will discuss in more depth the impact of the CAFC and NEV policy on other parts of electric vehicles, especially on the battery industry.

ACKNOWLEDGEMENT

This research is funded by project supported by the National Science Foundation (Grant No. 71901121, 71972101, 71931006); and Support by Fundamental Research Funds for the Central Universities (Grant No. 30919013202).

REFERENCES

Gu X , Ieromonachou P , Li Z . A game theory approach in subsidizing electric vehicle supply chain[C]// 2016 International Conference on Logistics, Informatics and Service Sciences (LISS). IEEE, 2016.

Li Y, Zhang Q, Li H et al (2019) The impact of Dual-credit Scheme on the Development of the New Energy Vehicle Industry. Elsevier Ltd, Hong Kong, China

Ma, H., Lou, G., Fan, T., Chan, H. and Chung, S., 2022. Conventional automotive supply chains under China's dual-credit policy: fuel economy, production and coordination.

Ou S, Lin Z, Qi L et al (2018) The dual-credit policy: Quantifying the policy impact on plug-in electric vehicle sales and industry profits in China. Energy Policy 121:597–610

Wang, Y., Zhao, F., Yuan, Y., Hao, H. and Liu, Z., 2022. Analysis of Typical Automakers' Strategies for Meeting the Dual-Credit Regulations Regarding CAFC and NEVs.

Yin, Y., Zhan, Z. (2021). Research on "Dual-Credits" Policy of Automobile Enterprises. In: Proceedings of China SAE Congress 2019: Selected Papers. Lecture Notes in Electrical Engineering, vol 646. Springer, Singapore.

Yang, DX., Yang, L., Chen, XL. et al. Research on credit pricing mechanism in dual-credit policy: is the government in charge or is the market in charge?. Environ Dev Sustain (2022).

Yu, Y., Zhou, D., Zha, D., Wang, Q. and Zhu, Q., 2021. Optimal production and pricing strategies in auto supply chain when dual credit policy is substituted for subsidy policy.

Liu, D., Xiao, B. 2018. Exploring the development of electric vehicles under policy incentives: A scenario-based system dynamics model, Energy Policy, vol. 120, pp. 238-249.

Diwu. S, Zhang. X, 2016. Dual-channel ordering strategy of new energy vehicles, 2016 International Conference on Logistics, Informatics and Service Sciences (LISS), 2016, pp. 1-5.

Xu. X, Tao. R, 2021. Study on Supply Chain Pricing Strategy of Government-Subsidized Manufacturers. 2021 5th Annual International Conference on Data Science and Business Analytics (ICDSBA), 2021, pp. 554-559.