Carbon emission reduction strategy of road freight firm under carbon cap and trade

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Abstract. In order to implement the carbon emission reduction strategy of road freight transportation, this paper considers the scheme of using electric vehicles to replace fuel vehicles under the carbon cap and trade mechanism. We establish three types of models, including fuel vehicles, electric vehicles without subsidies, and electric vehicles with subsidies. We point out that compared with fuel vehicles, when the carbon trade price is too high, electric vehicles are more conducive to improve the income of logistics enterprises. In addition, we also find that as long as the government subsidy reaches a certain amount, the profits of enterprises using electric vehicles will be more than those using fuel vehicles.

Keywords: Carbon cap and trade; Road freight; Electric vehicle; Subsidy

1 Introduction

Carbon cap and trade mechanism is one of the important means to reduce carbon emissions, which has played an important role in the past decades. Scholars have put forward many suggestions on supply chain decision-making under this regulation [1], but few suggestions on logistics enterprises under the constraints of this mechanism.

In order to implement the low-carbon strategy, the most direct way for road freight enterprises is to replace fuel vehicles (FV) with electric vehicles (EV) for transportation. In addition, for enhancing the determination of enterprises to reduce carbon emissions, the government has proposed a subsidy policy for carbon emission reduction. At this time, scholars considered the carbon emission reduction decision under government subsidies from multiple perspectives [2-4]. These strategies provide a reference for us to consider low-carbon subsidies, but these results still do not involve the problem of road freight enterprises replacing FV with EV.

Based on this, considering the carbon emission reduction decision-making of road freight enterprises, this paper starts with the use of FV and EV, and introduces subsidies to discuss the conditions for using EV.

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2 Assumption

We consider that manufacturer transport products through logistics enterprise. The selling price is p Yuan per product and the freight rate is w Yuan/kg-km. Market demand is $a-bp>0$, where a is the potential quantity of the products, b is the price sensitivity. The weight of single product is m kg. The transportation distance is D km.

Constrained by carbon cap and trade regulation, road freight enterprise need to pay the excess carbon emissions with the carbon trading price of c_e Yuan/kg when exceeding the carbon cap $\bar{e}$ kg. When carbon emissions quota is lower than $\bar{e}$, there are two options to deal with the unused carbon emission quota. First, the government directly subsidy γ Yuan/kg of unused carbon emissions quota. The other is that, with the permission of the government, enterprise sells to carbon trading market.

When applying the fuel vehicle, the fuel expense is c_o Yuan/L, the oil consumption is α L/kg-km, the weight of the vehicle itself is Q_o kg and the rated load is q_o kg. The carbon emission coefficient is e_o kg/L. When applying EV, the electric charge is c_n Yuan/ kWh, the power consumption is β kWh/kg-km, the weight of the vehicle itself is Q_n kg and the rated load is q_n kg. The integer function $[\frac{m(a-bp)}{q_o}]+1$ and $[\frac{m(a-bp)}{q_n}]+1$ represent the number of FV and EV, respectively.

If enterprise adopts EV, she will buy each EV c_b Yuan , and she will dispose of each FV to earn an income of s Yuan. Moreover, firm can get subsidy v Yuan of each EV purchasing or subsidy λ Yuan of each kg-km transported goods from the government. In addition, π represent to the expected profit of road freight enterprise.

3 Models

This section only considers the problem of one-time transportation by road freight enterprise, and does not consider the multiple transportation.

3.1 No carbon cap and trade policy

When using the fuel vehicle, the expected profit of road freight enterprise is

$$\pi^1 = \text{Transportation income - fuel cost} = wm(a-bp)D - c_o\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D. \quad (1)$$

3.2 Carbon cap and trade policy

When using the fuel vehicle, the expected profit of road freight enterprise is

$$\pi^2 = \text{Transportation income- fuel cost- carbon cap and carbon trading}$$
$$= wm(a-bp)D - c_o\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D - c_e(e_o\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D-\bar{e}). \quad (2)$$

Since $\pi^2 < \pi^1$, it shows that carbon cap and trade policy increase the burden of enterprise, thus enterprise may adopt EV to alleviate this dilemma.
When using the electric vehicle, the expected profit of road freight enterprise is

$$\pi^3 = \text{Transportation income - electricity fee+(income of selling FV-cost of purchasing EV)}$$
$$\text{+income of carbon trading} \quad (3)$$
$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + (s-c_b)([\frac{m(a-bp)}{q_n}]+1) + c_e\bar{e}.$$

3.3 Carbon cap and trade policy with subsidy

Subsidy to unused carbon emissions quota.

$$\pi^4 = \text{Transportation income- electricity fees+(income of selling FV -cost of purchasing EV)}$$
$$\text{+ subsidy to unused carbon emission quota} \quad (4)$$
$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + (s-c_b)([\frac{m(a-bp)}{q_n}]+1) + \gamma\bar{e}.$$

Subsidy for purchasing of EV.

$$\pi^5 = \text{Transportation income-electricity fee+income of carbon trading}$$
$$\text{+(income of selling FV-cost of purchasing EV+subsidy for purchaisng EV)} \quad (5)$$
$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + c_e\bar{e} + (s-c_b+v)([\frac{m(a-bp)}{q_n}]+1).$$

Subsidy to transported goods.

$$\pi^6 = \text{Transportation income -electricity fee + (income of selling FV - cost of buying EV)}$$
$$\text{+ income of carbon trading+subsidy to transported goods} \quad (6)$$
$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + (s-c_b)([\frac{m(a-bp)}{q_n}]+1) + c_e\bar{e} + \lambda m(a-bp)D.$$

Subsidy to unused carbon emissions quota and subsidy for purchasing of EV.

$$\pi^7 = \text{Transportation income -electricity fee +susidy to unused carbon emission quota}$$
$$\text{+(income of selling FV -cost of purchasing EV+subsidy for purchaisng EV)} \quad (7)$$
$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + \gamma\bar{e} + (s-c_b+v)([\frac{m(a-bp)}{q_n}]+1).$$

Subsidy to unused carbon emissions quota and subsidy to transported goods.

π^8 = Transportation income -electricity fee +(income of selling FV - cost of buying EV) +subsidy to carbon emission quota+subsidy to transported goods

$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + (s-c_b)([\frac{m(a-bp)}{q_n}]+1) + \gamma\bar{e} + \lambda m(a-bp)D. \tag{8}$$

Subsidy for purchasing of EV and subsidy to transported goods.

π^9 = Transportation income -electricity fee +carbon trading income+subsidy to transported goods + (income of selling FV- cost of buying EV+susidy for purchasing EV) (9)

$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + c_e\bar{e} + \lambda m(a-bp) + (s-c_b+v)([\frac{m(a-bp)}{q_n}]+1).$$

Subsidy to unused carbon emissions quota, transported goods and purchase EV.

π^{10} = Transportation income-electricity fee + (income of selling FV- cost of buying EV+susidy for purchasing EV) +subsidy to carbon emission quota+subsidy to transported goods (10)

$$= wm(a-bp)D - c_n\beta([\frac{m(a-bp)}{q_n}]+1)(Q_n+q_n)D + (s-c_b+v)([\frac{m(a-bp)}{q_n}]+1) + \gamma\bar{e} + \lambda m(a-bp)D.$$

4 Results analysis

Theorem **1** $\pi^3 > \pi^2$ *if* $c_e > \dfrac{(c_n\beta D(Q_n+q_n) - s + c_b)([\frac{m(a-bp)}{q_n}]+1)}{e_o\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D} - \dfrac{c_o}{e_o}$.

Theorem 1 reflects that under the constraints of carbon cap and trade, road freight enterprise does not directly use electric vehicles to replace fuel vehicles to obtain more profits. Only when the price of carbon trading is too high, changing cars will reduce the cost of carbon trading for enterprises, which will increase the profit of enterprise. At this time, enterprise is willing to buy electric vehicles.

Theorem 2 $\pi^5 > \pi^2$ *if* $v > c_n\beta(Q_n+q_n)D - s + c_b - (c_o + c_e e_o)\alpha \dfrac{[\frac{m(a-bp)}{q_o}]+1}{[\frac{m(a-bp)}{q_n}]+1}(Q_o+q_o)D.$

$\pi^4 > \pi^2$ and $\pi^7 > \pi^2$ *if* $\gamma > \gamma_1$ *where,*

$$\gamma_1 = \frac{(c_n\beta(Q_n+q_n)D - s + c_b)([\frac{m(a-bp)}{q_n}]+1) - (c_o+c_e e_o)\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D}{\bar{e}} + c_e.$$

$\pi^6 > \pi^2$, $\pi^8 > \pi^2$, $\pi^9 > \pi^2$ and $\pi^{10} > \pi^2$ *if* $\lambda > \max\{\lambda_1, \lambda_2\}$ *where,*

$$\lambda_1 = \frac{(c_n\beta(Q_n+q_n)D - s + c_b)([\frac{m(a-bp)}{q_n}]+1) - (c_o + c_e e_o)\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D}{m(a-bp)D}.$$

$$\lambda_2 = \frac{(c_n\beta(Q_n+q_n)D - s + c_b)([\frac{m(a-bp)}{q_n}]+1) - (c_o + c_e e_o)\alpha([\frac{m(a-bp)}{q_o}]+1)(Q_o+q_o)D + (c_e-\gamma)\bar{e}}{m(a-bp)D}.$$

Theorem 2 reflects that under the carbon cap and trade mechanism, as long as the government gives certain subsidies to help enterprise overcome difficulties, enterprise is willing to adopt electric vehicles.

5 Numerical investigations

This section applies light truck car transaction data to investigate the significance of management aspects. We examined the two light trucks of FAW Jiefang. They are both 4.2 meters long and have a total vehicle load of 4.495 tons. Among them, the one burning diesel is "Jiefang tiger V", and its parameters are $c_o = 8.22$ Yuan/L, $\alpha = 0.000034$ L/kg-km, $Q_o = 2805$ kg, $s = 110000$ Yuan, $e_o = 2.7$ kg/L, $k = 2$. The other is "Jiefang J6F" electric vehicle and its parameters are $c_n = 1$ Yuan/kWh, $\beta = 0.00016$ kWh/kg-km, $Q_n = 2995$ kg, $c_b = 198000$ Yuan, $v = 50000$ Yuan, $d = 2$. The other parameters are $\bar{e} = 50$ kg, $b = 1$, $a = 1000$, $\lambda = 0.001$ Yuan/kg, $c_e = 0.0585$ Yuan/kg, $\gamma = 0.03$ Yuan/kg, $m = 0.5$ Yuan/kg-km $w = 0.005$ Yuan/kg-km and $p = 10$ Yuan.

Changing c_e, we can obtain that $\pi^1 = 562.235$ Yuan, $\pi^2 = 562.235 - 9.211c_e$ Yuan, and $\pi^3 = 50c_e - 87360.7$ Yuan. It reflects that carbon cap and trade policy forces enterprises to implement emission reduction strategies due to $\pi^2 < \pi^1$. It also reflects that $\pi^3 > \pi^2$ if c_e>1758.46 Yuan. This indicates that the enterprise will replace FV with EV only when the carbon trading price at a high value. Here, it is obviously impossible, because the carbon trading price is required to exceed thousands Yuan/kg. Therefore, enterprises need to seek help from the government in order to make a living.

Changing v, we can obtain that $\pi^2 = 562.182$ Yuan, and $\pi^5 = v - 87360.4$ Yuan. It reflects that $\pi^5 > \pi^2$ if v>87360.4 Yuan. This indicates that the enterprise will replace FV with EV only when the subsidy for purchasing EV is very high at the carbon cap and trade policy.

Changing γ, we can obtain that $\pi^2 = 562.182$ Yuan, $\pi^4 = 50\gamma - 87360.7$ Yuan, $\pi^7 = 50\gamma - 37360.7$ Yuan. It reflects that $\min\{\pi^4, \pi^7\} > \pi^2$ if γ> 1758.46 Yuan/kg.

Changing γ, it holds that $\pi^2 = 562.182$ Yuan, $\pi^6 = 148500\lambda - 87360.4$ Yuan, $\pi^8 = 148500\lambda - 87360.6$ Yuan, $\pi^9 = 148500\lambda - 37360.4$ Yuan, $\pi^{10} = 148500\lambda - 37360.5$ Yuan. It reflects that $\min\{\pi^6, \pi^8, \pi^9, \pi^{10}\} > \pi^2$ if λ> 0.592072 Yuan/kg-km.

All the above results reveal a truth. That is, from the economic perspective, if the government wants to promote road freight enterprises to accelerate the implementation of carbon emission reduction, he needs to invest huge subsidies to help enterprises tide over the difficulties. Otherwise, even if it is limited by the carbon cap and trade mechanism, the enterprises would rather use fuel vehicles than electric vehicles.

6 Conclusion

Under the carbon cap and trade mechanism, this paper establishes three models including fuel vehicles, electric vehicles without subsidies and electric vehicles with subsidies. The results are as follows:

Firstly, when the carbon trading price is too high, electric vehicles are more conducive to improving the income of logistics enterprises. Secondly, it is found that as long as the government subsidy reaches a certain amount, the profits of enterprises using electric vehicles will be higher than those using fuel vehicles.

A managerial insight is that we encourage logistics enterprises to use electric vehicles for transportation under the case of high carbon trade prices. We suggest that enterprises seize the dividends of government subsidies and accelerate the pace of electric vehicles replacing fuel vehicles.

In reality, it is impossible for an enterprise to carry out transportation only once, and it is also impossible to have only one road freight enterprise. Therefore, in the future, we can consider the issue of multiple transportation of goods and the competition of multiple logistics enterprises.

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