Post-print version of the paper by Journal of cleaner production 210 (2019): 1281-1288.
https://doi.org/10.1016/j.jclepro.2018.11.124

The Government Regulation and Market Behavior of the New Energy Automotive Industry

Dong-xiao Yang[1], Lin-shu Qiu[2], Ming-xing Jiang[3], Zi-yue Chen[4], Jian-jun Yan[1*]

1. Collage of Economics and Trade, Hunan University of Commerce, Changsha, 410205, P.R.China; ydx622@foxmail.com

2. Hunan University of Commerce, Changsha, 410205, P.R.China; shu0223@foxmail.com

3. Institute of Industrial Economics, Jinan University, Guangzhou, 510632, P.R.China; 18620857820@163.com

4. School of Management, Xiamen University, Fujian, 361005, P.R.China; czy_0077@126.com

* Correspondence: yjjyzt75@163.com; Tel: +86-13875991701

Abstract: Environmental issues and cleaner production are getting increasing attentions currently, making the clean production and sustainable consumption with low emissions significant. Traditional energy vehicles are increasingly unsuitable for the development of current society. It's a trend in the current vehicle market to accelerate the substitution of new energy vehicles for traditional energy vehicles. This paper makes a theoretical study on the development of new energy vehicle market supported by the government. First, this paper establishes a Cournot duopoly model which includes domestic and imported new energy vehicle manufacturers. Through the analysis of this model, this paper argues that government support policies such as subsidies and tariffs can effectively expand the market share of domestic new energy vehicles with less technology. Yet this approach is unsustainable, because domestic new energy vehicles with less technology can only survive in the market by shortening the gap with imported brands. Secondly, this paper establishes a Stackelberg model with product price as the decision variable and find that when there is a technical gap, the first mover advantage in the market will no longer exist. Finally, this paper compares two kinds of subsidies for domestic new energy vehicles and believes that the two subsidies are not different from subsidizing consumers or enterprises in expanding market share, and the consumer can obtain higher social welfare level as the subsidy object.

Keywords: new energy vehicle, governmental regulation, Stackelberg model, social welfare

1.Introduction

Automotive industry is the important pillar of national economy and social development of China. In the past ten years, China's automotive production and ownership have been developing fleetly with the rapid development of economy and the acceleration of urbanization. The vehicle has entered the life of ordinary people from the symbol of luxury and status, becoming an indispensable part of contemporary Chinese families. The number of road vehicles in China has increased 26 times over the past 25 years (Wu, Zhang and Hao, 2017). From the automotive industry development experience of developed countries, the rigid demand and consumption upgrade of the automotive industry will drive the rapid growth of vehicle sales in China for a long time in the future. As a country with a population of 1.4 billion, China’s energy intensity and environmental problems will be more prominent in the process of speeding up entering the family. The international energy agency (IEA) reported that China’s highway transport sector emitted 618 million tons of carbon dioxide, which is more than 10% percent of China’s total carbon dioxide emissions, or about 2 percent of the world’s total fossil fuel emissions. Forecasts suggest that China's highway traffic will have between 1.2 and 1.7 billion tons of carbon dioxide emissions by 2030 if vehicle ownership continues to grow unchecked (He et al., 2005; Yan et al., 2009; Huo et al., 2012). So far, the haze has begun to plague many cities in China. As the "backbone force" of smog, excessive emission of exhaust has been criticized by all sectors of society and controlling carbon emissions has become an important issue in environmental protection of all countries in the world (Jiang and Yang, 2016; Yang et al., 2018). Researchers from different countries focuses on new energy automotive industry due to the characteristics of zero emission (Dhar et al., 2017; Choma and Ugaya, 2015; Fernández, 2018). Especially since the 2015 government work report meeting, Premier Li Keqiang has repeatedly mentioned that the promotion of new energy vehicles should be strengthened. So, to speed up the cultivation and development of new energy vehicles, not only can effectively reduce the pressure on energy and the environment, is also a solution to the contradiction between people's yearning for a better environment and the environmental degradation. At present, the development of new energy vehicles has become a consensus among governments, enterprises and the public.

However, in the early phase of development, new energy vehicles faced several big problems, which made it impossible to compete with traditional energy vehicles in the market, including: 1. Charging is difficult. In the case of lagging charging facilities in China, charging is a big problem for electric vehicles. The lack of public charging piles has seriously affected the travel. 2. Short range. Limited by battery technology, most of all-electric vehicles has only 100 to 200 kilometers range now, this phenomenon is evident in relatively backward technology of domestic new energy vehicle brands. 3. Charging is slow. At present, most charging piles have low charging efficiency. It generally takes 6 to 8 hours to fill a vehicle, which costs more time than traditional energy vehicles. 4. After-sales service needs to be strengthened. Although the structure of electric vehicle is more simple than traditional energy vehicle, with the greater difference between the structure of power output part of electric and traditional energy vehicles, electric vehicles are not as easy to maintain and repair as traditional energy vehicles.

Therefore, the new energy vehicle is similar to the new energy electric power industry which must rely on government support in its early development (Yang and Nie, 2016). China's new energy automotive industry was developed in a government-led way in the early stage of its development. As early as 2001, relying on the national high-tech research and development plan (863), a special plan for electric vehicles has launched, the industrial development layout of China’s “three vertical and three horizontals" was determined. Since 2009, China has promulgated the "Notice on carrying out the pilot work of demonstration and promotion of energy-saving and new-energy vehicles", and China has started to promote the production of new energy vehicles led by government. Today, although the intensity of subsidies has decreased, there is no denying that government support has played a vital role in the development of the new energy automotive industry.

Nowadays, there are many different types of vehicles in the market, and the choice behavior of consumers in the market has always been the focus of scholars. Many scholars have studied the choice behavior to different kinds of vehicles based on the cost to use of vehicles. Plotkinand Singh (2009) compares the cost of using the new power system of several light vehicles that replaced the original traditional energy engine, have come to a conclusion that advanced CV and HEV power systems may provide better cost effectiveness by fuel savings. Based on similar methods, Burke and Zhao (2012) put the uncertainty of battery life into the study and estimate the use-cost of the electric engine which could replace the vehicle power system in 2030. Peterson and Michalek (2013) estimate the cost-effectiveness of battery capacity in the plug-in hybrid electric vehicle system and find that PHEV and HEV with low battery capacity are more favorable solutions. The discussion on the role of the government in promoting the development of new energy vehicles has not stopped in academic circles. There are many studies on the influence of government incentives on consumer behavior. Ross Morrow et al. (2010) compare policies such as fuel tax, fuel economy standard and vehicle purchase tax, and they believe that excessive vehicle purchase tax will reduce the reduction efficiency. Skerlos and Winebrake (2010) claim in their research that when consumers buy vehicles in certain subsidized areas, higher social welfare will be generated. Through the establishment of a two-stage model of individual decision, Mueller and DE Haan (2009) analyze the impact of the reduction of energy efficiency on consumer's choice of different types of vehicles, they believe that consumers would have different views on vehicle consumption and will choose one of the smaller vehicles or more efficient vehicles. Al Alawi and Bradley (2013) study the existing electric vehicle market by establishing the model, they think that only solving the policy difference between state and local have significant positive influence on automotive market. And Yang (2010) believes that subsidies alone are not enough to commercialize electric vehicles, and it may be more effective to restrict conventional vehicles.

At the level of government regulation of new energy vehicles, many scholars have discussed the promotion methods of renewable energy vehicles from different regulatory policies. However, there is little attention paid to consumer preferences and different market situations. Based on this, this paper take consumer demand preference as the starting point, discusses the implementation effect of government regulation means (subsidy and tariff). In this paper, it is considered that the subsidy and tariff can be used to promote the development of domestic new energy automotive industry in a short period of time, but such policies are not sustainable. Secondly, this paper has analyzed the impact on the market caused by the different entry times of imported new energy vehicle brands with advanced technology and domestic new energy vehicle brands with relatively backward technology and find that the first-mover advantage will disappear in the presence of technology gap. Finally, this paper has discussed the problem that the subsidy object should be the consumer or enterprise and find that to improve the level of social welfare, subsidy for consumer is a better way.

This research not only contributes to formulating development strategy by new energy vehicle producers but also benefits on formulating the development policy of the new energy automobile industry by the government. From the perspective of new energy vehicle producers, it is pivotal to increase the share of the market by improving the quality of the product rather than reducing the price like most producers did in traditional industries. From the perspective of policy makers, we believe that subsidies on consumers are better than subsidies on producers according to the research.

The main chapters of this paper are arranged as follows: The second part is the establishment of the basic model, introduces the relevant parameters of government regulation into the model, then analyzes the behavior of government regulation. In the third part, a Stackelberg model with price as the decision variable is established, then analyzes the two market situations of domestic new energy vehicles entering the market first or later. The fourth part compares and analyzes various economic parameters of the two modes of subsidy, consumer subsidy and enterprise subsidy. Conclusions are remarked in the final section.

2.Basic model

In this article, the model on new energy vehicles are based on Cournot Model and Stackelberg Model, which are widely applied in analyzing government regulation on the development of energy power industry, including subsidies (Yang, Chen and Nie, 2016), carbon tax (Chen and Nie, 2016), emission permits allocation (Jiang, Yang and Chen, 2016), and related insurance (Nie, Wang and Chen, 2017). Due to the similarity between new energy vehicle industry and renewable energy power industry, we analyze the new energy automobile industry based on the former methods. In our model, we focus on the difference between new energy vehicle industry and renewable energy power industry, the heterogeneity of products and the choice behavior of consumers.

This paper assumes that there are domestic and imported new energy vehicles on the market. The variables in the model are shown as follows.

u_1 - The utility of consumers buying domestic new energy vehicles,

u_2 - The utility of consumers buying imported new energy vehicles,

u_0 - The basic utility of new energy vehicles,

Δu - The additional utility of imported new energy vehicles,

θ - Consumers' sensitivity to the added utility of imported new energy vehicles,

p_1 - The price of domestic new energy vehicles

p_2 - The price of imported new energy vehicles

q_1 - The production of domestic new energy vehicles

q_2 - The production of imported new energy vehicles

π_1 - Profit of domestic new energy auto manufacturers

π_2 - Profit of imported new energy auto manufacturers

c_1 - Production cost of domestic new energy vehicles

c_2 - Production cost of imported new energy vehicles

s - Government subsidies for production of domestic new energy vehicles

t - Tariffs on imported new energy vehicles

cs - Consumer surplus

The utility of two types of new energy vehicles selected by consumers who have a preference for new energy vehicles are u_1 and u_2 respectively, where the utility functions are

$$\begin{cases} u_1 = u_0 - p_1 \\ u_2 = u_0 + \Delta u\theta - p_2 \end{cases} \tag{1}$$

Where u_0 is the basic utility of two types of vehicles and satisfies the general demand of consumers for driving; Δu is additional utility for consumers due to the advantages of advanced technology, superior design sence and other advantages of imported new energy vehicles, and $\Delta u > c_2 - c_1$, where c_1 and c_2 are respectively the production costs of domestic new-energy vehicles and imported new-energy vehicles; p_1, p_2 are the prices of domestic and imported new energy vehicles; θ is the random variable representing the sensitivity of consumers to the additional utility of imported new energy vehicles, and the density function of random variable θ is uniformly distributed on (0,1), i.e:

$$f(\theta) = \begin{cases} 1, 0 < \theta < 1 \\ 0, others \end{cases} \tag{2}$$

It is obvious that when $u_1 > u_2$, consumers prefer to choose domestic new energy vehicles, on the contrary, they choose to import new energy vehicles. As can be seen from equation (1), when the sensitivity of consumers $\theta < \frac{p_2 - p_1}{\Delta u}$ they will choose domestic new energy vehicles and when the sensitivity of consumers $\theta > \frac{p_2 - p_1}{\Delta u}$, they will choose imported new-energy vehicles. According to equation (2), the sales volume of two different types of new energy vehicles is:

$$\begin{cases} q_1 = \int_0^{\frac{p_2 - p_1}{\Delta u}} f(\theta) d\theta = \frac{p_2 - p_1}{\Delta u} \\ q_2 = \int_{\frac{p_2 - p_1}{\Delta u}}^1 f(\theta) d\theta = \frac{\Delta u + p_1 - p_2}{\Delta u} \end{cases} \tag{3}$$

It can be seen from (3) that the profit functions of the two types of new energy vehicles are:

$$\begin{cases} \pi_1 = (p_1 - c_1) \frac{p_2 - p_1}{\Delta u} \\ \pi_2 = (p_2 - c_2)(\frac{\Delta u + p_1 - p_2}{\Delta u}) \end{cases} \tag{4}$$

In equation (4), c_1 and c_2 are respectively the production costs of two types of new energy vehicles. It is obvious that the profit function of two types of new energy vehicles is the concave function of price, from the first-order conditions, it can be seen that:

$$\begin{cases} \frac{\partial \pi_1}{\partial p_1} = \frac{p_2 - p_1}{\Delta u} - \frac{p_1 - c_1}{\Delta u} = 0 \\ \frac{\partial \pi_2}{\partial p_2} = \frac{\Delta u - p_2 + p_1}{\Delta u} - \frac{p_2 - c_2}{\Delta u} = 0 \end{cases} \tag{5}$$

The solution of combined vertical (5) can be obtained:

$$\begin{cases} p_1^* = \dfrac{\Delta u + 2c_1 + c_2}{3} \\ p_2^* = \dfrac{2\Delta u + c_1 + 2c_2}{3} \end{cases} \tag{6}$$

The equation (6) shows that in the case of perfectly competitive market with no government intervention, the equilibrium price of the imported new energy vehicles is affected not only by the cost, also by the additional utility caused by its superior quality and both products of two types new energy vehicles manufacturers will be affected by price spillovers from their competitors. Although the equilibrium price of the products of the two types of vehicles manufacturers is affected by the production cost of the competitors, the degree of influence is smaller than that of their own costs. When the production cost of domestic new energy vehicles is relatively close to that of imported new energy vehicles, the additional utility of imported new energy vehicles will significantly increase the price differences between imported and domestic new energy vehicles.

Substituting equation (6) into equation (3), it can be obtained that the output of domestic new energy vehicles and imported new energy vehicles are respectively:

$$\begin{cases} q_1^* = \dfrac{\Delta u - c_1 + c_2}{3\Delta u} \\ q_2^* = \dfrac{2\Delta u + c_1 - c_2}{3\Delta u} \end{cases} \tag{7}$$

Proposition 1: in a perfectly competitive market, the increase of the additional utility value of imported new energy vehicles can increase the market share of imported brands.

According to equation (7), it can be seen that $\begin{cases} q_1^* = \frac{1}{3} - \frac{c_1 - c_2}{3\Delta u} \\ q_2^* = \frac{2}{3} + \frac{c_1 - c_2}{3\Delta u} \end{cases}$, and on the basis of the reality, although the imported new energy vehicles has a higher level of production technology, at the same time, its also has a higher labor costs in the process of production, and expensive overseas transport costs, so the production cost of the imported new energy vehicles is higher than the domestic new energy vehicles, that is $c_1 - c_2 < 0$. Therefore, when the higher quality of imported new energy vehicles is than that of domestic new energy vehicles, the more market share it will gain. So in the process of market competition between domestic and imported new energy vehicles, it is almost impossible to improve market share just by price war, the only way out of domestic brands is to improve its product quality, narrow the gap between their and imported products.

By substituting equation (6) (7) into equation (4), the profit functions of the two types of new energy vehicles enterprises are:

$$\begin{cases} \pi_1^* = \frac{(\Delta u - c_1 + c_2)(\Delta u + 2c_1 + c_2)}{9\Delta u} \\ \pi_2^* = \frac{(2\Delta u + c_1 - c_2)(2\Delta u + c_1 + 2c_2)}{9\Delta u} \end{cases} \quad (8)$$

By the profit function (8), the market share and price of imported new energy vehicles are higher than that of domestic new energy vehicles, so in the competition of producer surplus, imported brands is still far ahead of domestic brands. Moreover, it can be seen from equation (11) and (12) that the conclusion shown in proposition 1 is also true for the perfectly competitive market under government intervention.

When tariffs are imposed on domestic new energy vehicles and subsidies are imposed on imported new energy vehicles, the profit function of the two types of enterprises is:

$$\begin{cases} \pi_1^e = (p_1 - c_1 + s)\dfrac{p_2 - p_1}{\Delta u} \\ \pi_2^e = (p_2 - c_2 - t)(\dfrac{\Delta u + p_1 - p_2}{\Delta u}) \end{cases} \tag{9}$$

The subsidy for domestic new energy vehicles described in this paper is the most widely used production subsidy (Yang, Chen and Nie, 2016), in terms of s, t is the tariff imposed on imported new energy vehicles. At this time, the first-order condition for profit maximization is:

$$\begin{cases} \dfrac{\partial \pi_1^e}{\partial p_1} = \dfrac{p_2 - p_1}{\Delta u} - \dfrac{p_1 - c_1 + s}{\Delta u} = 0 \\ \dfrac{\partial \pi_2^e}{\partial p_2} = \dfrac{\Delta u - p_2 + p_1}{\Delta u} - \dfrac{p_2 - c_2 - t}{\Delta u} = 0 \end{cases} \tag{10}$$

The equilibrium price is:

$$\begin{cases} p_1^{e*} = \dfrac{\Delta u + 2c_1 + c_2 + t - 2s}{3} \\ p_2^{e*} = \dfrac{2\Delta u + c_1 + 2c_2 + 2t - s}{3} \end{cases} \tag{11}$$

The equilibrium output is:

$$\begin{cases} q_1^{e*} = \dfrac{\Delta u - c_1 + c_2 + t + s}{3\Delta u} \\ q_2^{e*} = \dfrac{2\Delta u + c_1 - c_2 - t - s}{3\Delta u} \end{cases} \tag{12}$$

Proposition 2: in a perfectly competitive market, the production scale of domestic new energy vehicles can be expanded either through subsidies to domestic new energy vehicles or through tariffs on imported new energy vehicles.

Today, with the rapid development of vehicle technology, the automotive industry especially the new energy automotive industry, is a new industry that has not yet developed and matured in some backward countries. For the time being, it is not able to compete with the more developed foreign similar industries. However, the new energy automotive industry still enjoys a demographic dividend in China and has great market development potential. Moreover, the automotive industry, as the largest machinery manufacturing industry, has a large industrial correlation, which is closely related to the development of many domestic industries and has positive externalities for these industries. Based on the above two points, the subsidy to the domestic new energy automotive industry with backward technology and the tariff on imported new energy automotive brands will help increase the market competitiveness and market share. However, although in theory, the theory of protecting infant industry has its rationality and has a positive side to the domestic economy, the implementation effect in reality remains to be discussed. The protection of infant industries is effective because it can help improve the efficiency and enhance the market competitiveness. But in many cases, subsidies will cause great pressure on government finance (Li et.al, 2017), in addition subsidies are still facilitating the inefficient development of the industry. Once the protection is gone, the industry will also be destroyed by competition from similar foreign industries. Combined with proposition 1, although the establishment of trade barriers has increased the market share of domestic new energy vehicles, the brand difference between domestic and imported products cannot be narrowed. The technology differences between two types of brands still exist, as long as unable to reduce or eliminate the additional effects of domestic and imported new energy vehicles, the domestic brands must constantly rely on the government's policy support, once the support weaken or eliminate will cause huge impact.

3. The competitive strategy of the Stackelberg model

In the dynamic competitive market of new energy vehicle, the two oligarchs are often a stronger and weaker, whether determining production or setting price, the weaker always tend to follow the stronger, observe their actual actions, and then formulate their own strategies. For most countries with developed automotive industry, the development of new energy vehicles starts early, and its brand has a high technical level. For such countries, it is difficult for new energy vehicles of foreign brand to compete with local brands in the domestic market, so this paper does not discuss the new energy vehicle market of such countries. For the country whose technical level is relatively backward, based on the foreign trade policy formulation of different government, some countries set a high threshold for foreign brands before their own brands have a certain scale, other countries have recognized the free trade of the new energy automotive industry from the very beginning, so that the imported brands have a place in the domestic market first. Based on these two different market situations, this section will analyze the situation when the imported brand and the domestic brand are the first to go respectively.

Assume that domestic new energy vehicles enter the market first, because the sales volume of two types of brands is determined by the different distribution of consumer preferences, so in this paper, the decision variables of Stackelberg model market situation is commodity prices. In this case, the product price of new energy vehicle is a continuous variable, which can be used to solve the game equilibrium in different situations by backward induction method. First, starting from the second stage of the game, considering the product price p_1 of domestic new energy vehicles given, the response function of imported new energy vehicle brands can be obtained from equation (10):

$$p_2 = \frac{\Delta u + p_1 + c_2 + t}{2} \tag{13}$$

By substituting equation (13) into equation (9), the optimization problem of domestic brands at this time is the maximization of profits of domestic new energy vehicles:

$$\pi_1 = \frac{(p_1 - c_1 + s)(\Delta u - p_1 + c_2 + t)}{2\Delta u} \tag{14}$$

The optimization condition means that equation (14) takes the partial derivative of p_1 and makes it equal to 0:

$$\frac{\partial \pi_1}{\partial p_1} = \frac{\Delta u - 2p_1 + c_1 + c_2 - s + t}{2\Delta u} = 0 \tag{15}$$

It can be seen that at this time, the price of domestic new energy vehicles is:

$$p_{11}^{*}=\frac{\Delta u+c_1+c_2-s+t}{2} \tag{16}$$

Substituting equation (16) into equation (13), the price of imported new energy vehicles is:

$$p_{22}^{*}=\frac{3\Delta u+c_1+3c_2-s+3t}{4} \tag{17}$$

At this time, the output of the two types of cars is:

$$\begin{cases} q_{11}^{*}=\dfrac{\Delta u-c_1+c_2+s+t}{4\Delta u} \\ q_{22}^{*}=\dfrac{3\Delta u+c_1-c_2-s-t}{4\Delta u} \end{cases} \tag{18}$$

If imported new energy vehicles enter the market first, the reaction function of domestic new energy vehicles can also be obtained from equation (10).

$$p_1=\frac{p_2+c_1-s}{2} \tag{19}$$

Substituting equation (18) into equation (9), it can be seen that:

$$\pi_2=\frac{(p_2-c_2-t)(2\Delta u-p_2+c_2-s)}{2\Delta u} \tag{20}$$

From the first-order conditions, it can be seen that:

$$\frac{\partial \pi_2}{\partial p_2}=\frac{2\Delta u-2p_2+c_1+c_2-s+t}{2\Delta u}=0 \tag{21}$$

At this point, the price of imported new energy vehicles is:

$$p_{22}^{e*}=\frac{2\Delta u+c_1+c_2-s+t}{2} \tag{22}$$

Substituting equation (21) into equation (18), the price of domestic new energy vehicles is:

$$p_{11}^{e*} = \frac{2\Delta u + 3c_1 + c_2 - 3s + t}{4} \tag{23}$$

At this time, the equilibrium output of the two types of vehicle enterprises is:

$$\begin{cases} q_{11}^{e*} = \dfrac{2\Delta u - c_1 + c_2 + s + t}{4\Delta u} \\ q_{22}^{e*} = \dfrac{2\Delta u + c_1 - c_2 - s - t}{4\Delta u} \end{cases} \tag{24}$$

Proposition 3: the earlier domestic vehicles enter the market, the smaller the price difference between the two brands of new energy vehicles.

We can know from equation (11), $p_2^{e*} - p_1^{e*} = \dfrac{\Delta u - c_1 + c_2 + t + s}{3}$, and from equation (16) and (17), $p_{22}^{*} - p_{11}^{*} = \dfrac{\Delta u - c_1 + c_2 + t + s}{4}$, apparently $p_2^{e*} - p_1^{e*} > p_{22}^{*} - p_{11}^{*}$, this shows that compared with the perfectly competitive market, the pricing stragedy of domestic new energy vehicles who enter the market first will be different from the Pareto Optimality in perfectly competitive market, there will be "blind confidence" in the pricing strategy of domestic new energy vehicles. By contrast, when imported new energy vehicle brands first entered the market, $(p_{22}^{e*} - p_{11}^{e*}) - (p_2^{e*} - p_1^{e*}) = \dfrac{2\Delta u + c_1 - c_2 - t - s}{12}$, and $\Delta u > c_2 - c_1$, so $p_{22}^{e*} - p_{11}^{e*} > p_2^{e*} - p_1^{e*}$, at this point, when domestic vehicles enter the market, domestic new energy vehicle brands can better understand the gap between themselves and imported brands, then pricing can reflect the difference in quality between two different brands of products, therefore, the price difference between imported and domestic new energy vehicles is greater than that in the perfectlu competitive market.

Proposition 4: the later domestic new energy vehicles enter the market, the higher the market share it can get.

Contrast equation (12), (18) and (24), domestic new energy vehicles with backward technical level doesn't have first-move advantage under the price game in Stackelberg's case. The main reasons are as follows: first of all, in the situation of the price game, the first entrant bears the uncertainty of technology and market choice caused by entering the market first, and the second entrant can avoid the mistakes made by the first mover and gain the competitive advantage (Wernefelt and Karnani, 1987). In the situation of the price game that has the first entrant, the product output is determined by consumer preference and product price, since there are no competitors in the market, it is difficult for the first entrant to have a complete understanding of the market situation, and there may be the possibility of deviating from the optimal selection of the target in pricing, later entrants, especially those with lagging technology, will have more advantages in market information and will be more cautious in pricing. Studies have shown that when market demand is uncertain, and later entrants can observe the personal information from the actions of the first mover, the latter can obtain higher profits (Gal-Or, 1987; Shinkar, 2000). Secondly, the discontinuity of technology and the dynamics of consumer demand provide new entry opportunities for later entrants. In the process of technological change, the old technology also develops when new technology appears, it is difficult for incumbents to be aware of the threat posed by new technologies and the effect of pre-emptive preventive measures is not obvious, in addition, the demand of consumers is always in a dynamic change, which provides an opportunity for the future development of enterprises. Finally, the existence of "incumbency inertia" makes it difficult for incumbents to adapt to changes in the environment. Arrow (1962) proposes that incumbent oligopolies are reluctant to innovate compared with new entrants, because innovation will destroy their existing product profitability. Because the incumbent's sinking investment makes it difficult to transition, at the same time he is not willing to use the same new products to compete with existing products, and the organizational structure is lacking in market flexibility, all these aspects provide opportunities for new entrants to achieve better market performance through innovation.

4. Expansion: the situation of subsidizing consumers

In the subsidy regulation of new energy vehicles, the government not only takes the new energy vehicle manufacturer, but also takes the consumers as the subsidy object. In the above analysis, the government takes enterprises as subsidy objects, and in the following analysis, the government uses consumers as subsidy objects. Like equation (1), the consumer's utility function can be written as:

$$\begin{cases} u_1 = u_0 - p_1 + s \\ u_2 = u_0 + \Delta u\theta - p_2 \end{cases} \tag{25}$$

Similarly, when $u_1 > u_2$ is adopted, consumers choose domestic new energy vehicles, otherwise, they choose imported new energy vehicles. At this time, the demand function of two different brands of new energy vehicles is:

$$\begin{cases} q_1^c = \int_0^{\frac{p_2-p_1+s}{\Delta u}} f(\theta)d\theta = \dfrac{p_2-p_1+s}{\Delta u} \\ q_2^c = \int_{\frac{p_2-p_1}{\Delta u}}^{1} f(\theta)d\theta = \dfrac{\Delta u+p_1-p_2-s}{\Delta u} \end{cases} \tag{26}$$

In a similar way, the equilibrium price in this case can be obtained by first order conditions:

$$\begin{cases} p_1^{c*} = \dfrac{\Delta u+2c_1+c_2+s}{3} \\ p_2^{c*} = \dfrac{2\Delta u+c_1+2c_2-s}{3} \end{cases} \tag{27}$$

And equilibrium output is:

$$\begin{cases} q_1^{c*} = \dfrac{\Delta u-c_1+c_2+s}{3\Delta u} \\ q_2^{c*} = \dfrac{2\Delta u+c_1-c_2-s}{3\Delta u} \end{cases} \tag{28}$$

Proposition 5: there is no difference between subsidizing consumers and subsidizing enterprises in improving consumers' utility, while subsidizing consumers is more likely to improve social welfare than subsidizing enterprises.

As can be seen from equations (1), (11) and (12), when the government takes enterprises as subsidy objects and only considers subsidy policies, the consumer surplus can be expressed as:

$$\begin{aligned} cs^e &= (u_0-p_1^{e*})q_1^{e*}+(u_0+\Delta u\theta-p_2^{e*})q_2^{e*} \\ &= \frac{(3u_0-\Delta u-2c_1-c_2+s)(\Delta u-c_1+c_2+s)}{9\Delta u}+ \\ &\quad \frac{(3u_0+\Delta u\theta-2\Delta u-c_1-2c_2+s)(2\Delta u+c_1-c_2-s)}{9\Delta u} \end{aligned} \tag{29}$$

We can know from equations (25), (27) and (28), when the government takes consumers as the subsidy object, the consumer surplus can be expressed as:

$$cs^c = (u_0 - p_1^{c*} + s)q_1^{c*} + (u_0 + \Delta u\theta - p_2^{c*})q_2^{c*} = \frac{(3u_0 - \Delta u - 2c_1 - c_2 + s)(\Delta u - c_1 + c_2 + s)}{9\Delta u} + \frac{(3u_0 + \Delta u\theta - 2\Delta u - c_1 - 2c_2 + s)(2\Delta u + c_1 - c_2 - s)}{9\Delta u} \tag{30}$$

It can be seen from the comparison of equations (29) and (30), $cs^e = cs^c$, therefore, whether the government takes consumers or enterprises as subsidy objects, consumers can get the same effect. And comparing two different ways of subsidies, in the case of subsidizing consumers, domestic new energy vehicles have a higher price which of imported new energy vehicle are unchanged, and any kind of subsidy has no effect on the market share of the two brands. Then, when government subsidies are the same, domestic new energy vehicle enterprise can achieve higher profits by targeting consumers as a subsidy object. Considering that social welfare = consumer surplus + producer surplus of domestic enterprises, it is more appropriate for the government aiming at social welfare maximization to choose the way to subsidize consumers. See figure 1 and 2.

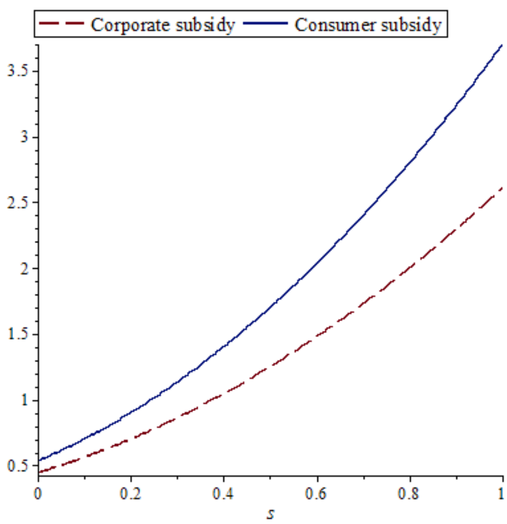

Fig.1 Comparison of social welfare under two forms of subsidy for

($\Delta u = 0.2, c_1 = 1, c_2 = 1.2, u_0 = 1.5, \theta = 0.5$)

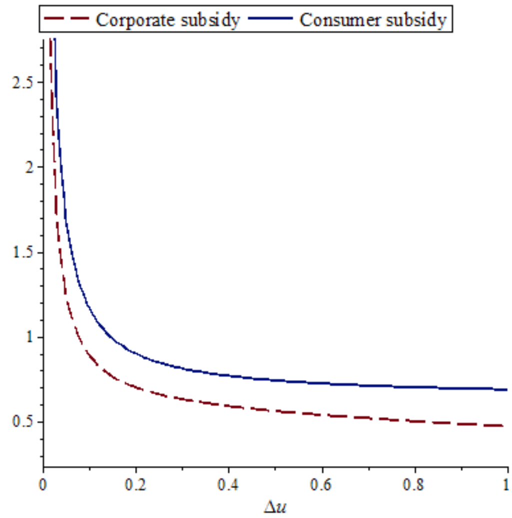

Fig.2 Comparison of social welfare under two forms of subsidy for

($s = 0.2, c_1 = 1, c_2 = 1.2, u_0 = 1.5, \theta = 0.5$)

Numerical simulation results of figure 1 and 2 are shown that under the condition that other parameters remain unchanged, the level of social welfare brought by the subsidy method of consumers as the subsidy object is greater than that of enterprises as the subsidy object. The difference is that the social welfare level brought by the two subsidy methods increases with the increase of the subsidy intensity of the government, but the influence mechanism is different. The way enterprises are targeted for subsidies is to improve social welfare by influencing product prices, at this point, the price of new energy vehicles will fall affected by subsidies, which will bring more consumer surplus; the way consumer as the subsidy object is to influence the overall social welfare level by improving the profits of domestic enterprises.

5. Concluding remarks

As the future development trend of automobile industry, new energy vehicles are bound to completely replace the role of traditional energy automobile in daily life in the near future. However, for the time being, the new energy vehicles cannot be compared with the traditional energy car in both the daily use process and the market recognition. Therefore, in the market competition between new energy vehicles and traditional energy vehicles, the new energy vehicles industry needs to rely on government support (Li et al., 2016; Olson, 2017). in the countries with relatively poor technology, in order to ensure the healthy development of domestic new energy vehicle industry. It is also necessary for the government to set up trade barriers to reduce the impact of foreign products of high-tech countries on domestic industries. Therefore, based on the perspective of game theory, this paper establishes a Cournot duopoly model which includes a domestic producer and a foreign producer, and the influence of government regulation (subsidy and tariff) on market behavior is analyzed. The study found that although the implementation of subsidy policy and the establishment of trade barriers in a fully competitive market can effectively improve the market share of domestic new energy vehicle brands, but such government incentives are unsustainable, because only by reducing the quality difference between domestic and imported new energy vehicles can make domestic new energy vehicle brands which with backward technology have a real position in the market. Although the implementation of subsidy policy and the establishment of trade barriers can protect domestic brands in the short term, they cannot really improve the quality of domestic brands, however, it cannot really improve the quality level of domestic brands. Once such government regulation measures are cancelled or weakened, it will have a huge negative impact on domestic brands. Therefore, in the short term, the government's subsidy policy and trade barriers can effectively improve the market share of domestic brands. However, in the long run, the government should pay more attention to how to improve the quality of domestic products. As a result, in the new energy auto industry, a new industry dominated by a technology, firms cannot higher the market share by reducing their price in market competition, because consumers pay more attentions on the added utility of the new energy vehicle compared to traditional vehicle instead of the price. Therefore, new energy automobile companies should give priority to improving product quality when formulating market strategies.

Secondly, considering in the new energy vehicle market that domestic brands and imported brands generally enter the market in a sequential order, in this paper, a Stackelberg model with product price as the decision variable is established. And this paper makes a comparative analysis on the two situations of domestic brands entering the market first or imported brands entering the market first. In this paper, we found that in the case of Stackelberg game, where price is the decision variable, the first-mover advantage does not exist. Therefore, compared with the fully competitive market, in the case of Stackelberg game, the domestic car can gain a higher market share if it enters the market later. In this paper, we consider the first entrant will face more market uncertainty, technological discontinuity and consumer demand dynamics, that will provide new entry opportunities for later entrants. And the existence of the incumbent's inertia is also the main reason for the loss of the first-mover advantage in game equilibrium.

Finally, based on the above analysis on the subsidy mode of enterprises as the subsidy object, this paper adds an expanded research on consumers as the subsidy object. The research found that there was no difference between the two modes of subsidy for enterprises and consumers in terms of market share and consumer surplus. The difference is that subsidize consumers can raise the price of domestic new-energy vehicles to increase the profits of domestic new energy vehicle manufacturers. Therefore, under the premise that the government subsidy intensity is the same, the government that aims to maximize social welfare is more suitable to adopt the way of subsidizing consumers to promote the development of the renewable energy vehicle industry. The principle of subsidizing consumers and subsidizing producers is different. When the government subsidizes consumers, the increase of disposable income lead to an increase in demand, thereby promoting production. The effect of government subsidizing consumers is more direct than the subsidizing producers since the former one avoids the possibility of producer fraud.

Author Contributions: Each of the authors contributed to the preparation of this research paper. Dong-xiao Yang, Ming-xing Jiang and Zi-yue Chen proposed the analytical mechanical design idea and mmodel. Dong-xiao Yang and Lin-shu Qiu calculated the key parameters, finished main simulations, and wrote the paper.

Jian-jun Yan contributed to review and edit the manuscript.

Acknowledgments: This work is partially supported by National Social Science Foundation of PRC (14BGL020); National Natural Science Foundation of PRC (71703028); Guangdong Social Science Foundation (GD17XYJ23)； Innovative Foundation (Humanities and Social Sciences) for Higher Education of Guangdong Province (2017WQNCX053).

Conflicts of Interest: The authors declare no conflict of interest.

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