Supportive Policy Analysis for Promoting Electric Vehicle Products in Beijing

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Abstract

Recently, the Chinese central and local governments have announced a series of supportive policies and incentives to greatly promote the development and marketization of plug-in and pure electric passenger cars. In this research, a model-based method is used to determine the feasibility of Beijing near-term New Energy Vehicles (NEV) target and evaluate the effectiveness of current policies. The market diffusion rate and population of NEV are analysed by modifying the Market Acceptance of Advanced Automotive Technologies (MA3T) model. The localized key parameters include vehicle miles travelled (VMT), all electric range (AER), vehicle survival rate, driving patterns and utility factor (UF). The simulation results show that only 1 scenarios within the 6 pathways could achieve the Beijing government near-term NEV population goal. Under the current policies, only 46.4% of the 170,000 NEV target in 2017 is achieved, the PHEV30 Subsidy Scenario and Local Subsidy for PHEV have limited effect on the NEV market diffusion. The scenarios of Purchasing Limitation Exemption, Strengthened EV and PHEV Technology Development could achieve the target. The analysis implies the more subsidy from government and breakthroughs in the technology, the better NEV market diffusion.

Keywords: electric vehicle, market diffusion, MA3T, supportive policies

1 Introduction

With the growth of vehicle populations in China, the issues of energy safety and environmental pollution have been increasingly remarkable. The number of vehicle production and sales has risen from 2.1 million in 2000 to 22 million in 2013, ten times growth in 13 years’ period [1]. At the same time, the production and sales have ranked 1st for 5 years in the world since 2009. The rapid growth of production and sales directly resulted in the rapid growth of vehicle population, and the national vehicle population in 2012 exceeded 100 million and ten people owned one vehicle averagely in 2013. The rapid growth of vehicle population, especially the level of vehicles in cities approaching the level in developed countries, has caused the intensified deterioration of pollution in regional cities. The huge emissions from urban vehicles have drawn attentions and the results released by Environmental Protection Department in Beijing and Shanghai indicate that the 20%-25% of particle emissions come from vehicles [1]. Therefore, to find the energy-saving and emission-
free power sources for vehicles and promote new energy vehicles are the proficient pathways to solve the issues of vehicle energy safety and environmental pollution. The global sales of electric vehicles have tripled in the past two years, increasing from about 45,000 in 2011 to 200,000 more, and have showed obvious regionality [2]. The diffusion rate of electric vehicles in America has increased from 0.3% in 2011 to 1.25% in 2013, and sales from 17,763 to 97,102; the diffusion rate in Japan has risen from 0.3% in 2011 to 0.58% in 2013, and the sales in 2013 reached 28,716; the diffusion rate in Western Europe has achieved 0.34%, and the sales have increased from 10,000 in 2011 to 38,617 in 2013, for Norway the diffusion rate has exceeded 5% in 2013 [3]. Affected by the battery cost and the charging infrastructure, the new energy vehicle markets in China start up slowly. In the aspect of infrastructure construction, State Grid and China Southern Power Grid have built 15,000 charging piles. Until December, 2013, the market share of new energy passenger cars was only 0.2% [4]. After three years’ policy incentives, the market share of battery electric vehicles is still below 0.1% of total vehicle sales, and most of them are purchased by central and local governments [3]. The State Council officially issued the “Energy-saving and New Energy Vehicle Industry Development Project” (2012-2020) [1] in June, 2012, the cumulative production and sales of Battery Electric Vehicle (BEV), Plug-in Hybrid Electric Vehicle (PHEV) and Extended Range Electric Vehicle (EREV) are strives to reach 500,000 by 2015; The production of BEV and PHEV can achieve 2 million by 2020, and the accumulative production and sales exceed 5 million, Fuel Cell Electric Vehicle (FCEV) and hydrogen energy industries develop at the same pace of international level. Beijing has positively promoted the industrialization of new energy vehicles, and led the project “Thousands of Electric Vehicles in Ten Cities” in 2009, launching the demonstration operation of EV and FCEV and putting forwards several policies to subsidize the new energy vehicles. In 2013, Beijing government proposed the “Beijing Clean Air Project”, aimed to promote the popularization of EV via several ways and improve the air quality of Beijing [5]. At the same year, the “Clean Air Act Project” (2013-2017) [6] has set goals to achieve the 170,000 population of PHEV and EV in 2017. This research mainly works on the impact of vehicle miles travelled (VMT), manufacturer's suggested retail price (MSRP), vehicle key parameters like all electric range (AER), the government subsidies and policies on the development of China new energy vehicle markets. The research is also used to determine the feasibility of promoting 170,000 new energy vehicles in Beijing by 2017.

2 Methodology

Based on the MA3T model from Oak Ridge National Laboratory (ORNL), in which nested multinomial logit (NMNL) algorithm stem from discrete choice theory is applied, the prediction model for this research is established [7, 8]. The whole market is segmented while data including macro economy, vehicles, consumers and policies serve as inputs, so that market diffusion rate and sales in each segment market is calculated. In the end, the results of all segments are combined and become the output of the whole prediction model. The process of this research is as follows: Firstly, under the authorization of ORNL, a domestic market diffusion model is established based on the original MA3T model. Then, through investigation and prediction from previous research or other models, domestic input data are obtained. Through multi-scenario simulations, the clean energy vehicle market diffusion predictions are acquired. This results are further compared with the current goals of Beijing, vehicle parameters and subsidies are further iterated so that road maps to reach current goals can be finally proposed.

2.1 Model Establishment

The original MA3T model is firstly localized so as to fit the market environment of China. The structure of original MA3T model can be seen from figure 1: for each year, the vehicle parameters including vehicle characteristics, infrastructure, consumer behaviours, energy price, subsidies as well as other quantitated policy impacts serve as the input of NMNL module, and the result of current year is obtained. The result of previous year has further impact for the calculation of next year through feedback loops, so that the self-adjustment behaviour of market is considered. The latest version of MA3T can also calibrate the result from the actual market diffusion data, so that the accuracy of calculation is improved. This research retained the original structure and algorithm of MA3T while the choice structure and
type of input data are modified according to the local market.
For a better understanding of the function of the model, the NMNL algorithm is briefly introduced. Stem from discrete choice theory, NMNL assumes that consumers would choose the vehicle which could provide them with maximum utility, including tangible and intangible. However, due to the information asymmetry, consumers can not fully realize the utility of a vehicle, so the process of making purchase choices is semi-random. From a set of n alternatives, the sensed utility $V_i$ of the vehicle i by a consumer can be specified as:

$$V_i = X_i^c + x_i$$  \( i = 1, 2, ... n \)  \( (1) \)

Where $X_i^c$ is the certain utility item, which can be calculated from all related input data, while $x_i$ represents random utility item or the observation error of the consumer. Furthermore, previous research has shown that $x_i$ can be assumed to follow an unbiased Gumbel distribution, whose probability density function is as follows

$$g(x_i) = \exp(\mu \exp(-\mu x_i))$$
$$G(x_i) = \exp(-\exp(-\mu x_i))$$  \( (2) \)
$$ (3) \)

Where $u_iX_i$ represents the multiplication of the certain utility item and an observation-sensitivity coefficient. In this manner, the choice probability for vehicle i can be expressed as

$$P_i = \frac{e^{\mu u_iX_i}}{\sum_{j=1}^{n} e^{\mu u_jX_j}}$$  \( (4) \)

To avoid the IIA (Independence of Irrelevant Alternative) feature of the single nest model [9], multi-nest choice structure is applied. In this case, the choice probability can be calculated with the conditional probability formula.

The nest structure of the original MA3T contains two vehicle types and 20 powertrains, including ICE, HEV, PHEV, EV and FCEV, altogether 40 vehicle choices. In this research, as far as the domestic condition as well as the availability of data are considered, only passenger cars are considered, the powertrains are simplified to ICE, HEV, PHEV and EV, altogether 8 vehicle choices, as can be seen from figure 2.

2.2 Localization of Model

Based on the differences between China and US, we made some modifications and localization to the key parameters of the MA3T model. The vehicle population and sales, products' performance and costs, coverage rate of charging infrastructure, prices of energy, driving patterns and utility factors are localized below.

2.2.1 Vehicle Survival Rate, Sales and Population

China’s vehicle survival rate is influenced by automobile mandatory scrapping standards, life span of vehicles and the practical purposes, among which automobile mandatory scrapping standards have the most significant effect on the vehicle survival rate.

According to the former research [10], we conclude the rules of China’s vehicle survival rate, represented by Beijing. As is shown in figure 3, we analyse and compare the survival rate between Beijing and America. Since there is a period of concentrated scrappage for China’s passenger vehicles after 15 years of vehicle age, Beijing survival rate decreases significantly after 15 years.
According to Statistical Yearbook of China [11~27], we conclude the population of Beijing private passenger cars. Regarding compact vehicles and micro vehicles as passenger cars, we make some reasonable estimates of the data before 2002 via investigating sales data of specific vehicle brands, and obtain the tendency figure of Beijing private passenger vehicles, as is shown in figure 4.

Figure 4: Population of Beijing Private Passenger Vehicles

According to “The Provisional Regulations of Beijing Passenger Vehicles’ Quantity Limitation” [28], since 2011, the quota of vehicle sales in Beijing is 200,000 per year, and quota of private passenger vehicles is 176,000, accounting for 88%. The quota of the lottery-free purchase for new energy vehicles from 2011 to 2013 is 30,000, averagely 10,000 per year. Assuming that the drivers will buy new vehicles after their vehicles are scrapped, the population of the current year is equal to the population of the last year plus the quota of this year.

We have calculated out the number of scrapped vehicles, the estimated sales, as is shown in figure 5.

Figure 5: Scrappage and Sales

2.2.2 Products’ Characteristics and Costs

The Honda Accord vehicles are chosen as the model inputs of the MA3T model, vehicles including conventional vehicles, hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) with different AERs and battery electric vehicles (BEV) with different AERs. The relevant parameters include Manufacturers’ Suggested Retail Price($), comb AER(mile), comb Charging Depleting electricity consumption (Wh/mile), comb Charging Sustaining fuel economy(MPG, only for conventional vehicles, HEV and PHEV). The tendency figure of MSRP is as follows.

Figure 6: The MSRP Change of 8 Vehicle Types

We use 8 types of Honda vehicles, including conventional vehicles, HEV, PHEV30, PHEV60, PHEV90, EV70, EV140 and EV210, and the number after the type means the AER (kilometre).

2.2.3 Coverage Rate of Infrastructure

Refuelling facilities: The coverage rate remains as 100%.

Charging facilities: In residential areas, according to the related development project in Beijing, the newly constructed residential areas are required to install EV charging piles to a scale within the Fifth Ring Road since 2015, and the older residential communities are required to construct charging infrastructure to some scale. Supposing that the coverage rate of charging piles is 10% in 2015, and 25% in 2020, coverage rate increasing in linear modes from 2015 to 2020.

In public areas, according to related development project, 33% of public parking lots are required to install charging piles up to by 2015. Because of insufficient data and reference materials about public charging piles and charging stations for private drivers’ use, we assume that 50% of public parking lots have charging piles in 2020 and 66% in 2030, the coverage rate rising in linear modes between the periods of time.
2.2.4 Energy Price

Based on the forecast trends of energy prices, we standardize the gasoline and electricity prices into gasoline price per litre according to the international standards [29]. We obtain the projected energy prices from 2010 to 2030.

Using the shape parameters and scale parameters of gamma distribution obtained from the GPS-based research, we draw the probability density distribution figure of daily vehicle miles travelled to compare the Beijing driving patterns with US driving patterns.

Using the driving pattern data of Beijing range distribution samples, we calculated out the Beijing utility factors (UF) and compare it with American UF.

2.2.5 Driving Patterns

Based on the research project [30], we have concluded the driving patterns of private passenger vehicles in Beijing and analysed the driving characteristics on workdays, weekends and holidays. The annual vehicle miles travelled (AVMT) on workdays, weekends and holidays are 11461km, 14271.5km and 17520km, respectively, which we regards as the AVMT of modest, average and frequent driving frequency respectively. From figure 9, we compare the AVMT of Beijing with US.

Using the shape parameters and scale parameters of gamma distribution obtained from the GPS-based research, we draw the probability density distribution figure of daily vehicle miles travelled to compare the Beijing driving patterns with US driving patterns.

Using the driving pattern data of Beijing range distribution samples, we calculated out the Beijing utility factors (UF) and compare it with American UF.

3 Policy Introduction

The policies and taxes on passenger vehicles in China include several kinds as follows:

1) Value-added tax

According to “The Implementation of the Provisional Regulations of the People’s Republic of China on Value-added Tax” (2008) [31], we set the value-added tax of Beijing passenger vehicles as 17%.

2) Consumption tax

According to “The Announcement of the State Taxation Administration on the Adjustment of Passenger Vehicle Consumption Tax” (2008) [32], we set the consumption tax as 9%, and “The Reformation Project of Gasoline Price Tax” [33] was put into effect after Jan 1st, 2009.

3) Vehicle purchase tax

According to the “The Provisional Regulations of the People’s Republic of China on Vehicle
Purchase Tax” (2000) [34], we set the vehicle purchase tax as 10%.
According to “The Announcement on Exemption of New Energy Vehicles from Vehicle Purchase Tax” (2014) [35], from Sep 1st, 2014 to Dec 31st, 2017, new energy vehicles are exempted from vehicle purchase tax. In this paper, we assume that EVs and PHEVs satisfy the tax-free standards.

4) Vehicle and vessel tax
According to “The Announcement on Imposing Vehicle and Vessel Tax on Private Vehicles in 2011” (2010) [36], the vehicle and vessel tax in Beijing was $80 for year 2011.
According to “The Announcement on Imposing Vehicle and Vessel Tax on Private Vehicles in 2012” (2011) [37] and no further regulations released on the vehicle and vessel tax, we regard the vehicle and vessel tax as constant and the tax amount is $150 per year from 2012 to 2029(for engine capacity 2-2.5L).
According to “The Announcement on Imposing Vehicle and Vessel Tax on New Energy Vehicles and Vessels” (2012) [38], from Jan 1st, 2012, the energy-saving vehicles and vessels are charged for half the tax; the new energy vehicles and vessels are free of this tax. We regard that the PHEV and EV are free of vehicle and vessel tax after Jan 1st, 2011.

5) Central and local government subsidy
According to “The Announcement of the Project ‘Energy-saving Products Benefit People’ from National Development and Reform Commission” [39], HEVs with engine capacity below 1.6L and satisfying energy-saving requirements are provided with $500 purchase subsidy. According to “Tentative Subsidy Scheme on Private Purchase of New Energy Vehicles”, PHEVs are subsidized by $8300 per vehicle at the most; EVs are subsidized by $10,000 per vehicle.

6) Purchase Limitation
According to “The Provisional Regulations of Beijing Passenger Vehicles’ Quantity Limitation” [28], people who purchase EV passenger vehicles don’t need to do lottery. The quota of the free-lottery purchasing is 30,000.

4 Policy Scenario Analysis

4.1 Reference Scenario

1) Assumptions
In the reference scenario, no radical changes in vehicle characters and consumer behaviours take place. All powertrain technologies develops mildly. No other new policies from the central and local government will further accelerate the diffusion of clean energy vehicles. The current purchase limitation policy is maintained, which creates approximately $5000 benefit for EV users.

2) Results

![Figure 12: Tax and Policy for Passenger Vehicles](image)

![Figure 13: Vehicle Sales 2011-2017 of Beijing in Reference Scenario](image)

![Figure 14: Population of NEV 2011-2017 of Beijing in Reference Scenario](image)

The simulation results are shown in Figure 13 and 14. As can be seen from Figure 13, the annual sales volume of HEV shows a decreasing trend yearly, from 2011 to 2017. Among PHEV and EV, PHEV30, PHEV60 and EV140 show a higher growth rate. This is because the policy support for HEV is very limited: no tax refund together with low subsidy; PHEV30, PHEV60 have lower electric consumption per kilometer as well as lower retailing prices than PHEV90, making it easier for them to take advantages among PHEVs. With a higher subsidy, EV140 obtains higher purchase subsidy than EV70 but also better electric
4.2 Single Policy Scenario

4.2.1 Subsidy for PHEV30

1) Assumptions
According to the current subsidy policy of the state, only EV with all kinds of AERs and PHEV with AER more than 50km earn a subsidy. As can be known from previous analysis, PHEV with short electric ranges may show a higher energy economy. Therefore, in this scenario the low electric range PHEVs are set to obtain a state subsidy as well, and the amount of subsidy is set according to the proportion of UF. Figure 11 shows the comparison between the UF curve of Beijing and US. From the figure 11, the UF for 60km E-range is 0.83, so the UF for 30km E-range is taken as 0.6. Proportionally, the subsidy for PHEV 30 is the multiplication of subsidy for PHEV60 and 0.723, which is the proportion of these two UFs.

2) Results
The simulation results can be seen from figure 15 and 16. In comparison with reference scenario, the annual sales volume of PHEV30 is increased, for year 2017, from 3000 up to 7000 units; for conventional vehicles, sales are reduced from 332060 units to 328000 units by 1.8%. Figure 18 showed that the population of PHEV has increased steadily to 31550 units to 2017 since this subsidy is given, which is a 50% increase compared with reference scenario. The population of EV and HEV has only changed slightly until 2017. Therefore, the share increase of PHEV is mostly based on the shrink of the population of traditional vehicles.

Figure 15: Vehicle Sales 2011-2017 of Beijing in Subsidy for PHEV30 Scenario

Figure 16: Population of NEV 2011-2017 in Subsidy for PHEV30 Scenario

4.2.2 Local Subsidy for all PHEV Types

1) Assumptions
Based on the reference scenario, all PHEV obtain additionally same amount of local subsidy as from the state, which is similar with subsidy from EV.

2) Results
The simulation results are shown in figure 17 and 18. As can be seen from figure 17, in comparison with the reference scenario, the annual sales volume of PHEV30, 60, 90 are increased, especially for PHEV60, which reached 8323 units for 2017. The sales volume for traditional vehicles reduced from 332060 units to 326060 units by 1.8%. Figure 18 showed that the population of PHEV has increased steadily to 31550 units to 2017 since this subsidy is given, which is a 50% increase compared with reference scenario. The population of EV and HEV has only changed slightly until 2017. Therefore, the share increase of PHEV is mostly based on the shrink of the population of traditional vehicles.

Figure 17: Vehicle Sales 2011-2017 of Beijing in Local Subsidy for PHEV Scenario
Above all, this 1:1 subsidy has shown significant effects for PHEV market diffusion as well as low negative impact on EV and HEV diffusion, which effectively controlled the population of traditional vehicles.

4.2.3 Purchasing Limitation Exemption Scenario

1) Assumptions
According to the policy for the limitation of purchasing private passenger cars, only EV can be exempted. This scenario analysis further studies the effects of purchasing limitation as well as the exemption for PHEV. Taking the license auction price ($13000) in Shanghai, trading price ($5000) in Beijing into account, the effects of license exemption for PHEV are studied.

2) Results
Assuming that the benefit for the exemption of purchase limitation is set to $5,000, the results show as figure 19 and 20. The total population of NEV will reach 111,050 units. Until 2017, EV70, EV140 and EV210 account for 2%, 27% and 11% of the total population respectively; PHEV30, PHEV60 and PHEV90 account for 32%, 25% and 3% of the total population respectively.

4.2.4 PHEV Development Scenario

1) Assumptions
In this scenario, the PHEV technology has shown a faster development, the total retail price decrease by 2% in 2015, 4% in 2016 and 6% in 2017 compared with the initial price.

2) Results
The simulation result can be seen from Figure 21 and 22. In this scenario, the market diffusion of PHEV accelerates gradually. By 2017, the annual sales volume of PHEV has increased from 5448 units to 15729 units; The sales of NEV has researched 35324, which takes up around 13% of total sales; In comparison, the sales of traditional vehicle has decreased by 9760 units, namely from 332060 to 322300 units.

As is shown from figure 22, by 2017, the total population of PHEV and EV has increased by 15823 units. While the share of PHEV among EV and PHEV is increased from 20% in reference scenario to 34%; among them PHEV30 have a large share of 19%.
4.2.5 EV Development Scenario

1) Assumptions
In this scenario, the EV technology has shown a faster development, the total retail price decrease by 2% in 2015, 4% in 2016 and 6% in 2017 compared with the initial price.

2) Results

The simulation result can be seen from figure 23 and 24. Figure 23 shows, the market diffusion of EV accelerates gradually. By 2017, the annual sales volume of EV has increased from 20000 units to 31037 units. In comparison, the sales of traditional vehicle has decreased by 17214 units, namely from 332061 to 314847 units. As is shown from figure 24, by 2017, the total population of PHEV and EV has increased by 19936 units. While the share of EV among EV and PHEV is increased from 80% in reference scenario to 85%; among them EV140 have a share of 55%.

4.3 Discussion

4.3.1 Comparison between Different Scenarios

The results for all scenarios discussed above are summarized in figure 25, the effects of different policy stimulations varies greatly. Only the purchase limitation exemption ($8000 and $13000) reached the 17,000 NEV target of Beijing by 2017, indicating that the effects for most of single polices are not effective enough. By 2017, the annual total sales of NEV has reached 23139 units, while in the exemption scenario $8000 and $13000, the total sales are 73187 and 154022 units respectively.

4.3.2 Strengthened EV and PHEV Development Scenarios

By 2017, in PHEV development scenario, the total population of EV and PHEV has increased from 78910 to 94733 units; in EV development scenario, the total population of EV and PHEV has increased 98846 unit. These results indicates that both of them could not reach the 17000 target for Beijing by 2017. Further based on EV and PHEV development scenario, the retail price are further reduced respectivly and the result can be seen from Table 1.

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<th>Table 1: Cost Reduction in Different Scenarios</th>
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<td>PHEV Development</td>
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By 2017, the total population of EV and PHEV has reached 172880. Meanwhile, in further strengthened PHEV scenario, the total population of EV and PHEV has reached 175812, both of them finally reached the 170000 target.

5 Conclusion
1) Vehicle miles travelled, all electric range, vehicle survival rate, driving patterns and utility factor in China situation are integrated in the MA3T model for its localization.
2) Under the current policies, only 46.4% of the 170,000 NEV target in 2017 is achieved, the PHEV30 Subsidy Scenario and Local Subsidy for PHEV have limited effect on the NEV market diffusion.
3) The scenarios of Purchasing Limitation Exemption, Strengthened EV and PHEV Technology Development could achieve the target.
4) The analysis implies the more subsidy from government and breakthroughs in the technology, the better NEV market diffusion.

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