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Economic Cost Analysis of New Energy Vehicle Policy -Empirical Research Based on Beijing's Data

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Abstract

In recent years, in order to improve Beijing's air quality and reduce vehicle emissions, the Beijing Municipal Government promotes the popularization of new energy vehicles through purchase subsidies, plate lottery, and driving restriction policy. However, the increase in the number of new energy vehicles and the increase in the number of vehicles travelling on roads have intensified the traffic pressure in Beijing. Traffic congestion has increased the emissions of motor vehicle exhaust in turn, resulting in higher socio-economic costs. Based on the actual data of Beijing, this paper quantitatively analyzes the economic cost of new energy vehicle policies by discussing the impact of current new energy vehicle policies on time, energy consumption and tail gas cost. Empirical results show that during the implementation period of the new energy vehicle policy, time cost and tail gas cost increase, energy consumption cost decreases, and the overall economic cost of the policy implementation period increases from 50 million yuan to 321 million yuan.

Keywords: New Energy Vehicle (NEV), policy cost, economic cost, Beijing

1. Introduction

In order to reduce vehicle emissions and improve air quality, the Beijing Municipal Government actively promotes new energy vehicles by relaxing restrictions on new energy vehicles regarding the plate lottery policy and the driving restriction policy. First of all, the new energy vehicles are not restricted by the driving restriction policy. According to the Beijing Municipal Government's General Regulations on the implementation of the restricted traffic management measures during the peak hours of the working day, the pure electric passenger cars are not restricted by this policy. Secondly, judging from the license plate lottery policy, compared with traditional energy vehicles, new energy vehicles have a higher probability of obtaining new licenses. The proportion of new energy vehicle quota in the total annual quota for the 2011 to 2017 plan has risen to 40% (see Table 1).

Table 1. 2011-2017 Beijing New Passenger Car license quota (10,000 units)

Year	Traditional energy vehicles	New Energy Vehicles	Total Quota	NEV Propotion（%）
2011	24	0	24	0%
2012	24	0	24	0%
2013	24	0	24	0%
2014	13	2	15	13%
2015	12	3	15	20%
2016	9	6	15	40%
2017	9	6	15	40%

（Data source: Beijing Traffic Management Bureau, http://jtgl.beijing.gov.cn/）

In recent years, more and more researches have focused on the impact of new energy vehicle policies on traffic congestion and air quality.

2. Literature Review

In the process of implementation of the new energy vehicle industry policy, it will have an impact on air quality and traffic congestion. In order to quantify the impact of these two aspects, this section summarizes the academic research results on air pollution costs and traffic congestion costs.

First of all, air pollution costs include the health costs of residents. Kan & Chen (2002) find that air pollution directly affects the health of local residents. The main components of smog are closely related to the health of residents. The higher the concentration of fine particles, the higher the mortality and morbidity of residents. Second, air pollution costs also include transportation costs. Malm (1999) finds that the concentration of smog is closely related to visibility, especially to the optical properties of the urban atmosphere up to 99%. Therefore, the smog will directly hamper the efficiency of transportation through land, sea and air modes and result in increasing traffic costs. Up to now, domestic and foreign scholars have used the methods of human capital, direct loss assessment, and statistical life value to account for the losses caused by air pollution in China. Among them, the World Bank assessed the health losses caused by air pollutants in China in 2007, which was calculated to be 157 billion yuan by the human capital method and 529 billion yuan by statistical biological value method, equivalent to 1.2% and 3.8% of the gross national product. In January 2013, many cities in China suffered from severe smog pollution. Mu and Zhang (2013) assessed the economic costs of the smog in terms of transportation and health losses. The research results show that the direct economic loss of this severe haze incident is conservatively estimated at 23 billion yuan.

Although the concept of traffic congestion costs and air pollution costs may overlap, there are still significant differences. Delucchi (2004) defines congestion costs as delays in travel time caused by traffic congestion, including opportunity costs and intrinsic costs, compared to smooth driving. The study of congestion costs began in the United States, and Vickrey (1963) first discussed the use of traffic pricing to solve congestion problems. Xie *et al*. (2011) believe that the additional energy consumption and exhaust emissions of traditional energy vehicles (such as diesel and gasoline vehicles) caused by traffic congestion, should also be included in the congestion costs. In this study, the authors collected the traffic volume and vehicle speed in the congested section of Beijing, and used the general traffic cost algorithm to estimate the social cost caused by congestion in Beijing. Wu *et al*. (2011) predicted the transportation cost in 2009 based on the estimated 2008 Beijing traffic congestion cost, and compared the results with the existing researches.

At present, the academic research on the traffic conditions and the emission of air pollutants by the policy factors mainly uses the system dynamics model to conduct qualitative analysis and simulation. However, few studies have quantitatively analyzed the impact of new energy vehicle policies on traffic conditions and environmental pollution, and cannot quantify the economic cost effects of policy factors. This paper analyzes the impact of policy factors on the traffic congestion and air quality of new energy vehicles by establishing a quantifiable new energy vehicle industry policy evaluation model, and estimates the economic costs of policy implementation using Beijing's traffic and air quality data.

3. Model

Based on the literature review, this paper mainly discusses the time cost, energy consumption cost and exhaust cost caused by congestion when studying the economic cost of the NEV policy implementation. At the same time, this paper estimates the cost of the implementation and non-execution of the NEV policy. The difference is the economic cost of the NEV policy studied in this paper.

This paper examines the impact of new energy vehicle policies on traffic congestion, vehicle emissions, and the economic costs of policy implementation. The plate lottery policy has increased the number of new energy vehicles. The driving restriction policy does not restrict new energy vehicles driving on the road, which increases the total number of vehicles driving in the road network, which may worsen traffic conditions. As for the impact of air quality, on the one hand, the deterioration of the traffic condition under the implementation of the policy has led to an increase in the emissions of traditional gasoline vehicles and increased emissions from motor vehicle exhaust. On the other hand, the increase in the number of new energy vehicles and the increase in the amount of electricity used during operation have indirectly increased the amount of sulfur dioxide (SO_2) emitted by thermal power plants. Therefore, the implementation of the new energy vehicle policy has both positive and negative factors for Beijing's air quality. In the process of implementing the new energy vehicle policy, the road traffic congestion situation is aggravated, which increases the time cost due to congestion and affects the energy cost and tail gas treatment cost of traditional energy vehicles. These three parts constitute the economic cost of the new energy vehicle policy. Therefore, the economic cost of the new energy vehicle policy studied in this paper refers to the increased traffic congestion caused by the implementation of the new energy vehicle policy, and the resulting traffic congestion costs, including time cost, energy cost and exhaust gas cost.

The congestion cost of this paper refers to the additional cost of driving in a congested state than in a smooth driving state. In the congestion state, the additional cost includes the time cost incurred by the traveler's travel time. Additional energy consumption from motor vehicle idling and additional environmental pollution costs resulting from increased vehicle exhaust emissions at idle state. Wu *et al*. (2011) economically congested congestion costs into direct and indirect costs. Based on the actual situation of Beijing residents' travel and motor vehicles, and referring to other scholars' research (such as Qin & Li, 2018), this paper ignores the cost that is difficult to quantify and complicated in practice. Therefore, the model of congestion costs is as follows:

$$EC_{total} = C_{time} + C_{fuel} + C_{exhaust} \tag{1}$$

In formula (1), EC_{total} indicates the total cost of congestion, C_{time} indicates the additional time cost incurred by congestion, C_{fuel} indicates additional fuel consumption costs due to congestion, $C_{exhaust}$ indicates additional air pollution costs resulting from congestion.

3.1 Additional Time Cost

The time the vehicle travels is related to the speed of the vehicle. The lower the running speed of the vehicle, the longer it takes for the vehicle to travel. Based on the human capital assessment method, under the same economic development the longer the travel time and the greater the time cost. Based on the impact model of new energy vehicle policy on road traffic, the plate lottery policy and the driving restriction policy make the number of vehicles on the road network increase. Under the premise that the road rate remains stable, the number of vehicles on the road network traffic increases, increasing the vehicle density of the road network and slowing the speed of running the vehicle. Based on the empirical model of road traffic, this paper calculates the average vehicle speed under the new energy vehicle policy and without NEV policy. Based on the Beijing Statistical Yearbook data, we calculate the average hourly wage of employees in Beijing during the policy implementation period, and we also calculate the time cost in each state. Assume that Beijing's free-flow speed and working day commute time are in line with the traffic analysis report of major cities in China published by Gaode Map.

3.2 Additional Energy Costs of Traditional Energy Vehicle

The energy consumption of a motor vehicle is related to its driving state. The study found that the energy consumption of a motor vehicle in a congested state is greater than the energy consumption of a motor vehicle in a smooth driving situation. When the probability of congestion increases and the mileage of congested sections increases, the energy consumption of motor vehicles will increase accordingly. The implementation of new energy vehicle policy ultimately increases the probability of road traffic congestion. This paper calculates the road network congestion probability under the implementation of the new energy vehicle policy and the road network congestion probability without implementing the new energy vehicle policy respectively. Subsequently, we calculate the energy cost in two states according to the energy consumption under the smooth running of the motor vehicle and the energy consumption under the congestion state. Assume that the smooth-running energy consumption and the energy consumption in the congested state are in accordance with the research of Wu *et al*. (2011). The annual mileage of the motor vehicle complies with the report published by ISSRC.

3.3 Additional Exhaust Gas Costs of Traditional Energy Vehicle

Based on the impact model of new energy vehicle industry policy on air quality, the emission of motor vehicle exhaust is related to the state of vehicle driving. In the state of congestion, the exhaust emissions of motor vehicles are greater than the emissions of motor vehicles under smooth driving. Exhaust emissions from motor vehicles include volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NOx) and other polluting gases and large amounts of greenhouse gases (CO_2). In the process of calculating the cost of exhaust emissions, this paper distinguishes the treatment costs of greenhouse gases and the treatment costs of polluting gases. The cost of greenhouse gas treatment is exemplified by the international carbon rights transaction price, and the annual investment of the Beijing Municipal Government's atmospheric management is regarded as the treatment cost of air pollution. Existing domestic and foreign researchers have found that the average contribution of motor vehicle exhaust emissions to atmospheric pollution is 40% (Liu *et al*., 2014; Zhang *et al*., 2013). Therefore, this paper considers 40% of the annual investment in the Beijing Municipal Government's atmospheric management as the cost of treating polluting gases in motor vehicle exhaust.

Based on the impact model of air quality on the policy, this paper calculates the exhaust emissions of motor vehicles under the new energy vehicle policy and the exhaust emissions of motor vehicles that do not implement the new energy vehicle policy. Based on the cost of vehicle exhaust gas treatment in Beijing, the cost of exhaust gas in two states is calculated.

4. Empirical Analysis

This paper firstly calculates the average speed, congestion probability and exhaust emissions of motor vehicles under the two states of implementing new energy vehicle policy and not implementing new energy vehicle policy. In the following step, according to the average hourly wage, congestion status and smooth driving state of the employees in Beijing, the international carbon rights transaction price and the Beijing Municipal Government's annual air pollution management cost, this paper calculates the time cost and energy consumption in two states. According to whether to implement the congestion cost of the new energy vehicle policy, this paper estimates the congestion cost caused by the implementation of the new energy vehicle policy, that is, the economic cost of the new energy vehicle policy referred to in this paper.

To quantify the economic cost of the new energy vehicle policy, this paper calculates the congestion costs under the two states of implementing the new energy vehicle policy and not implementing the new energy vehicle policy. The difference is the economic cost of the new energy vehicle policy. Among them, the new energy vehicle policy is referred to the policy of small passenger car indexing and the restriction of new energy vehicles. The implementation of the new energy vehicle policy will increase the number of vehicles on the road, thereby increasing the number of vehicles traveling in the road network and increasing the vehicle density of the road network. Compared with the policy of not implementing new energy vehicles, the average speed of vehicles in the road network will decrease, the probability of congestion increases, and the cost of congestion increases. That is, the congestion cost of the road network when the new energy vehicle policy is implemented will be greater than the congestion cost when the new energy vehicle policy is not implemented.

4.1 Calculate the Additional Time Cost

Time cost refers to the economic cost corresponding to the time it takes to travel in a congested state and the time it takes to travel in a smooth state. Therefore, when calculating the time cost, this paper first calculates the economic cost per unit time. Then we calculate the time cost of road congestion due to the implementation of the new energy vehicle policy, and calculate the time cost of the new energy vehicle policy.

(1) Economic cost per unit of time

The study found that cities with more developed economies and higher basic wages have more losses due to congestion. The main reason is that the more economically developed, the higher the basic wage, the higher the economic cost per unit time. This paper calculates the economic cost per unit time based on the number of employees at the end of the year and the total wages of urban employees in Beijing. According to China major cities traffic analysis report (Gaode map), and we assume that Beijing residents work 22 days a month, 12 months a year. Table 2 shows the economic costs per unit time in Beijing from 2014 to 2017.

Table 2. Economic time per unit time in Beijing from 2014 to 2017

Year	Number of employees (10 thousand)	Total wages of employees (billion yuan)	Average hourly wage (yuan)
2014	708.8	7293.3	48.72
2015	724.8	8225.2	53.73
2016	744.1	9042.9	57.55
2017	761.7	9892.2	61.49

(2) Congestion time affected by the NEV policy

The congestion time affected by the policy refers to the difference between the congestion time under the new energy vehicle policy and the congestion time when the new energy vehicle policy is not implemented.

$$\Delta t = t_1 - t_2 \tag{2}$$

$$t_i = t - \frac{t \times v_i}{v_f}, i = 1,2 \tag{3}$$

Δt indicates the congestion time affected by the NEV policy. t_1 and t_2 respectively indicate the congestion time under the current new energy vehicle policy and the non-implementation of new energy vehicle policy. i indicates two states of implementing new energy vehicle policy and not implementing new energy vehicle policy. v_i indicates the actual speed in two states. v_f indicates the free flow speed in Beijing. t indicates the assumed daily commute time.

Table 3 shows that the congestion time caused by policy implementation per person per day in Beijing during the implementation period of the new energy vehicle policy (2014-2017) is increasing year by year: from 0.00072 hours per person per day to 0.00603 hours per person per day. The results show that with the implementation of the NEV policy, the impact of policies on traffic conditions is intensified, resulting in increased congestion time due to policy implementation.

Table 3. Congestion time caused by the NEV policy per person per day in Beijing (hour)

Year	Congestion time under NEV policy	Congestion time without NEV policy	Time cost caused by the NEV policy
2014	0.8037	0.8030	0.00072
2015	0.8127	0.8109	0.00180
2016	0.8276	0.8237	0.00393
2017	0.8458	0.8398	0.00603

(3) Time cost of the NEV policy

The time cost of the NEV policy is determined by the economic cost per unit time, the congestion time affected by the policy, and the annual working day time in Beijing and the number of employees on the job.

$$C_{TIME} = c_{time} \times \Delta t \times d \times N_{employee} \tag{4}$$

C_{TIME} indicates the economic cost per unit of time. d indicates the number of working days per year. $N_{employee}$ indicates the number of employees at the end of the year.

Table 4. Time cost of new energy vehicle policy from 2014 to 2017

Year	Time cost (billion yuan)
2014	0.65
2015	1.85
2016	4.44
2017	7.46

Table 4 shows that during the implementation period of the NEV policy, the time cost of the new energy vehicle policy has increased year by year, from 65 million yuan to 746 million yuan. The reasons mainly include three aspects: (1) With the urban construction and economic construction in Beijing, the economic cost per unit time has increased year by year; (2) According to the research results of the impact of the new energy vehicle policy on road traffic, the implementation of the new energy vehicle policy increases the vehicle density of road network traffic and deteriorates the traffic conditions, so that the congestion time of policy influence increases year by year. (3) With the further improvement of the urbanization level in Beijing, the number of employees in urban areas in Beijing has increased year by year, which has led to an increase in the number of people affected by the policy, which ultimately led to an increase in the time cost of the policy.

4.2 Calculate the Additional Energy Cost

The study found that the operating state of the vehicle is one of the main factors affecting the energy consumption of traditional energy vehicles. The energy cost refers to the economic cost corresponding to the energy consumption of the motor vehicle in the congestion state compared with the energy consumption required for the motor vehicle in the unblocked driving state. Therefore, when calculating the energy cost, this paper first calculates the congestion mileage caused by road congestion due to the implementation of the new energy vehicle policy, and then calculates the energy cost of the new energy vehicle policy based on the energy consumption in the congested state and the energy consumption of smooth driving.

(1) Congestion mileage affected by the NEV policy

The congestion mileage affected by the NEV policy refers to the difference between the congestion mileage under the current NEV policy and the congestion mileage when the NEV policy is not implemented. Based on the impact model of new energy vehicle policy on traffic congestion, this paper calculates the congestion probability in two states, and calculates the respective congestion mileage based on the congestion probability, and finally obtains the congestion mileage affected by the policy.

$$\Delta S = S_1 - S_2 \tag{5}$$

$$S_i = S \times P_i, i = 1, 2 \tag{6}$$

ΔS indicates the congestion mileage affected by the policy. i indicates the current state of new energy vehicle policy and the non-implementation of new energy vehicle policy. S_1 and S_2 indicates the congestion mileage in two states. P_i indicates the probability of congestion in two states. S indicates the annual mileage of the motor vehicle.

Table 5. The congestion mileage of a single motor vehicle in Beijing due to the NEV policy

Year	Congestion probability under the NEV policy	Congestion probability without the NEV policy	Congestion mileage affected by the NEV policy (km)
2014	19.82%	19.77%	9.73
2015	20.55%	20.40%	24.82
2016	21.77%	21.45%	55.27
2017	23.31%	22.80%	87.10

Table 5 shows that during the implementation period of the new energy vehicle policy, the congestion mileage of individual vehicles in Beijing due to the new energy vehicle policy increased year by year, from 9.73 kilometers to 87.10 kilometers.

(2) The energy cost of the NEV policy

The energy cost of the new energy vehicle policy is determined by the congestion mileage affected by the policy, the unit energy consumption in the congested state, the unit energy consumption during smooth driving, the unit price of energy consumption, and the possession of traditional energy vehicles.

$$C_{energy} = C_1 - C_2 \tag{7}$$

$$C_i = \left(e_{congestion} - e_{flow}\right) \times \mathrm{S} \times price \times N_i, i = 1,2 \tag{8}$$

C_{energy} indicates the energy cost of the new energy vehicle policy. i indicates the current state of new energy vehicle policy and the non-implementation of new energy vehicle policy. $C_1$and C_2 respectively indicates the energy consumption cost of congestion in two states. $e_{congestion}$and e_{flow} indicates the unit energy consumption of the motor vehicle in the state of congestion and smooth running, respectively. $price$ indicates the average unit price of energy consumption. N_i indicates the amount of traditional energy vehicles in state i.

Table 6. Energy costs of the NEV policy from 2014 to 2017

Year	Energy Cost (billion yuan)
2014	-0.02
2015	-0.26
2016	-0.13
2017	-0.23

Table 6 shows that the energy cost of the NEV policy is negative. That is, the current NEV policy consumes less energy than when the NEV policy is not implemented. Since new energy vehicles do not consume traditional energy sources such as gasoline and diesel, they use electricity as a power source, which ultimately reduces the energy cost of the NEV policies.

(3) Exhaust gas cost

The driving condition of a motor vehicle is one of the main factors affecting the exhaust emissions of motor vehicles. According to the IVE model, the vehicle exhaust emission factors under different operating conditions are obtained. Exhaust gas cost refers to the difference between the treatment cost required for the exhaust gas emitted by the traditional energy vehicle in the congested state and the treatment cost required for the tail gas discharged by the conventional energy vehicle under the free-flow driving state. The tail gas emitted by traditional energy vehicles can be divided into greenhouse gases (CO_2) and polluting gases (VOC, NO_X and CO).

i. Greenhouse gas costs of the NEV policy

This paper is based on the greenhouse gas cost under the influence of international carbon rights trading price calculation policy.

$$C_{greenhouse} = \Delta E_{CO_2} \times P_{CO_2} \times ER \tag{9}$$

$C_{greenhouse}$ indicates greenhouse gas costs. ΔE_{CO_2} indicates the amount of carbon dioxide emissions under the influence of the new energy vehicle policy, that is, the difference between the carbon dioxide emissions under the new energy vehicle policy and the carbon dioxide emissions when the new energy vehicle policy is not implemented. P_{CO_2} represents the price of international carbon rights transactions. ER indicates the average exchange rate of the US dollar against the RMB in the current year.

Table 7. Greenhouse gas costs under current NEV policy in Beijing

Year	Average exchange rate (USD/RMB)	CO_2 emissions under the NEV policies (10000 tons)	Greenhouse gas costs (billion yuan)
2014	6.14	-7.40	-0.08
2015	6.23	-18.91	-0.21
2016	6.64	-43.28	-0.52
2017	6.90	-149.50	-1.86

Table 7 shows that during the implementation period of the new energy vehicle policy, the carbon dioxide emissions under the influence of the policy changed from -74,400 tons to -149,500 tons. The carbon dioxide emissions under the influence of the policy are negative, and the absolute value of the number is increasing year by year. This shows that the carbon dioxide emissions from motor vehicle exhaust emissions under the current new energy vehicle policy are less than the carbon dioxide emissions from motor vehicles when new energy vehicles are not implemented, and with the implementation of policies, carbon dioxide emissions are increasing year by year. At the same time, the greenhouse gas cost has changed from -0.08 billion yuan to -186 million yuan, the greenhouse gas cost is negative, and the absolute value of greenhouse gas costs is increasing year by year. This shows that the cost of carbon dioxide emissions from traditional energy vehicles under the current new energy vehicle policy is less than the cost of carbon dioxide emissions from traditional energy vehicles when the new energy vehicle policy is not implemented.

ii. Pollutant gas costs of the NEV policy

The exhaust gas emitted by motor vehicles contains greenhouse gases and polluting gases. We calculate the pollutant gas costs based on the annual budget of the Beijing Municipal Government. First, we calculate the unit cost of polluting gas treatment from 2014 to 2017. Subsequently, we calculate the pollutant emissions under the influence of the policy. Finally, we calculate the polluting gas cost of the new energy vehicle policy.

a. Unit cost of polluting gas treatment

This paper calculates the vehicle exhaust emissions under the current Beijing policy based on the impact model of new energy vehicle policy on air quality. Then, according to the annual investment of the Beijing Municipal Government in air pollution control, we calculate the unit treatment cost of polluting gas in the exhaust gas of motor vehicles.

$$c_{cg} = \frac{I \times 40\%}{E_{cg}} \tag{10}$$

Where c_{cg} indicates the cost of polluting gas treatment; I indicate Beijing Municipal Government's annual investment in air pollution control. E_{cg} indicates pollutant gas emissions from motor vehicle exhaust in the current year. Table 8 shows that Beijing Municipal Government's investment in air pollution has increased year by year, and the cost of pollution control gas per unit of motor vehicles has also increased year by year. From 2014 to 2017, the cost of pollution control of motor vehicles per unit in Beijing increased from RMB 500 million/ton to RMB 101.4 million/ton, reflecting the people's determination to air pollution control and increasing emphasis on air quality.

Table 8. Unit cost of polluting gas treatment in Beijing, 2014-2017

Year	Investment in air pollution control (billion RMB)	Motor vehicle exhaust emissions (ton)	Unit cost of polluting gas control (billion RMB/ton)
2014	61.2	4559.82	0.005
2015	134	4666.87	0.011
2016	165.6	4929.34	0.013
2017	182.2	5245.78	0.014

b. Polluted gas emissions affected by the NEV policy

The polluting emissions affected by the policy refer to the difference between the traditional energy vehicle exhaust emissions under the current new energy vehicle policy and the conventional energy vehicle polluting gas emissions when the new energy vehicle policy is not implemented. Based on the impact model of new energy vehicle policy on air quality, this paper calculates the exhaust emissions of motor vehicles in two states and obtains the emissions under the NEV policy.

$$\Delta E_{cg} = E_{cg_1} - E_{cg_2} \tag{11}$$

ΔE_{cg} indicates pollutant gas emissions under the influence of the NEV policy. E_{cg_1} and E_{cg_2} indicate pollutant gas emissions from traditional energy vehicles under the current new energy vehicle policy and polluting emissions from traditional energy vehicles when new energy vehicle policies are not implemented, respectively.

Table 9 shows that the amount of polluting gas emissions affected by the policy has changed from -0.34 million tons in 2014 to -56,200 tons in 2017. The amount of polluting gas emissions affected by the policy is negative, and the absolute value of the number is increasing year by year. Thus, the pollutant gas emitted under the current new energy vehicle policy is less than when the new energy vehicle policy is not implemented, and as the policy is implemented, the emission reduction gas increases year by year. This is also in line with the empirical findings of the new energy vehicle policy on air quality impact models.

Table 9. Pollutant gas emissions affected by the NEV policy in Beijing, 2014-2017.

Year	Pollutant gas emissions with the NEV	Pollutant gas emissions without NEV	Pollutant gas emissions affected by the NEV policy
2014	167.91	168.25	-0.34
2015	171.20	172.05	-0.86
2016	179.73	181.66	-1.93
2017	189.92	195.53	-5.62

c. Pollutant gas costs of the NEV policy

The cost of polluting gases of the new energy vehicle policy is determined by the cost of polluting gas treatment and the amount of polluting gas emissions affected by the policy.

$$C_{pg} = \Delta E_{cg} \times c_{cg} \tag{12}$$

C_{pg} indicates the pollutant gas costs of the NEV policy. Table 10 shows that the cost of polluting gas of the NEV policy has changed from -0.05 billion yuan to -2.16 million yuan. From 2014 to 2017, the cost of polluting gases in the new energy vehicle policy is negative, and the absolute value of polluting gas costs is increasing year by year. This shows that the cost of treatment for the emission of polluting gases from traditional energy vehicles under the current new energy vehicle policy is less than the cost of treatment for polluting gases from traditional energy vehicles when the new energy vehicle policy is not implemented.

Table 10. Pollutant gas cost of the NEV policy in Beijing, 2014-2017

Year	Pollutant gas cost (billion RMB)
2014	-0.05
2015	-0.27
2016	-0.71
2017	-2.16

iii. Exhaust gas treatment costs of the NEV policy

Exhaust gas treatment costs under the influence of new energy vehicle policies include greenhouse gas treatment costs and pollution gas treatment costs.

$$C_{gas} = C_{greenhouse} + C_{pg} \tag{13}$$

Table 11 shows that the tail gas cost of Beijing's new energy vehicle policy has changed from -0.13 billion to -4.01 million yuan. The tail gas cost of the new energy vehicle policy is negative, and its absolute value is increasing year by year. This shows that the cost of motor vehicle exhaust emissions under the current new energy vehicle policy is less than the cost of motor vehicle exhaust emissions when the new energy vehicle policy is not implemented.

Table 11. Tail gas costs of the NEV policy in Beijing, 2014-2017 (billion RMB)

Year	Tail gas cost	Greenhouse	Polluting gas
2014	-0.13	-0.08	-0.05
2015	-0.48	-0.21	-0.27
2016	-1.23	-0.52	-0.71
2017	-4.01	-1.86	-2.16

4.3 The Economic Cost of the NEV Policy

The economic costs of the NEV policy studied in this paper include the time cost of the NEV policy, the energy cost of the NEV policy, and the tail gas cost of the NEV policy. Based on the annual cost of the previous empirical study, this paper calculates the economic cost of Beijing's NEV policy from 2014 to 2017. Table 12 shows that the total economic cost of Beijing's NEV policy has increased from 50 million yuan to 321 million yuan. Empirical results show that the total cost of Beijing's NEV policy is positive and increasing year by year. This means that the current NEV policy is not the most "economic" strategy. Compared with the non-implementation of the NEV policy, although the current NEV policy reduces the energy cost of motor vehicles and the cost of exhaust gas emissions from traditional energy vehicles, the NEV policy increases the time cost of travel. In addition, the increase in time cost is much greater than the reduction in energy costs and tail gas costs, making the current NEV policy uneconomical compared to not implementing the NEV policy.

Table 12. The economic cost of the NEV policy in Beijing, 2014-2017

Year	Total Cost	Time Cost	Energy Cost	Tail Gas Cost
2014	0.50	0.65	-0.02	-0.13
2015	1.11	1.85	-0.26	-0.48
2016	3.08	4.44	-0.13	-1.23
2017	3.21	7.46	-0.23	-4.01

5. Discussion and Conclusion

In recent years, with the continuous increase in the number of motor vehicles in Beijing, the road congestion problem in Beijing is severe increasingly. In order to alleviate the traffic congestion problem, the Beijing Municipal Government introduced and implemented the motor vehicle license plate lottery policy and the motor vehicle driving restriction policy. Since 2013, severe smog events with fine particulate matter ($PM_{2.5}$) as the main pollutant have appeared frequently in Beijing. Academic researchers have found that the average contribution rate of motor vehicle exhaust to air pollution in Beijing is 40%. In order to reduce vehicle exhaust emissions and improve Beijing's air quality, the Beijing Municipal Government has promoted new energy vehicles. Although new energy vehicles have potential benefits for air quality, the findings in this paper suggest:

First, the NEV policy will increase the traffic congestion probability in Beijing by increasing the total number of vehicles and the amount of the vehicles driving on the roads. Second, the NEV policy reduces vehicle emissions by reducing the number of traditional energy vehicles. However, due to the increase in traffic congestion, the emission of exhaust gas from a single traditional energy vehicle has increased. The effect of exhaust emissions becomes not obvious. Consequently, the implementation of the NEV policy will increase the economic costs.

Based on Beijing's actual traffic and air data modeling model and empirical research, this paper quantifies the time cost, energy cost and tail gas cost generated by the new energy vehicle policy to calculate the comprehensive economic cost of the NEV policy. The theoretical model of the economic cost of the NEV policy shows that the increase in the proportion of new energy vehicles to the total number of new motor vehicles will also affect the three indicators of the economic costs of the policy, namely time cost, energy cost and tail gas cost. In terms of time cost, the increase in the proportion of new energy vehicles will lead to a decrease in the average speed of vehicles, which will increase the congestion time affected by policies, leading to increased time cost caused by the NEV Policy. In terms of energy consumption costs, on the one hand, the increase in the proportion of new energy vehicles will lead to an increase in the congestion probability of road networks, increasing the congestion mileage of vehicles. Increased energy consumption, resulting in increased energy costs of the NEV policy. On the other hand, the increase in the proportion of new energy vehicles will lead to a decrease in the number of traditional vehicles, which will slow down the growth of traditional energy vehicles and reduce energy costs. The cost of exhaust gas is similar to the cost of energy consumption. On the one hand, the increase in the proportion of new energy vehicles has led to an increase in the probability of congestion in the road network, which has led to an increase in emissions from a single vehicle, resulting in an increase in the cost of exhaust gas for new energy vehicle policies. On the other hand, the increase in the proportion of new energy vehicles will lead to a decrease in the number of new energy vehicles, resulting in a reduction in the cost of new energy vehicles.

Based on the theoretical model, this paper empirically studies the model based on actual statistics in Beijing to assess the economic cost of the current new energy vehicle policy. The results show that during the policy implementation period, the economic cost of implementing new energy vehicle policies increased from 50 million yuan to 321 million yuan. That is, during the same research period, the congestion cost of implementing the new energy vehicle policy is greater than the congestion cost of not implementing the new energy vehicle policy. Therefore, this paper believes that the current NEV policy will generate greater economic costs, and it is recommended to adjust the existing policies on the quantity of ownership (plate lottery policy) and the number of roads (driving restriction policy) in order to give full play to the advantages of energy vehicles in energy conservation and emission reduction and control its adverse effects on traffic congestion.

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