Article

An Empirical Study on the Policies Affecting the Market Penetration of New Energy Vehicles in China

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Abstract

Air pollution is an important issue that is closely related to people's health and comfortable life. Especially with the development of economy and industry, the number of cars is increasing, resulting in more and more serious traffic pollution. Therefore, China has introduced a series of policies to support new energy vehicles (NEVs). Among these policies, the three most important ones are the subsidy policy, the purchase tax exemption policy and the dual-credit policy. Hence, one of the main goals of this paper is to analyze whether these three policies are effective for the market penetration of NEVs. Meanwhile, this paper compares the policy effects.

In addition, this paper believes that air quality is the main factor that attracts the attention of the government and formulates policies to encourage NEVs. Hence, another major goal of this paper is to analyze whether the air quality index also promotes the market penetration of NEVs.

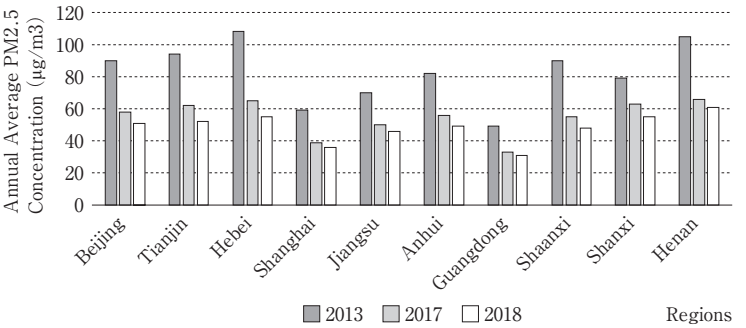
To sum up, this paper studies the effects of government subsidies, tax exemptions, dual-credit policies and air quality index on the market penetration of NEVs. This paper also makes further policy recommendations based on the regression results.

1. Introduction

Countries all over the world are committed to solving environmental problems, among which air pollution is the most important, because air problems will not only cause acid rain to deteriorate the earth's ecological environment, but also directly lead to people's respiratory diseases. In order to protect the health and homes of the citizens, the Chinese government has also started to tackle air pollution since the 1970s (Wang et al., 2019).

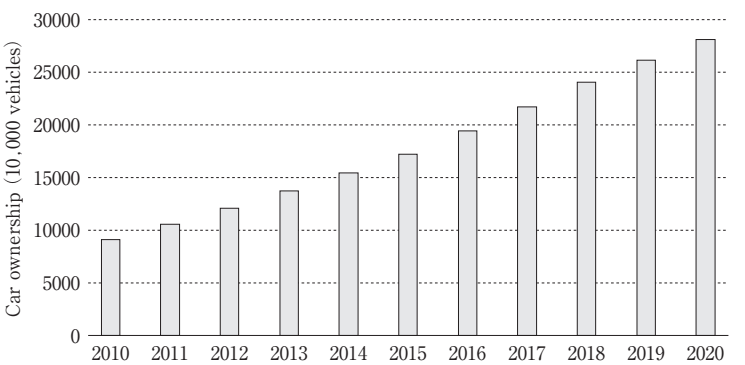
As is shown in Figure 1, through the efforts of the government, from 2013 to 2018, the annual average $PM_{2.5}$ concentration in China's key cities has dropped significantly. Howev-

Figure 1. Changes in Annual Average $PM_{2.5}$ Concentration in Key Regions of China 2013–2018



Source: Clean Air Alliance of China

Figure 2. Car Ownership in China from 2010 to 2020



Source: Clean Air Alliance of China

er, there is still a big gap between the recent concentration and China's secondary and primary standards for concentration limits, which are $35\mu g/m^3$ and $15\mu g/m^3$, respectively.

Moreover, it can be seen from the Figure 2 that the car ownership in China is increasing sharply, driving up the consumption of gasoline and diesel oil, which has put enormous pressure on air pollution.

Car exhaust is a source of major air pollutants such as $PM_{2.5}$, carbon monoxide, hydrocarbons, and nitrogen oxides. Hence, in order to control the air pollution, the Chinese government promotes the new energy vehicle industry.

To promote NEVs, the Chinese government has implemented several policies from 2010, including the subsidy policy, phase-out of subsidy, tax exemption policy and dual-credit policy. Although a growing number of scholars have focused on the policy effect on the NEVs industry, such as the subsidy policies (Lu et al., 2017). However, most of these studies have focused on one of these policies, and few have studied the effects of the subsidy policy, tax exemption policy, and dual credit policy all together. Moreover, previous studies have ignored the fact that the original motivation for these policies was the prevention of deteriorating air quality, which means that air quality can also have an impact on the new

energy vehicle industry.

Therefore, this paper will explore the role of subsidies, tax exemptions, and dual-credit policies in driving the market penetration of NEVs and compare the effect of each policy. Furthermore, the role of air quality as the initial motivation for the Chinese government to promote the new energy vehicle industry on the market penetration of NEVs will be investigated.

In the following text, the second chapter is a specific introduction to the main policies implemented in China to promote NEVs and the specific definition of NEVs. The third chapter is the empirical method, which introduces the specific research model and the reasons for introducing each variable. The fourth chapter shows the regression results. Finally, in the fifth and final chapter, future policy implication and conclusion will be presented.

2. Government Policies for New Energy Vehicles

Since this paper mainly focuses on the role of policies in promoting new energy vehicle industry, it is necessary to know well about each policy. In the past ten years, the Chinese government's incentive policies for the new energy vehicle industry mainly include a subsidy policy, a tax exemption policy and a dual-credit policy. This chapter will explain these policies in more detail. Before explaining the policies, it is necessary to clarify what types of NEVs are supported by these policies. In other words, it is important to know the object of these policies.

2.1 Definition of new energy vehicles

In China, NEVs have both broad and narrow definitions. According to the 2009 "Entry management rules for NEV-manufacturing enterprises and products", NEVs are vehicles that use unconventional fuels (as opposed to gasoline and diesel) or those that use conventional fuels but with a new vehicle power unit. Integrating advanced power control and driving system technologies, NEVs hold unique characteristics due to their new technologies and structures. In this broad sense, NEVs include electric vehicles, hydrogen-powered vehicles, solar vehicles, and alternative energy source vehicles (such as those that use natural gas or ethanol). However, due to technical limitations, electric vehicles that represent NEVs in the narrowest sense have the largest market share. The NEVs mentioned in the "The development plan for the energy-saving and new energy vehicles industry (2012–2020)" include plug-in hybrid electric vehicles (PHEVs), pure electric vehicles (PEVs), and fuel cell electric vehicles (FCEVs). This is the main definition applied to NEV policies in China.

Table 1. Summary of Main Policies Relating to NEVs

Time	Polisy	Detail
2010	Notice on the Piloting of Subsidies for Private Purchase of New Energy Vehicles	Start the piloting of subsidies for private purchase of new energy vehicles
2012	Energy-saving and New Energy Vehicles Industry Development Plan (2012–2020)	Increase the financial support to support the implementation of energy-saving and new energy vehicle technology innovation projects
2013	Notice on Continuing the Promotion and Application of New Energy Vehicles	Plan to reduce the subsidy standard by 20% from 2016 in 2017–2018, 40% from 2016 in 2019–2020 and to completely phase-out the subsidy in 2020.
2014	Guidance on Accelerating the Promotion and Application of New Energy Vehicles	Exempt vehicle purchase tax
2017	Parallel Management of Average Fuel Consumption of Passenger Vehicle Enterprises and New Energy Vehicle Credits	Aim to form a market-based mechanism to promote the coordinated development of energy-efficient and new energy vehicles by establishing a credit trading mechanism.

2.2 Government policies

After determining the definition of new energy vehicles, this paper provides detailed information on the policies formulated by the Chinese government for the new energy vehicle industry. Table 1 shows the main policies that the Chinese government has implemented in the new energy vehicle industry since 2010, including the subsidy policy, the purchase tax exemption policy and the dual-credit policy. These three policies will be explained separately below.

2.2.1 Subsidy policy

In order to accelerate the technological progress of the automobile industry, in June 2010, "Notice on the Piloting of Subsidies for Private Purchase of New Energy Vehicles" was issued, which identified five cities, including Shanghai, Changchun, Shenzhen, Hangzhou, and Hefei, to start the piloting of subsidies for private purchase of new energy vehicles.

The policy is mainly to give a one-time subsidy for the private purchase of plug-in hybrid passenger cars and pure electric passenger cars in the pilot cities. The subsidy standard is determined according to the power battery pack energy. The NEVs that meet the support conditions are subsidized at 3,000 yuan/kWh. Plug-in hybrid passenger cars are subsidized up to 50,000 yuan each, and pure electric passenger cars are subsidized up to 60,000 yuan each (Fu et al., 2020). Subsidy funds are allocated to car manufacturers to sell NEVs to private users or leasing companies at their post-subsidy prices, i.e., to attract consumers with price advantages and thus promote sales and market penetration of NEVs.

In September 2013, the "Notice on Continuing the Promotion and Application of New Energy Vehicles" continues to promote the application of NEVs by relying on areas with a heavy task of fine particulate matter control, such as Beijing, Tianjin and Hebei.

In 2015, the "Notice of Four Departments on the Financial Support Policy for the Promotion and Application of New Energy Vehicles from 2016–2020" stated that in order to

Table 2. The Change in Subsidy Amount for PEVs and PHEVs from 2018 to 2019

Pure Electric Vehicles						
Projects	Recharge mileage (km)	Subsidy amount in 2018 (thousand yuan)	Recharge mileage (km)	Subsidy amount in 2019 (thousand yuan)	Reduction in subsidy (thousand yuan)	Phase-out (%)
Recharge mileage	100-150	0	100-150	0	0	/
	150-200	15	150-200	0	15	/
	200-250	24	200-250	0	24	/
	250-300	34	250-400	18	16	47.06
	300-400	45	/	/	/	/
	≥400	50	≥400	25	25	50.00
Plug-in Electric Vehicles						
Recharge mileage	Subsidy amount in 2018 (thousand yuan)		Subsidy amount in 2019 (thousand yuan)		Reduction in subsidy (thousand yuan)	Phase-out (%)
R≥50 km	22		10		12	54.50

Source: China Association of Automobile Manufacturers

maintain policy continuity and promote the accelerated development of the new energy vehicle industry, the subsidy policy will continue to be implemented from 2016-2020 and the scope of implementation will be extended to the whole country. However, taking into account the production cost, scale effect and technological progress of NEVs, the subsidy standard will be gradually reduced in 2017-2020, of which: the subsidy standard in 2017-2018 will be reduced by 20% on the basis of 2016, and the subsidy standard in 2019-2020 will be reduced by 40% on the basis of 2016.

As is shown in Table 2, In 2018 and 2019, for example, pure electric vehicle with a recharge mileage of 200-250 can enjoy a subsidy of 24,000 yuan in 2018 but cannot enjoy any subsidy in 2019; pure electric vehicles with a recharge mileage of 250-300 have a subsidy of 34,000 yuan in 2018, but in 2019, the subsidy is reduced by 16,000 to 18,000 yuan.

2.2.2 Tax exemption policy

The "Guidance on Accelerating the Promotion and Application of New Energy Vehicles" adopted a purchase tax exemption program for pure electric vehicles, plug-in hybrid electric vehicles and fuel cell vehicles from September 1, 2014 to the end of 2017.

In 2017, the "Announcement on Vehicle Purchase Tax Exemption for New Energy Vehicles" proposed that from January 1, 2018, to December 31, 2020, NEVs purchased will be exempted from vehicle purchase tax. In 2020, according to the "Announcement on the Policy of Exemption from Vehicle Purchase Tax for New Energy Vehicles", the policy of exemption from vehicle purchase tax would be extended again until December 31, 2022.

2.2.3 Dual-credit policy

On September 27, 2017, the "Parallel Management Measures for Average Fuel Consumption of Passenger Vehicle Enterprises and New Energy Vehicle Credits" (dual-credit policy)

was issued in order to improve the energy efficiency of passenger vehicles, alleviate energy and environmental pressure, and promote the healthy development of the automobile industry. The regulations stipulate that a company must meet the regulations on passenger vehicle fuel consumption and produce a certain percentage of new energy vehicles (EV/PHV/FCV).

The dual-credit policy consists of two parts: CAFC credits and NEV credits. CAFC credits measure the deviation between the actual fuel consumption value of passenger cars sold by a company and the national fuel consumption target value. The corporate average fuel consumption is calculated by curb weight, fuel consumption and sales volume of the model. The target value of a corporation is the average target value of all vehicles, which depends on which mass segment the vehicle belongs to.

The NEV credits are used to measure the deviation between the percentage of new energy vehicles in the passenger cars sold or imported by the company and the target percentage set by the government, which is the requirement put forward by the governemnt to car companies in the development of NEVs. NEV credit is calculated as the sum of pure electric vehicle credit, plug-in hybrid vehicle credits and fuel cell vehicle credits. According to dual-credit policy, each enterprise is required to achieve the standard credits (positive credits). Enterprises are penalized if they do not reach the target credits. The penalty for negative CAFC is that companies must suspend the declaration and production of high fuel consumption products; the penalty for negative NEV is that companies must suspend the production of high fuel consumption models.

In order to avoid penalties, there are three ways to compensate negative credits: transfer positive fuel consumption credits, purchase NEV credits, and generate NEV credits by the enterprise itself. Similarly, for NEV credits, there are two ways to compensate for negative credit: buy NEV credits or generate NEV credits by the enterprise itself. However, the transfer of positive fuel consumption points can only be carried out in affiliated companies, which is severely restricted. The purchase of NEV credits also consumes corporate funds, which is not conducive to the long-term development of the company. Therefore, the best way to avoid negative credits is to produce as many new energy vehicles as possible. The NEV credits generated by the company can offset the negative CAFC credits or NEV credits.

3. Methodology and Data

Gallagher and Muehlegger (2011) take tax incentives into econometric model to assess the impacts of incentives on national hybrid electric vehicle sales data per capita. Sierzchula et al. (2014) conducted a cross-national statistical analysis of financial subsidies affecting

Figure 3. Factors Affecting the Market Penetration of NEVs

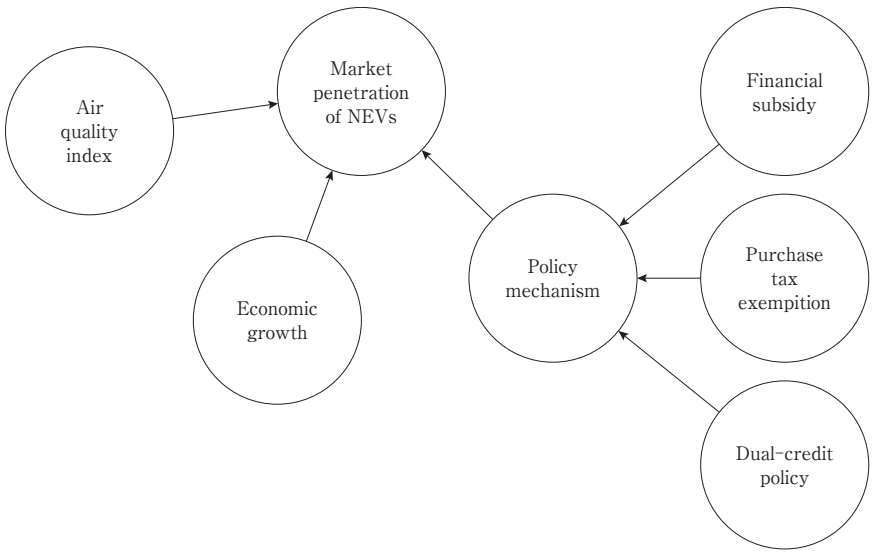


Table 3. List of Variables

Variable	Description	Unit	Data Source
NEVpene	New energy vehicle market penetration ratio (NEV cumulative sales number/All vehicle cumulative sales number)	/	China Association of Automobile Manufacturers
AQI	Air quality index	/	China National Environmental Monitoring Centre
GDPpc	GDP per capita	Yuan	China Statistical Yearbook
Subsidy	Dummy variable of subsidy policy	/	/
Taxexemp	Dummy variable of purchase tax exemption policy	/	/
Dual	Dummy variable of dual-credit policy	/	/

EV adoption rates for 30 countries in 2012.

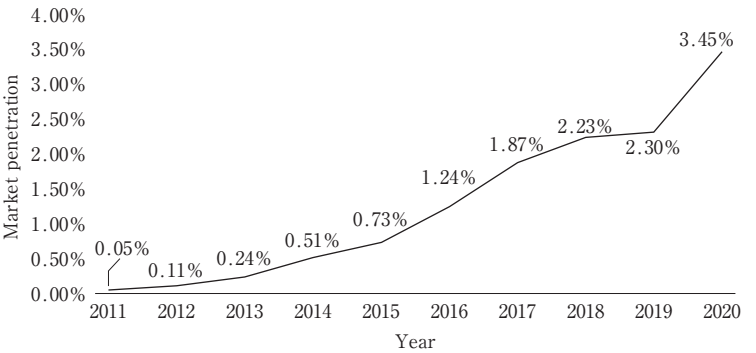
In China, the government not only implemented subsidy and purchase tax policies but also carried out dual-credit policy to promote new energy vehicle industry. In Figure 3, the mechanism of the factors affecting the NEV market penetration is clearly showed. To analyze and compare the role of these three policies in driving the market penetration of NEVs and also the role of air quality to promote new energy vehicle industry, the following model is formulated:

$$NEVpene_{i,t} = \beta_0 + \beta_1 lnAQI_{i,t} + \beta_2 lnGDPpc_{i,t} + \beta_3 Subsidy_{i,t} + \beta_4 Taxexemp_{i,t} + \beta_5 Dual_{i,t} + \alpha_i + \varepsilon_{i,t} \quad (1)$$

The fixed effect regression model is adopted to estimate the coefficients. The i in the dataset refers to 31 provinces in China, and the t is annual data from 2011 to 2020.

Table 3 explains the meaning, unit and data source of variables in the econometric mod-

Figure 4. Market Penetration of NEVs in China 2011–2020



Source: China Association of Automobile Manufacturers

el. The detailed information of each variable and the reason for introducing the variable are described below.

3.1 New energy vehicle market penetration

This variable represents the cumulative sales ratio of NEVs to the cumulative sales of the overall vehicle market. Using market penetration ratio rather than simply using sales volume as a proxy for the development of the new energy vehicle industry is because with the growth of people's income, as a part of the automobile market, the sales of NEVs will increase with the development of the overall automobile market. If the sales growth of NEVs is not higher than that of traditional fuel vehicles, it cannot be said that the new energy vehicle industry has developed. The increase in market penetration ratio can better represent the development of the new energy vehicle industry. The Figure 4 shows the overall change in NEVs market penetration in China from 2011 to 2020, from which it can be told that there is an obvious upward trend. The data can be gathered from China Association of Automobile Manufacturers.

3.2 Air quality index

According to the Law of the People's Republic of China on Environmental Protection and the Law of the People's Republic of China on Prevention and Control of Air Pollution, the government issued the Technical Provisions of Ambient Air Quality Index (AQI) (for trial implementation) as the national environmental protection standard in order to protect the environment.

The Air Quality Index is based on measurement of particulate matter ($PM_{2.5}$ and PM_{10}), Ozone (O_3), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2) and Carbon Monoxide (CO) emissions, among which Nitrogen Dioxide (NO_2), $PM_{2.5}$ and Carbon Monoxide (CO) are the main pollutants emitted from vehicle.

Table 4 shows what the different values of AQI represent. An increase in the air quality

Table 4. The Standard of AQI

AQI Value	Levels of concern	Description of air quality
0–50	Good	Air quality is satisfactory, and air pollution poses little or no risk.
51–100	Moderate	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
101–150	Unhealthy for sensitive groups	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
151–200	Unhealthy	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
201–300	Very unhealthy	Health alert: The risk of health effects is increased for everyone.
301 and higher	Hazardous	Health warning of emergency conditions: everyone is more likely to be affected.

index represents an increase in the degree of air pollution, which means that air pollution has a greater negative impact on people's health. The data of AQI is published by the China National Environmental Monitoring Centre.

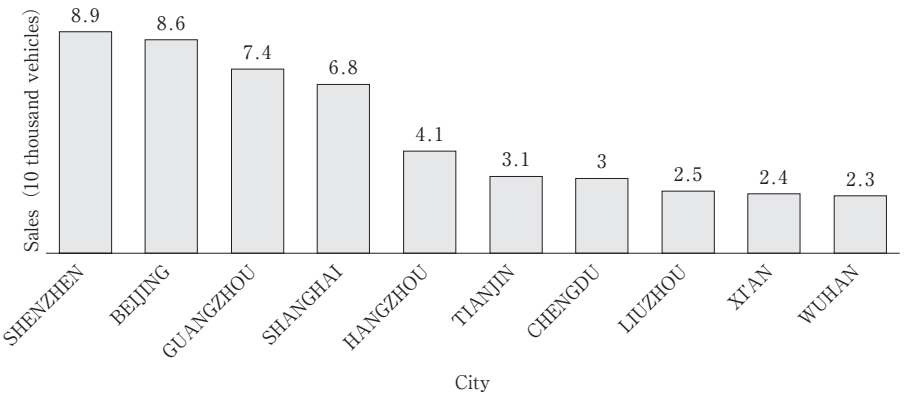
The pollution is concentrated in more developed areas such as northern coastal economic zone, eastern coastal zone and Guangdong Province (see Appendix 1). The common feature of these regions is that they are the most developed economic zones in China. Three major sources of air pollution — industry, automobiles, and construction — are pillars of economic development. With the development and transformation of the economy, heavy industry has gradually shifted to relatively backward areas, and vehicle emissions have become the main source of urban air pollution, which requires a special attention. Therefore, national policies will also be implemented from these regions, focusing on promoting the development of NEVs in developed regions and increasing the market penetration of NEVs in these regions.

3.3 GDP per capita

From 2011 to 2020, the growth rate of China's macroeconomic and industrial economy has been continuously strengthened. From the perspective of indicators, the motor and equipment manufacturing industries related to the entire automobile industry show a gradual upward trend, and as an industry with obvious cycles, the automobile industry has a trend of changing with the fluctuation of the macro economy. NEVs are in line with country's social development and economic operation.

As is shown in Appendix 2, northern coastal economic zone and eastern coastal economic zone have higher NEV market penetration reaching 13% and 12% because these two regions are the regions with the most developed economy, manufacturing and high-tech technology, and the highest degree of urbanization. Based on the above information, the positive effect of the macro economy on the automobile industry and NEVs will show an

Figure 5. Top 10 cities by Sales of New Energy Vehicles in 2019



Source: China Association of Automobile Manufacturers

Table 5. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
NEVpene	310	.021	.021	0	.122
AQI	310	81.132	21.097	37.375	135
GDPpc	310	53,357.28	26,989.89	16,165	164,889
Subsidy	310	.61	.489	0	1
Taxexemption	310	.7	.459	0	1
Dual	310	.3	.459	0	1

upward trend with the continuous development of society. Moreover, the reality also proves that in economically developed cities, the sales of NEVs are higher.

As shown in Figure 5, the top ten cities with the highest economic development are also the cities with the highest sales of NEVs. With the increase of per capita GDP, people's consumption power becomes stronger, which will inevitably have an impact on the market penetration of NEVs. Hence, GDP per capita is introduced as a control variable. The data are downloaded from the China Statistical Yearbook.

3.4 Subsidy policy

Policy dummy equals to 1 if the subsidy policy is implemented in a specific region during a specific period; otherwise, the dummy variable equals to 0.

3.5 Tax exemption policy

Policy dummy equals to 1 if the tax exemption policy is implemented in a specific region during a specific period; otherwise, the dummy variable equals to 0. The tax exemption policy started in 2014.

Table 6. Estimated Result

	Without lnGDPpcsq	With lnGDPpcsq	L. lnAQI instead of lnAQI
	NEVpene	NEVpene	NEVpene
lnAQI	0.011 (0.010)	0.018** (0.009)	
L. lnAQI			0.019** (0.009)
lnGDPpc	0.002 (0.008)	−.534*** (0.076)	−.531*** (0.094)
lnGDPpcsq		0.025*** (0.004)	0.025*** (0.004)
Subsidy	0.004 (0.002)	0.006*** (0.002)	0.008*** (0.002)
Taxexemption	0.024*** (0.003)	0.024*** (0.002)	0.024*** (0.002)
Dual	0.003 (0.003)	0.001 (0.002)	0.004 (0.003)
Constant	−0.072 (0.102)	2.716*** (0.403)	2.779*** (0.509)
Observations	310	310	279
R-squared	0.560	0.630	0.582

Standard errors are in parentheses. ***p<.01, **p<.05, *p<.1

3.6 Dual-credit policy

Policy dummy equals to 1 if the dual-credit policy is implemented in a specific region during a specific period; otherwise, the dummy variable equals to 0. The dual-credit policy started in 2018.

Table 5 shows the descriptive statistics of the variables in the dataset, including observations, mean, standard deviation, minimum value and maximum value.

4. Estimated Result and Discussion

After building the model and collecting all the required data, the fixed-effect regression was run, and the estimated result was obtained as shown in Table 6. This chapter will show and interpret the regression results for every variable in this model.

4.1 Air quality index

This paper not only analyzes the lnAQI but also takes one-year lag of lnAQI, which means the AQI one year before, because the government usually uses the current year's or previous year's AQI to make policy arrangements for the subsequent year or years. The results of lnAQI and Lag.lnAQI show that they are both significant at the 5% level of significance and the coefficients are not too far apart, both around 0.018. The coefficient means that with 1% increase of AQI, the NEV penetration will increase by 1.8 percent

point. This shows that AQI does act as the government's initial motivation to promote the new energy vehicle industry and can have a positive effect on the market penetration of NEVs.

4.2 GDP per capita

The regression only with lnGDPpc shows that the coefficient of lnGDPpc is not significant, which means that the market penetration ratio of NEVs and lnGDPpc are not a simple linear relationship. After drawing the picture of the relation between the NEVs market penetration and the lnGDPpc, it is found that there is a U-shaped relationship between these two variables. Therefore, lnGDPpcsq, which is the square term of lnGDPpc, is added into this model. The regression coefficients of lnGDPpc and lnGDPpcsq were significant at the 1% level of significance. The coefficient of lnGDPpcsq is positive and the coefficient of lnGDPpc is negative, which indeed shows a U-shape relationship. At first, the market penetration ratio of NEVs will decline with the growth of per capita GDP, but when the per capita GDP exceeds a certain threshold, the market penetration ratio of NEVs will rise as per capita GDP grows. This is not only related to the higher price of NEVs, but also to people's awareness of environmental protection. When the economy grows to a certain level, people's awareness of environmental protection and purchasing power also rises, which increases the market penetration of NEVs.

4.3 Subsidy and tax exemption policy

The coefficient of subsidy policy dummy is significant at the 1% level, indicating that the subsidy policy has a positive effect on the new energy vehicle market penetration, and that the presence of subsidies increases the market penetration of NEVs by 0.6 to 0.8 percent points compared to the absence of subsidies. However, it should be noted that this coefficient includes the role of the entire subsidy policy implementation period, the late subsidy withdrawal may in general dilute the role of the early subsidies.

The coefficient of tax exemption policy dummy is also significant at the 1% level of significance. The coefficient means that the existence of tax exemption policy helps to increase the market penetration of NEVs by 2.4 percent point.

Comparing the coefficients of the above two policies, we will find that the role of the tax exemption policy is greater than that of the subsidy policy. I think there are two reasons: First, as mentioned above, the subsidy policy has experienced pilot work, popularization to the whole country and gradual phase-out during the decade, the role of this policy will fluctuate at different stages, for example, when the subsidy is reduced, the role of the policy will be smaller than when the subsidy is not reduced.

Secondly, in the early days of the subsidy policy, various related audits were not standardized. A few enterprises may be cheating the government by misrepresenting the spec-

ifications of their products and obtaining subsidies, resulting in the market penetration of new energy vehicles not being effectively improved. The tax exemption policy has been very stable since it was implemented in 2014. Unlike the subsidy policy, the tax exemption policy works directly on consumers. Hence, the tax exemption policy can more effectively promote the penetration of the new energy vehicle market without any corporate fraud.

4.4 Dual-credit policy

The coefficient of dual-credit policy is not significant at any level. The reason may be that it is a relatively new policy, starting in 2018, with only two years of data in the database of this paper, which is much less compared to the subsidy policy and the tax exemption policy, leading to the inability to effectively measure the effect of the policy. Moreover, the policy not only covers NEVs, but also requires the average fuel consumption of traditional vehicles. Coupled with the ability to trade credits between companies, traditional car companies are able to purchase new energy vehicle credits to offset the negative credits for producing traditional fuel vehicles, which reduces the cost for traditional car companies to meet the national required standards. Therefore, the effect of the dual-credit policy on the market penetration of NEVs is yet to be proven.

5. Policy Implications

The above results show that air quality indicators have a certain positive effect on the market penetration ratio of NEVs. In response to this result, the suggestions given in this paper are as follows. Firstly, the air quality report of each region should be released at the end of each quarter to assess the state of air quality and the causes of harmful air quality. Air quality goals and air quality improvement policies should be further formulated for the next stage suitable for each region. In addition, in the context of the overall improvement of air quality nationwide, the government should update the standards of air quality indicators every two years and formulate overall air quality goals and corresponding policies.

Secondly, to improve residents' awareness of air quality protection, this paper suggests that residents' exposure to air quality indicators should be increased as much as possible. For example, highlighting air quality in weather forecasts; raising alarms when air quality is particularly harmful; displaying air quality on car control screens; and placing displays on store counters that show real-time air quality, would all be effective ways to benefit residents.

The subsidy policy is effective for the market penetration rate of NEVs, but it is not as effective as the purchase tax exemption policy. This is not only because the subsidy has been reduced since 2017, which has weakened the role of the subsidy, but also because of

insufficient supervision, which has led to some companies defrauding subsidies. In response to these problems, this paper proposes the following suggestions:

First, strengthen industry supervision and management. In the context of the continuous expansion of the new energy vehicle industry, the government should continue to strengthen industry supervision and conduct strict inspections on whether the car models that companies apply for subsidies meet the subsidy requirements.

Secondly, although the subsidy policy increases the government's financial burden, making it unsustainable, the estimated result show that this policy is effective. It is recommended to continue to retain the subsidy policy for high-quality products and fuel cell vehicle products after 2022. Specifically, the government can reward models and companies whose technical indicators and cost reductions have reached the target requirements ahead of schedule and are ranked high in market size.

Regarding the policy of exempting purchase tax, in view of its strong policy effect, this paper believes that the tax preferential policy system should be further improved, rather than directly canceling the policy. From 2022 to 2025, with the substantial growth in sales of NEVs, preferential policies will be gradually tightened. The preferential tax policy is gradually declining, so only products with high energy efficiency will be given preferential treatment.

The dual-credit policy needs to be further optimized. The government should adjust the policy implementation standards in a timely manner according to technological progress and market changes. According to our analysis, the dual-credit policy has no significant effect on the market penetration of NEVs. Based on this result, the government can increase the requirements for the production ratio of new energy vehicles and raise the threshold for obtaining NEV credits.

In addition, the price of NEV credits needs to be stabilized. For new energy vehicle companies, credit trading is an important source of profit. In 2020, Tesla, inc. earned $1.58 billion in operating income by selling credits, and its net profit that year was $720 million (Kolodny, L., 2020). At the same time, BYD Co., Ltd, SAIC General Motors Corporation Limited and other car companies have profited from the dual-credit transaction. The dual-credit transaction supports NEV companies to a certain extent. However, with the increase in the total number of NEVs, the demand for NEV credits by car companies has decreased, resulting in a reduction in the price of credits for NEVs, a reduction in the income of car companies, and a reduction in the role of encouraging industrial transformation and development.

Considering factors such as the shortage of semiconductor chips and rising raw material prices, the overall profitability of car companies is facing challenges. According to this situation, stabilizing the price of credits has become an important demand for the dual-credit policy. The lack of accurate predictions about the price changes of credits is due to infor-

mation asymmetry. This paper suggests that relevant departments should set up virtual trading platforms or credit pools. When the supply of credits exceeds the demand, put the excess credits into the pool; when the supply is less than the demand, the credits are taken out from the pool for use, so as to adjust the market supply and demand relationship and stabilize the price of points transactions.

Finally, due to the rapid development of NEVs in recent years, the industry predicts that by 2030, the sales of NEVs will account for more than half of the total sales. Therefore, electric infrastructure and the improvement of battery recycling mechanisms are paramount for a future where new vehicles can properly succeed.

6. Conclusion

Air pollution has always been a difficult problem for China. In order to prevent further air pollution from automobiles and traffic, the Chinese government has issued a series of policies to promote the development of the new energy vehicle industry, which has made the new energy vehicle industry grow by leaps and bounds in the past decade. This paper studies the role of air quality indicators as an early warning mechanism and subsidy policy, tax exemption policy and dual-credit policy on the market penetration of NEVs and compares the policy effects. The results show that air quality indicators, subsidy policies and purchase tax exemption policies can effectively increase the market penetration of new energy vehicles, and the policy effect of purchase tax exemption is stronger than the effect of subsidy policies. Therefore, this paper suggests that the government should constantly update the air quality index standards and improve the air quality goals. At the same time, the government should improve the exposure rate of air quality indicators to residents and increase their attention to air quality. As for subsidies and tax exemption policies, their focus should be on NEVs with high performance and new technologies to encourage further research and development by enterprises.

The effect of the dual-credit policy is not significant. This is because the policy is still in its infancy, and there are still many parts that need to be improved. For example, the production ratio of NEVs needs to be increased, and the price mechanism of credits trading needs to be developed for price stability.

However, this article has some limitations. The data used in this article only covers from 2011 to 2020, while the dual-credit policy just started from 2018, meaning that the data may be not abundant. In addition, this paper only studies the three most important new energy vehicle policies: subsidies, tax exemptions and dual-credit policy, while, according to the actual situation of each region, the local government has proposed some other policies to improve the penetration ratio of the local new energy vehicle market, for example, the

car-number plate licensing scheme relating to NEVs.

References

China Association of Automobile Manufacturers (CAAM) (2022). Available online: http://www.caam.org.cn/chn/4/cate_30/con_5235704.html (Assessed on 12 July, 2022).

China National Environmental Monitoring Center (CNEMC) (2020). Available online: http://www.cnemc.cn/ (Assessed on 10 Jun, 2022).

China Statistical Yearbook (2020). Available online: http://www.stats.gov.cn/english/Statisticaldata/AnnualData/ (Assessed on 5 Jun, 2022).

Clean Air Alliance of China (2020). Available online: https://chinadialogue.net/en/author/clean-air-alliance-of-china/ (Assessed on 20 May, 2022).

Fu, J., & Ng, A. W. (2020). Sustainable Energy and Green Finance for a Low-Carbon Economy. Springer International Publishing.

Gallagher, K. S., & Muehlegger, E. (2010). Giving green to get green? incentives and consumer adoption of Hybrid Vehicle Technology. Journal of Environmental Economics and Management.

Kolodny, L. (2020). Tesla's sale of environmental credits help drive to profitability. CNBC. Available online: https://www.cnbc.com/2020/07/23/teslas-sale-of-environmental-credits-help-drive-to-profitability.html (Assessed on July 15, 2022)

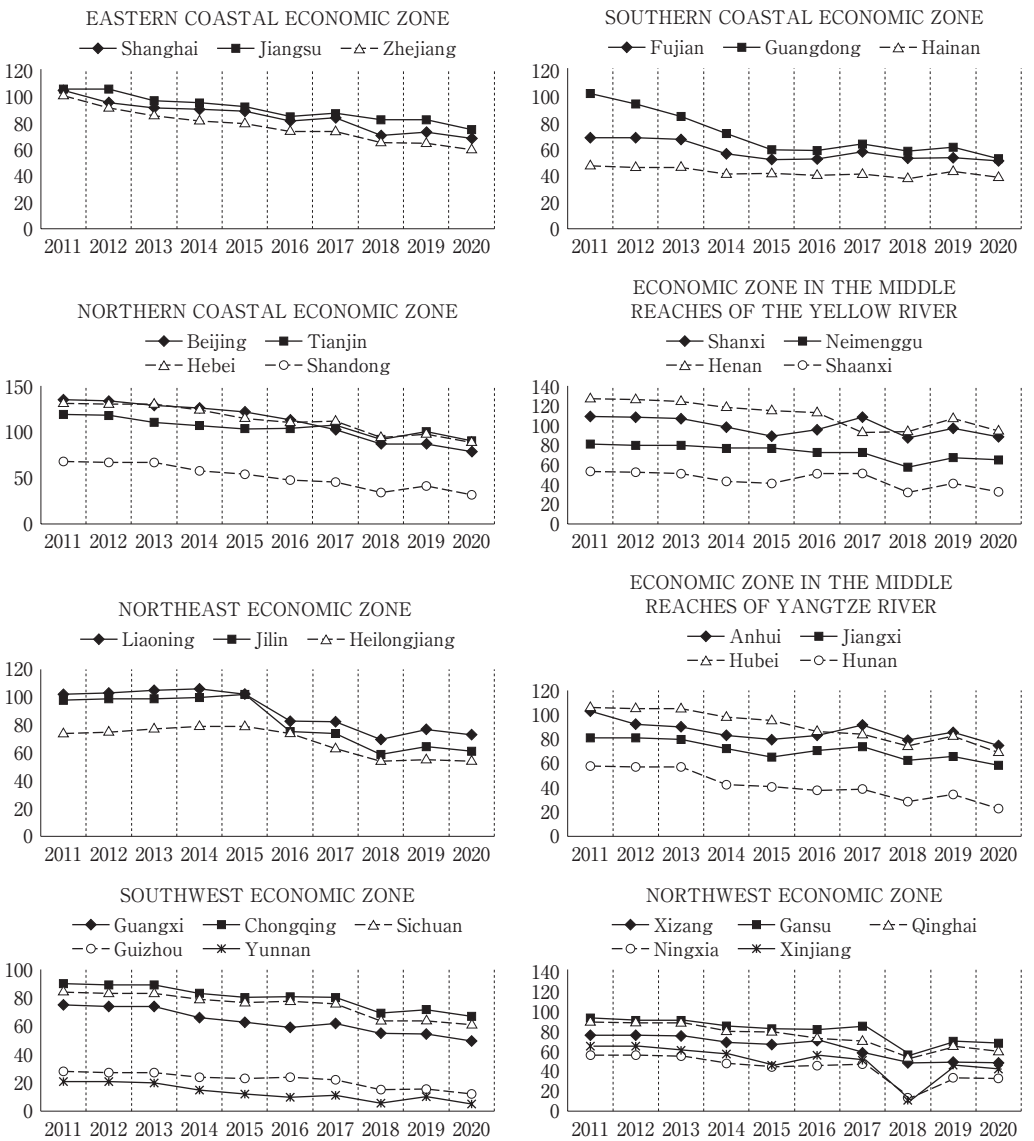
Lu, C., Liu, H.-C., Tao, J., Rong, K., & Hsieh, Y.-C. (2017). A key stakeholder-based financial subsidy stimulation for Chinese EV industrialization: A system dynamics simulation. Technological Forecasting and Social Change, 118, 1–14. https://doi.org/10.1016/j.techfore.2017.01.022

Sierzchula, W., Bakker, S., Maat, K., & Wee, B. van. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. Energy Policy.

Wang, W., Chai, F., Ren, Z., Wang, X., Wang, S., Li, H., Gao, R., Xue, L., Peng, L., Zhang, X., & Zhang, Q. (2019). Process, Achievements and Experience of Air Pollution Control in China Since the Founding of the People's Republic of China 70 Years Ago. Research of Environmental Sciences.

Appendix

Appendix 1 AQI in Eight Economic Zones in China from 2011 to 2020



Appendix 2 NEV Penetration in Eight Economic Zones in China from 2011 to 2020