World Scientific Research Journal Volume 6 Issue 5, 2020
ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

# Strength Evaluation of Incentive Policies for New Energy Vehicles: A Case Study Based on 19 Cities in China

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## Abstract

**Developing new energy vehicles (NEVs) has been a trend in the transportation industry. In China, the central government and local governments have introduced a series of incentive policies to promote NEVs. By investigating 19 large and medium-sized cities in China, this paper analyzes the characteristics and evaluates the strengths of these policies. First, we summarize the incentive policies from 2010 to 2015 and divide them into explicit and implicit policies. Then, we establish models to assess the strengths of these policies. The results show that, explicit policies were implemented earlier and were widely applied, mainly appearing as purchase subsidy (PS). In contrast, implicit policies were implemented late and were distributed within a small range, showing diverse incentive modes. Moreover, the strength of explicit policies was stronger than that of implicit policies. The research conclusions are favorable for improving the incentive policies for NEVs.**

## Keywords

**New energy vehicles; Strength evaluation; Implicit policies; Explicit policies.**

## 1. INTRODUCTION

In the past 50 years, the world's transportation industry has developed rapidly, accelerating global greenhouse gas (GHG) emissions (White and Sintov, 2017). According to the statistics, 17% of global GHG emissions are generated by road transportation (UFCCC, 2018). Facing the climate change, many countries try to replace oil with environment-friendly fuels (Hao et al., 2017). Developing new energy vehicles (NEVs) has been a trend (Gopal et al., 2018; Weiss et al., 2015). Major global economic entities have proposed development targets and plans for the NEV industry and issued a series of incentive policies.

Since 2009, China's automobile productions and sales have ranked first in the world for nine consecutive years. And as a major automobile consumer, China actively addresses global climate change issues. In 2009, China's government launched the "Ten Cities and Thousand Vehicles" project, and subsidies were provided for 13 pilot cities centered on public service. The demonstration and promotion of NEVs were implemented (MOF and MOST, 2009). Subsequently, governments adjusted the range and intensity of subsidies. In 2010, the pilot work on the promotion of NEVs began to enter the private field: five cities, including Hangzhou, Shanghai, Shenzhen, Hefei, and Changchun, started the pilot work on subsidising private NEV consumptions, lasting for three years (MOF et al., 2010). Governments tried to encourage the private consumption with incentives based on purchase subsidy (PS). In 2013, the first round of the promotion work in pilot cities ended and the governments decided to further promote NEVs. The Chinese government released two batches of lists concerning NEV promotion and application cities (city groups) in November 2013 and January 2014, including 39 city groups, making a total of 88 cities (MOF et al., 2013). It marks a shift in the application of incentive

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

policies issued by central government from the pilot application to the popularization nationwide.

With the promotion of policies from the central government, local governments released corresponding incentive policies. In 2010, the five pilot cities proposed subsidy schemes: apart from the subsidy provided by central government, local finance departments offered an extra purchase subsidy (PS) to consumers. Later in 2013, to increase the convenience of NEVs, local governments enriched their policies and proposed multiple policies, including releasing dedicated license plates of NEVs, free parking, and no driving restrictions, etc.

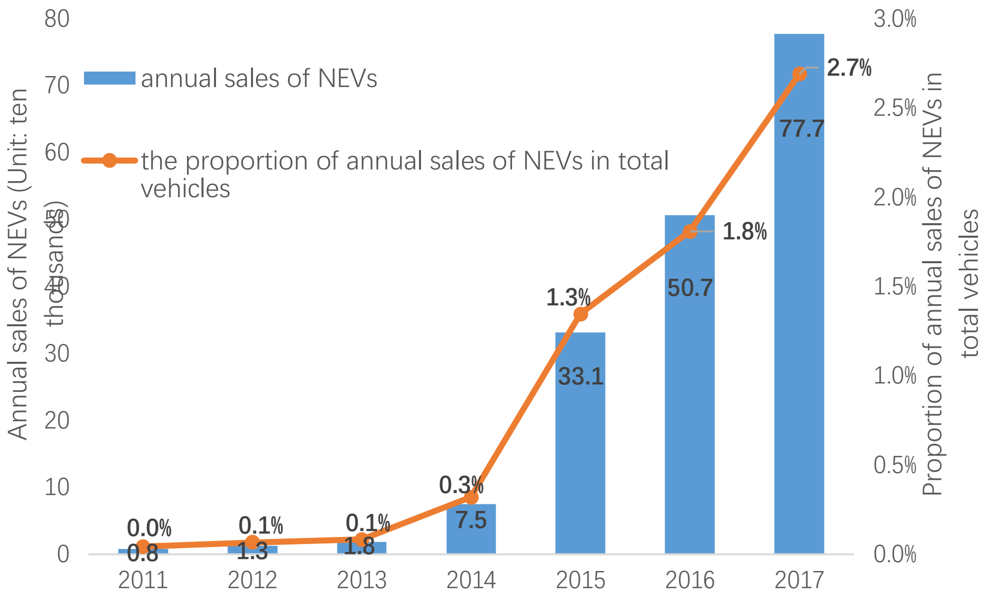


**Figure 1.** Annual sales of NEVs and the proportion in total vehicles

Source: China Association of Automobile Manufacturers: http://www.caam.org.cn/.

However, the commercialization of NEVs remains poor. According to the China Association of Automobile Manufacturers, the proportions of annual sales of NEVs among all automobiles during 2010-2017 were lower than 3% (Figure 1). NEVs have not been widely accepted in the private domain despite the NEVs promotion for many years (Xiong and Chen, 2017). This reality raises the questions: How many subsidies the NEV consumers can get from these policies? Are these policies truly effective? Therefore, it is necessary to analyze the application of the incentive policies and the strength of those policies.

In China, the private consumption of NEVs is concentrated in large- and medium-sized cities, and the incentive policies are mostly applied in large- and medium-sized cities. We select 19 large and medium-sized cities in China as target cities, including Beijing, Guangzhou, Hangzhou, Shanghai, Shenzhen, Suzhou, Xi'an, Chengdu, Dalian, Haikou, Hefei, Shenyang, Tangshan, Tianjin, Wuhan, Xiangyang, Changchun, Zhengzhou and Chongqing. Considering that the inventive policies mostly aim at BEVs and PHEVs and the consumptions of this two types of NEVs account for a large proportion of NEVs, this paper focuses on the incentive policies for BEVs and PHEVs.

The contributions of this paper are reflected in the following three aspects: firstly, the incentive policies for NEVs released by the central and local governments are collated to show the distribution characteristics of different policies. Secondly, the policies are divided into explicit policies and implicit policies. Thirdly, the models for evaluating the policy strengths are established, intuitively showing the differences in strength between the two types of policy.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

## 2. LITERATURE REVIEW

NEVs and its promotion attract scholars' attention (Hardman et al., 2016; Musti and Kockelman, 2011; Nordlund et al., 2018). Some studies sort out the incentives policies for NEVs. These policies include: purchase subsidies, tax exemption, subsidies for charging facilities, free parking, charging discounts, etc. (Bahamonde-Birke and Hanappi, 2016; Gnann et al., 2015; IREA, 2012).

Some studies focus on these incentive policies (Morton et al., 2017; Taefi et al., 2016). There are two types studies. The first type aims at the relationship between policy effects and policy implementation with econometric models (Chandra et al., 2010). Jenn et al. (2013) uses econometric methods to study the effectiveness of the Energy Policy Act of 2005 in USA based on the sales of HEV market during 2000 to 2010. The result shows that the incentive policies effectively increase the purchase amount of HEVs, but the incentive effect is significant only when the subsidy amount is high enough. From the global perspective, Sierzchula et al. (2014) examines the relationship between policy instruments and NEV market shares in 30 countries based on linear regression analysis. Similar studies include Lieven (2015), Contestabile et al. (2017) and Palmer et al.(2018).

The second type of study is based on questionnaires. Generally, scholars catch consumers' attitudes towards incentive policies through surveys at first and then explore the direction of developing policies based on the results (Shin et al., 2012). For example, Rudolph (2016) conducts a stated choice experiment among 875 German consumers to investigate the effect of five incentives policies. Bjerkan et al. (2016) describes the impact of incentives for promoting BEVs in Norway, and proves that the exemptions from purchase tax and VAT are critical for the most consumers. With a stated choice experiment, both Helveston et al. (2015) and Tanaka et al. (2014) compare consumers' preference on NEVs between different countries, and analyze the influence of incentive policies. Similar studies include Ziegler (2012), Jones et al.(2013), Hackbarth and Madlener (2016), Cherchi (2017) and Kwon et al.(2018).

With the development of China's NEV industry and the improvement of supporting policies, the incentive policies of China's NEVs becomes a hot topic for scholars (Ou et al., 2018; Wang et al., 2017c; Wells and Lin, 2015; Zheng et al., 2012). From the perspective of qualitative analysis, Zhang and Qin (2018) sorts out China's NEVs policies from 2010 to 2016, and describes the "plan-pilot-promotion-subsidy-development" process of China's NEV policy implementation. From the perspective of quantitative analysis, Wang et al. (2017) studies the factors affecting the promotion of NEVs based on the promotion data during 2013-2014. Ma et al.(2017) uses a multivariate co-integration model and an error correction model to study the effects of NEV policies in both a long term and a short term. In addition, some scholars study the impact of China's NEV policies on consumers' willingness to purchase through questionnaire survey. For example, with a survey in 10 of the first promotion and pilot cities of EVs in China, Wang et al.(2017) finds that the convenience policy measures are the most important policies to enhance consumers' adoption intention. Similar studies include Cherry et al., (2016), Zhang and Bai (2017), and Xiong and Li (2018).

Above studies have proved that incentive policies have a positive effect on NEVs promotion (Whitehead et al., 2014). However, the incentive policies which are empirically studied in the previous studies are usually purchase subsidies and tax exemption policies, and other policies (for example, free parking) are often not included in the empirical study. Even if some studies concern about those policies, they usually use dummy variables to show how the policy applications are, but the amounts of incentives from those policies are not calculated and presented (Zhang et al., 2013). Based on the previous studies, our study not only sorts out the NEV policies issued by the central government and local governments, categorizes them into two categories, "explicit" and "implicit" policies, but also evaluates the strengths of these

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

policies with different models, directly presents and compares the policy strengths of 19 China's cities with calculated results in the form of numbers.

## 3. REVIEW OF INCENTIVE POLICIES FOR NEVS

From the perspective of consumers, subsidies are classified into two kinds: explicit subsidy and implicit subsidy. The former refers to the currency subsidy provided by the government for consumers to increase the incomes of consumers; the latter denotes a certain subsidy offered by government for stakeholders except for consumers so that consumers can purchase commodities at a lower price. According to the explanations above, we see that explicit subsidy benefits consumers in the terms of currency, which means consumers clearly understand how much money they will be given from the policy. And the direct targets of implicit subsidy are not consumers but other social stakeholders, which means consumers will face the final consequence (lower price) without getting money. Based on the idea of explicit subsidy and implicit subsidy, we classify the incentive policies into two types: explicit policy and implicit policy (Figure 2).

Explicit policy in this study refers to the policy which state the subsidy amounts in official files and consumers clearly understand how much they are benefited from the policy. This type of policy provides a certain amount of currency to the NEV consumers. These policies include purchase subsidies (PS), vehicle replacement subsidy (VRS) 1 , charging infrastructure construction subsidy (CIS), charging subsidy (CS)2, electric vehicle using subsidy (US), and extra subsidy (ES)3.

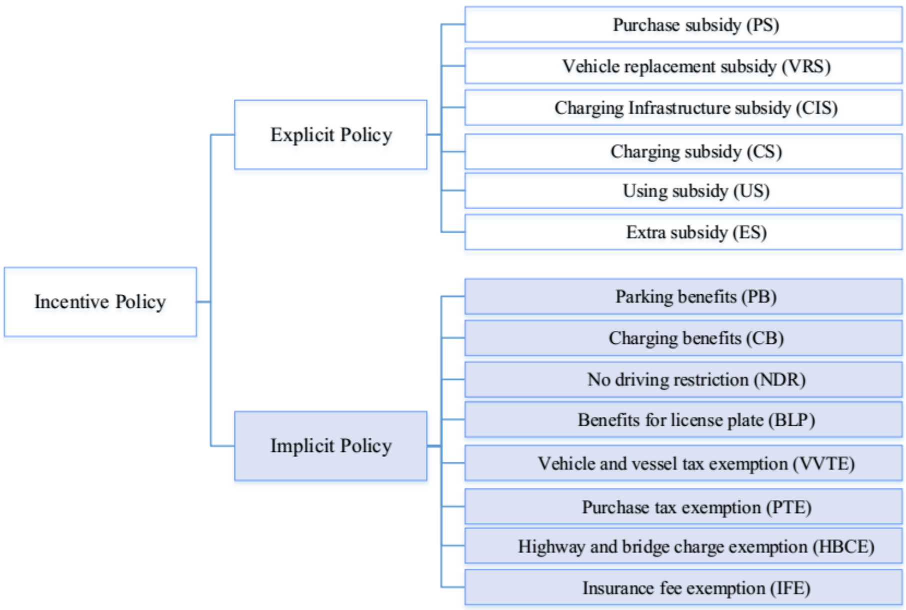


**Figure 2.** Classification of incentive policies for NEVs

1 Vehicle replacement subsidy (VRS) refers to a monetary subsidy offered by governments for those private persons who replace their own oil-fueled automobiles with NEVs.

2 Charging subsidy (CS) refers to the monetary subsidy provided by governments which reduces the charging cost of consumers. Consumers first pay for charging fees when they use the electric automobiles, and then apply for charging subsidy within stipulated time compensating for the previous expenditure for charging.

3 Extra subsidy (ES) refers to the monetary subsidy offered by governments, rewarding consumer NEV purchases.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

Implicit policy in this study denotes the policy which provides preference for consumers in different forms except directly giving money. There are two kinds of implicit policy. One is similar to the implicit subsidy. Consumers will not get currency from the policy, but will be able to get one NEV with less expenditure. This kind of implicit policies include charging benefits (CB)4, parking benefits (PB), benefits for license plate (BLP), vehicle and vessel tax exemption (VVTE), purchase tax exemption (PTE), highway and bridge charge exemption (HBCE), and compulsory insurance fee exemption (IFE). The other does not influence consumers' expenditure, but provides more convenience on using an NEV, like no driving restriction (NDR) 5.

## 3.1. Policies Launched by Central Government

As early as 2009, the Chinese Government issued the first incentive policy for NEVs, subsidising in public service domains. In 2010, subsidies entered the private sector. Afterwards, the incentive policies for NEVs were amended several times, and the objects, ranges, and amounts of subsidies were adjusted and refined.

The explicit policy of the central government appears mainly as PS. In 2010, five cities were designated as pilot cities for subsidising private consumers purchasing NEVs. According to the battery capacity, the central government provided PS (3,000 CNY/kW·h) for NEVs, and the subsidy for a BEV reached 60,000 CNY at most while that for a PHEV reached 50,000 CNY (MOF et al., 2010). Since 2013, incentive policies of the central government have been extended nationwide: The central government offered PS (ranging from 35,000 to 60,000 CNY) for a BEV whose cruise range exceeded 80 km and subsidized 35,000 CNY for a PHEV whose cruise range exceeded 50 km (MOF et al., 2013).

Since 2014, the central government has introduced a decreasing mechanism into PS and the subsidy standards for NEVs have been gradually reduced year by year. The subsidy standards in 2014 and 2015 respectively decreased by 5% and 10% compared with that in 2013 (MOF et al., 2013). From 2017 to 2018, the subsidy standards decreased by 20% compared with that in 2016, and from 2019 to 2020, the subsidy standards decrease by 40% compared with that in 2016. After 2020, the PS will be terminated (MOF et al., 2015).

The implicit policy issued by the central government includes VVTE and PTE. For NEVs, since 2012, the vehicle and vessel taxes have been exempted (MOF et al., 2012). From Nov. 1st, 2014 to Dec. 31st, 2017, vehicle purchase tax was exempted (MOF et al., 2014).

## 3.2. Policies Launched by Local Government

3.2.1 Explicit policies

The explicit policies issued by the local governments mainly aim at the purchasing part and the PS and VRS are the major forms. From 2010 to 2012, local governments of five pilot cities provided PS for consumers in addition to the subsidies from the central government. The amount of PS offered by local governments varied: Changchun provided the subsidy at 20% of the selling prices of NEVs and the maximum amount of subsidy for a single NEV was 45,000 CNY; four other cities provided PS according to the battery capacity. Hangzhou subsidized 2,000 to 3,000 CNY/kW·h and the maximum amount of subsidy per NEV was 60,000 CNY. Shanghai subsidized 2,000 CNY/kW·h and the maximum amount of subsidy per NEV was 40,000 CNY. Shenzhen subsidized each NEV 60,000 CNY at most with the standard of 1,000 to 2,000

4 Charging benefits (CB) takes preference on NEVs by exempting or reducing their charging fees.

5 Some large and medium-sized cities in China formulate traffic restriction policy to guarantee smooth daily transportation. Due to the NDR policy, NEVs are free from the traffic restriction policy.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

CNY/kW·h. Hefei subsidized each NEV 20,000 CNY at most with the standard of 1,000 CNY/kW·h. Additionally, Hangzhou and Hefei provided VRS at 3,000 CNY for the consumers who replaced oil-fueled automobiles with NEVs.

During 2010-2012, only Hangzhou formulated other explicit policies apart from PS and VRS. Hangzhou additionally offered CS at 0.09 CNY/km for NEV consumers, and the subsidy lasted for at most three years or 60,000 km. Taking the 60,000 km limit for instance, Hangzhou provided each NEV with CS of 5,400 CNY.

In addition, although Beijing was not a pilot city covered by the policies of the central government, it actively issued subsidy policies, and offered PS of 60,000 CNY for consumers from local financial departments during 2010 to 2012.

Since 2013, Beijing and the five pilot cities have constantly provided PS apart from the subsidies of the central government. The other thirteen cities also successively released PS schemes: in addition to the subsidy from the central government6, the extra PS provided by local governments for the BEVs whose cruise range exceeded 80 km and the PHEVs whose cruise range exceeded 50 km. For example, in 2013, the local governments of nine cities (Guangzhou, Suzhou, Dalian, Haikou, Shenyang, Tianjin, Xiangyang, Zhengzhou, and Chongqing) started providing the extra PS. Moreover, the local governments of Xi'an, Tangshan, and Wuhan started providing the extra PS in 2014 while Chengdu started in 2015.

During 2013 to 2015, the amounts of extra PS provided by local governments varied. For example, local governments of eight cities (Beijing, Xi'an, Tianjin, Wuhan, Xiangyang, Changchun, Zhengzhou, and Chongqing) provided an extra PS with the same standards of the central government. Dalian, Haikou, Shenyang, and Tangshan set the amounts of the extra PS as 80%, 60%, 90%, and 50% of the PS from the central government, respectively. Hefei subsidized each NEV 10,000 CNY in 2013, and subsidized with the same standards of the central government since 2014. In addition, the amounts of the extra PS in five cities (Guangzhou, Hangzhou, Shanghai, Shenzhen, and Suzhou) were not determined by the amount of the central government's subsidies. According to the cruise ranges, Guangzhou and Shenzhen provided an extra PS of 35,000 to 60,000 CNY while Suzhou7 provided extra PS of 46,000 to 71,000 CNY. In Hangzhou and Shanghai, 30,000 and 40,000 CNY were also subsidized respectively.

After 2013, local governments implemented abundant incentive policies and applied more explicit policies at the part of using NEV. For example, Shenzhen started US in 2013, Xi'an started VRS and CIS in 2014, Shenyang started VRS in 2014, and Hefei started CIS in 2015.

3.2.2 Implicit policies

The local governments formulated implicit policies late, and most cities implemented implicit policies after 2013. Before 2013, only six cities issued implicit policies. For example, Chongqing implemented HBCE during 2010-2012 while Shanghai started BLP in 2010. Hefei started PB in 2012 while Tianjin and Changchun started NDR in 2012. After 2013, seven cities (Suzhou, Dalian, Haikou, Shenyang, Tangshan, Xiangyang and Zhengzhou) did not apply local implicit policies and the other twelve cities implemented implicit policies with different combination modes. Xi'an and Hefei synchronously implemented three implicit policies, including PB, BLP and IFE. Wuhan also simultaneously implemented three implicit policies, including CS, NDR, and HBCE. Beijing, Hangzhou, Shenzhen, and Tianjin synchronously implemented two implicit

6 Since 2013, PS provided by the central government has been extended nationwide from the five pilot cities.

7 The extra PS was offered by provincial and municipal financial departments. The provincial finance subsidized at 25,000 yuan per NEV, and the municipal finance subsidized between 21,000 to 36,000 CNY according to the cruise range.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

policies while Guangzhou, Shanghai, Changchun, and Chongqing conducted single implicit policy.

# 4. STRENGTH EVALUATION OF INCENTIVE POLICIES

## 4.1. Evaluation Models and Parameters

As introduced hereinbefore, the central and local governments issued many incentive policies during 2010-2015 to encourage private consumers to purchase NEVs. Hereinafter, the strength of these policies will be evaluated.

Absolute total strength (ATS) is measured by the actual value of available subsidy for an NEV, that is the sum of all available allowances for an NEV benefiting from all policies in a city. It includes absolute explicit strength (AES) and absolute implicit strength (AIS). It is expressed as formula (1):

$$ATS = AES + AIS \tag{1}$$

AES and AIS are separately measured by the actual value of available allowance for an NEV benefiting from explicit and implicit policies. According to the classification of policies (Figure 2), explicit policies include PS, VRS, CIS, US, CS and ES. Implicit policies include PB, CB, NDR, BLP, VVTE, PTE, HBCE and IFE. So, AES and AIS is calculated by formula (2) and (3) respectively.

$$AES = PS + VRS + CIS + US + CS + ES \tag{2}$$

$$AIS = PB + CB + NDR + BLP + VVTE + PTE + HBCE + IFE \tag{3}$$

The value of allowance for an NEV from explicit policies has been accurately stated in the policies, but the value of allowance for an NEV from implicit policies should be estimated through different means. In the following context, the evaluation models for the values of allowance benefiting from implicit policies will be introduced.

4.1.1 Parking benefits (PB)

The value of allowance benefiting from PB is obtained by estimating the exempted parking fee of NEVs. It is expressed as:

$$PB = P_P \times T_y \tag{4}$$

Among them, $P_P$ represents the parking price per hour per car, and $T_y$ represents the maximum hours that PB covers every year.

$P_P$ is presented by the mean of the highest and the lowest hourly parking prices in a city. And, it is assumed that an NEV travel and park in public areas 360 days every year. Then, $T_y$ is the product of the maximum hours that PB covers a day ($T_d$) and the travelling days a year (which is assumed as 360). It is expressed as:

$$T_y = T_d \times 360 \tag{5}$$

4.1.2 Charging subsidy (CB)

The subsidy value of CB are acquired by estimating the exempted charging fees of NEVs. It is expressed as:

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

$$CB = P_E \times E \times D \tag{6}$$

Among them, $P_E$ represents the charging price per kW·h. $E$ represents the power consumption of a single NEV per kilometer, and $D$ denotes the driving mileage of a single NEV every year.

$P_E$ is presented by the mean of the highest and the lowest prices of charging fees. And, it is assumed that an EV consumes 20 kW·h electricity per 100 km, and the annual driving mileage is 20,000 km.

4.1.3 No driving restriction (NDR)

In China, to reduce the traffic pressure and the emission of environmental pollutants, many large- and medium-sized cities have enacted a traffic restriction policy based on the last digit on the license plates, including restriction mechanisms based on odd- and even-numbered license plates8 and restriction mechanisms based on the actual number of the last digit on license plates9. During 2010-2015, the cities, which applied traffic restriction policy and NDR, included Beijing, Chengdu, Tianjin, Wuhan, and Changchun.

Traffic restriction policy limits the decision-making of oil-fueled vehicles drivers and reduces consumers' satisfaction. The vehicle owner whose automobile is under traffic restriction needs another same car within restriction duration if he wants to take a self-drive journey. It means that they need at least one more homogeneous vehicle. In contrast, the NEVs owners are free from the restriction and save the expense of purchasing one more homogeneous vehicles. The saved expense is the subsidy benefiting from NDR.

The subsidy benefiting from NDR is estimated by the model established by Diao et al.(2016), which is expressed as:

$$NDR = \frac{P_V}{d-1} \tag{7}$$

Among them, $P_V$ represents the price of NEVs, which is the manufacturers' suggested retail price. $d$ represents the frequency of driving restriction, which means the drivers are restricted every $d$ days.

In the NEVs market, the shares of BYD-Qin and E-series of Beijing Automotive Group (BAIC Group) take the leading position. In 2015 and 2016, both of them ranked the top three in China in terms of sales volume among all NEVs. Therefore, the NEVs of BYD-Qin and E-series of BAIC Group are taken as the representative NEVs. The average prices of them are $P_V$. According to formula (7), the value of subsidy benefiting from NDR is calculated.

4.1.4 Benefits for license plate (BLP)

In China, a consumer need a license plate for the motor vehicle after purchasing. Therefore, the rationing of license plates to vehicles is an important means for local governments to relieve urban traffic pressure. Since the 1980s, Shanghai has implemented an auction mechanism for sales of license plates. In 2011, Beijing began to restrict vehicle registration by employing a lottery mechanism. Since 2012, Guangzhou, Tianjin, Hangzhou, and Shenzhen have also successively introduced restrictions on license plates and consumers can acquire a quota of

8 The vehicles with an odd last digit can only travel on odd-numbered dates while those with an even last digit can only travel on even-numbered dates.

9 Cities release the restricted number of the last digit on license plate every day in advance, in which generally two or three numbers are restricted.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

license plate through auction or lottery10. Both the auction and the lottery mechanism cause consumers' costs. The former requires consumers to pay for auction fee while the latter takes consumers time. Additionally, consumers have to pay for the material cost of license plates when their motor vehicles are registered.

To promote NEVs, some local governments stipulate that the NEVs owners enjoy a preferential policy when applying for license plates. Since 2010, Shanghai has released dedicated free license plates for private NEVs and therefore consumers are free from the auction cost. Since 2012, an NEV could be registered in Guangzhou without a lottery or an auction. Since 2014, the lotteries for NEVs in Beijing have been conducted separately and the average demand-to-offer ratio of lotteries of NEVs was larger than 90%, which was far larger than that for oil-fueled vehicles. Since 2014, an NEV could be registered in Tianjin and Hangzhou for without a lottery or an auction. Additionally, since 2014, NEV consumers in Xi'an and Hefei have saved the material cost of 125 CNY while registering.

The value of allowance from BLP is obtained by estimating the saved cost of NEV consumers during license-plate registration. There are three specific modes of BLP: exempting the material cost of license plates ($M$), exempting the auction process ($A$) and the lottery preference ($L$). The subsidy values of BLP in the cities that use single mechanism (auction or lottery) are estimated according to formula (8) while that in the cities where use both the auction and the lottery mechanisms are calculated according to formula (9).

$$PL = F + A + L \tag{8}$$

$$PL = F + \frac{1}{2} \times (A + L) \tag{9}$$

If a city does not implement an auction mechanism, $A$ is 0; and if it uses an auction mechanism, the allowance of $A$ is the saved cost of auction for NEV consumers, which is equal to the average transaction price of the auction every year. If a city does not implement a lottery mechanism, $L$ is 0; and if it uses a lottery mechanism, the subsidy from $L$ is equal to the saved cost of waiting for a lottery for NEV consumers.

We assume that consumers rent a car to satisfy their needs of self-drive travel before they successfully get a lottery, and thus the available subsidy from $L$ is equivalent to the saved car-renting cost due to the shortened duration of a lottery. Therefore, according to formula (10), the available subsidy from $L$ can be estimated.

$L = E(t) \times P_R (10)$

In which, $E(t)$ represents the average waiting time for a lottery, $P_R$ represents the annual renting price per car. The longer the average waiting time is, the larger the $L$ is; the shorter the average waiting time is, the smaller the $L$ is.

Hou et al. (2013) has used duration models to estimate the average waiting time for a lottery in Beijing. And we employ this model to calculate the average waiting time for a lottery $E(t)$ in each city. Set $F(t)$ as the distribution function of the waiting time for a lottery, whose probability density function is $f(t)$. In addition, it is supposed that $\lambda(t)$ is the hazard function, which means that the consumer has not gotten a lottery since period $t$, and during period $t$ to $t + h$, the lottery rate is $\lambda(t) = \lim_{h \to 0} \frac{Pr(t \le T \le t+h)}{h}$. So, the probability density funcition of the

10 The restriction policy for license plates has been implemented in Guangzhou, Tianjin, Hangzhou, and Shenzhen since 1 August 2012, 16 December 2013, 25 March 2014, and 29 December, 2014, respectively.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

waiting time for a lottery is $f(t)=\lambda(t)exp(-\int_0^t \lambda(s)ds)$, and the average waiting time for a lottery is $E(t)=\int_0^\infty tf(t)dt$.

Based on the assumptions and model above, when the lottery rate is p, the hazard function is:

$$\lambda(t)=(1-p)^t p \tag{11}$$

The probability density function of the waiting time for a lottery is:

$$f(t)=(1-p)^t pe^{\frac{p[1-(1-p)^t]}{ln(1-p)}} \tag{12}$$

The average waiting time for a lottery is:

$$E(t)=\int_0^\infty tp(1-p)^t e^{\frac{p[1-(1-p)^t]}{ln(1-p)}}dt \tag{13}$$

In practice, consumers apply for the lottery in advance. We assume that consumers apply for lottery half a year before they purchase a car, and the demand-to-offer ratio that consumers actually face when they purchase a new car is represented with the average demand-to-offer ratio from July of the year before purchasing to June of the purchasing year. According to formula (13), we use MATLAB™ to calculate the average waiting time taken before winning a lottery in each year . Based on the monthly price of annual rent for economical cars in China's largest car rental website, the renting price is represented with the mean value of the highest and the lowest rent. Thus, according to formula (10), the available allowance from $L$ is calculated. On this basis, according to formula (8) and (9), the allowances brought by BLP is calculated.

4.1.5 Vehicle and vessel tax exemption (VVTE)

According to the Notice of Preferential Vehicle and Vessel Tax Policies for Energy-saving and New-energy Vehicles and Vessels, since 1 January 2012, the BEVs, PHEVs have been exempt from vehicle and vessel tax (MOF et al., 2012). Therefore, the subsidy benefiting from VVTE for a single NEV is equal to the exempted amount of vehicle and vessel tax.

According to the List of the Terms and Amount of Vehicle and Vessel Tax of 19 target cities, the average amount of vehicle and vessel tax in each city during 2013 to 2016 is represented with the mean value of the lowest and the highest tax amount of vehicle and vessel tax (with the determined passenger capacity less than nine) during the same period.

4.1.6 Purchase tax exemption (PTE)

According to Notice on Exempting the Vehicle Purchase Tax of New Energy Vehicles, BEVs, PHEVs has been exempted from vehicle purchase tax from 1 September 2014 to 31 December 2017 (MOF et al., 2014). Therefore, the subsidy from PTE for a single NEV is equal to the amount of exempted purchase tax.

Purchase tax is calculated according to price-based rate. The tax rate of purchase tax is fixed, and does not vary with the number of taxed objects. At present, the purchase tax rate is $\frac{1}{11.7}$ (State Council, 2000).The allowance benefiting from PTE for an NEV is calculated with formula (14).

$$PTE=P_V\times\frac{1}{11.7} \tag{14}$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

$P_V$ represents the price of the NEVs. Similar to Section 4.1.3, the representative prices of a NEV is represented by the average price of representative NEVs.

4.1.7 Insurance fee exemption (IFE)

According to government regulations, the compulsory insurance fee is 950 CNY every year and the insurance premium should be paid once a year (State Council, 2006). Therefore, the allowances benefiting from IFE in these two cities were both 950 CNY every year.

## 4.2. A Comparison of Strengths of Regional Policies

To show the influence of economic development level on the strength of policy, 19 target cities are divided into different groups according to the incomes of urban residents (see in Table 1).

**Table 1.** Cities in two regions with different levels of per capita disposable income

| Region | City |
|---|---|
| Region I (7 cities) | Beijing/ Guangzhou/ Hangzhou/ Shanghai/ Shenzhen/ Suzhou/ Xi’an |
| Region II (12 cities) | Chengdu/ Dalian/ Haikou/ Hefei/ Shenyang/ Tangshan/ Tianjin/ Wuhan/ Xiangyang/ Changchun/ Zhengzhou/ Chongqing |

According to the classification standard of National Bureau of Statistics of China (NBSC), urban residents are divided into five grades (low, medium-low, medium, medium-high, and high-income residents) according to per capita disposable incomes (PCDI). Based on the standard of the NBSC, the classification criterion for 19 target cities is shown as following: the city, where PCDI of urban residents is higher than medium-high income level, belongs to in high-income region (region I); and the city, where PCDI of urban residents is lower than medium-high income level, belongs to low-income region (region II).

In the first stage of demonstration and popularization of NEVs, the central government subsidised five pilot cities. And during 2010 to 2012, the five pilot cities actively issued supporting policies in addition to following the policy of the central government. As a result, policy strengths of the five cities were stronger than those of the other cities. The incentive policies in this stage were mainly explicit policies while few implicit policies were implemented, and PS was the major mode of explicit policies.

During 2013 to 2015, there were more diversified incentive policies being enacted but the policy strengths in different cities were different. Figure 3 shows ATS during 2013 to 2015, where ATS involves AES and AIS.

The ATSs of various cities are significantly different. In 19 cities, the minimum amount of ATS was about 85,000 CNY (in Tangshan) while the maximum amount was more than 320,000 CNY (in Beijing), and the average level was 147,500 CNY. ATSs of six cities were higher than the average level: the ATS of Beijing was up to 321,000 CNY, which was significantly higher than the average level; the ATSs of Tianjin, Shenzhen, Shanghai, Wuhan, and Guangzhou were larger than 170,000 CNY, which were much higher than the average level.

Volume 6 Issue 5, 2020
DOI: 10.6911/WSRJ.202005_6(5).0028

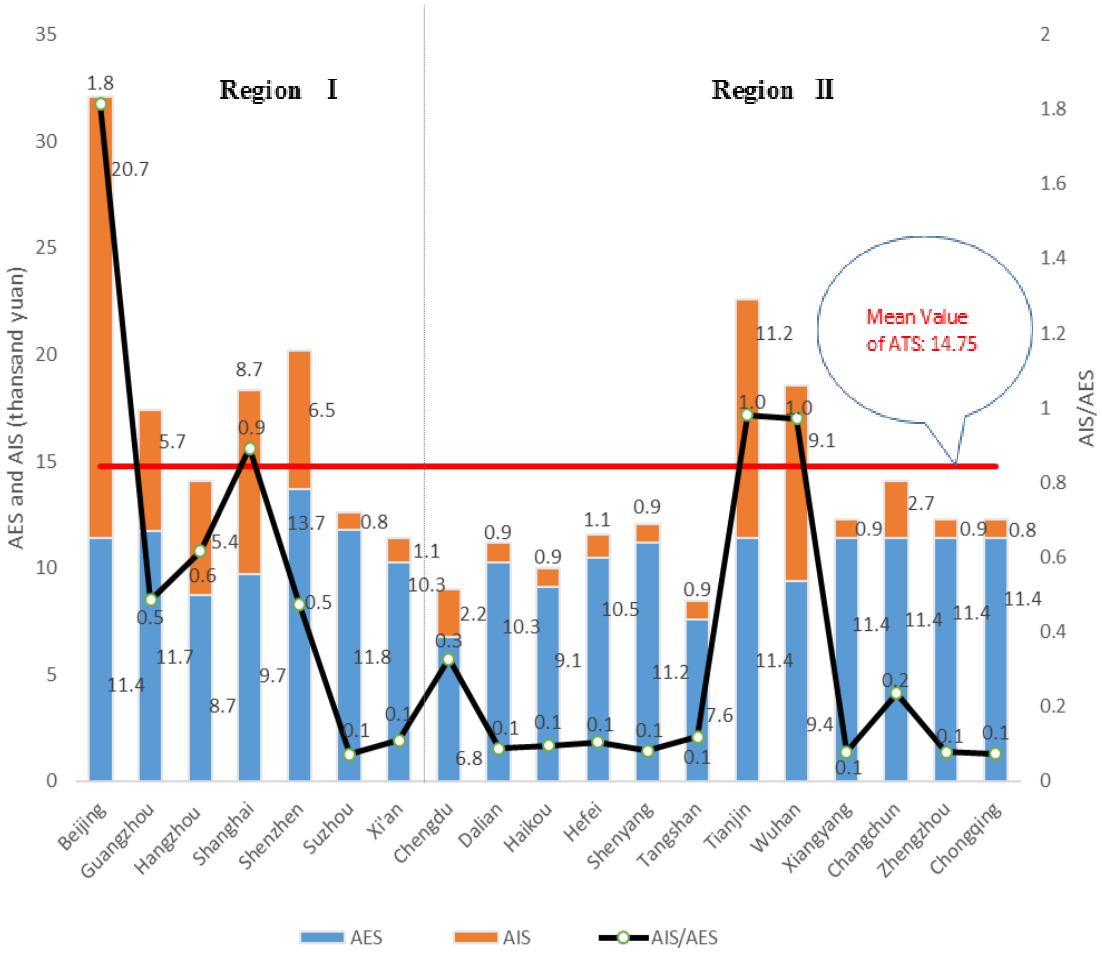


**Figure 3.** AES and AIS in 19 cities (2013-2015)

Note: The values of AES and AIS showed above are the average values of each during 2013-2015.

To reflect the difference between AES and AIS more directly, the relationship between the two parameters is reflected by the ratio of AIS to AES. As shown in Figure 3, the ratios of AIS to AES were all significantly less than 1 in a majority of cities during 2013 to 2015. The ratios were approximate to 1 in three cities (Shanghai, Tianjin, and Wuhan), and only in Beijing, the ratio was much greater than 1. This indicates that AES is greater than AIS in most cities in China.

In terms of AES, the amount of AES was ranged from 68,000 to 137,000 CNY. Shenzhen had the highest amount of AES (137,000 CNY), followed by Suzhou (118,000 CNY), and Guangzhou (117,000 CNY). Moreover, the AES in the other six cities (Beijing, Tianjin, Xiangyang, Changchun, and Chongqing) reached 114,000 CNY.

Explicit policies shows a single implementation mode. During 2013 to 2015, PS was still the most important mode in explicit policies. Since 2013, NEVs in 19 target cities have received PS from central government and the local governments. Only Shenzhen, Xi'an, Hefei, and Shenyang applied two or more explicit policies at that period.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

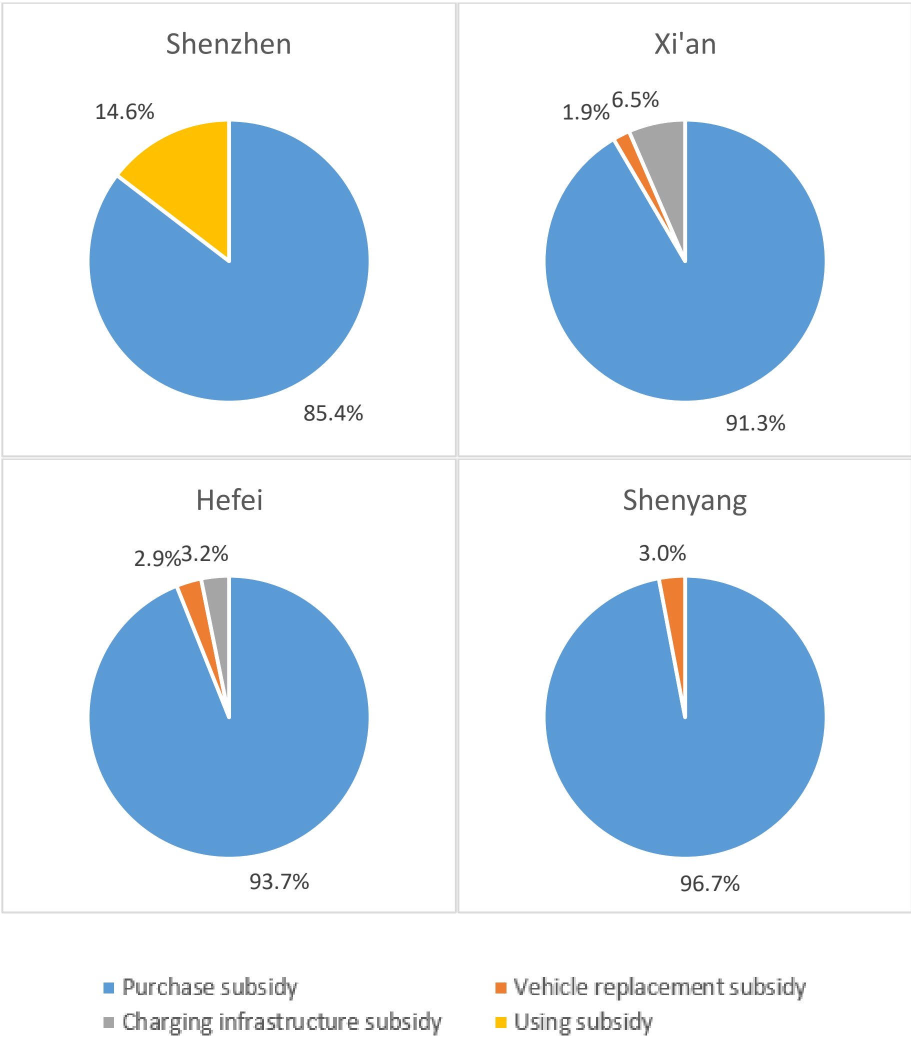


**Figure 4.** Explicit policies for NEVs in 4 typical cities

Figure 4 shows the compositions of explicit policies of the above four cities. Apart from PS, Shenzhen also offered a US of 20,000 CNY for NEV consumers. VRS was released in the other three cities while Xi'an and Hefei provided 10,000 CNY of CIS at one time. It's obvious that, PS was still the key mode although the four cities have applied different explicit policy combinations. The proportions of PS in AES were all greater than 85%. It can be seen that due to the long application time, wide application scope, and simple implementation process, PS is the most important one among explicit policies.In terms of AIS, the amount of AIS was between 9,000 and 207,000 CNY, and the difference between cities was significant (see in Figure 5).

ISSN: 2472-3703
DOI: 10.6911/WSRJ.202005_6(5).0028

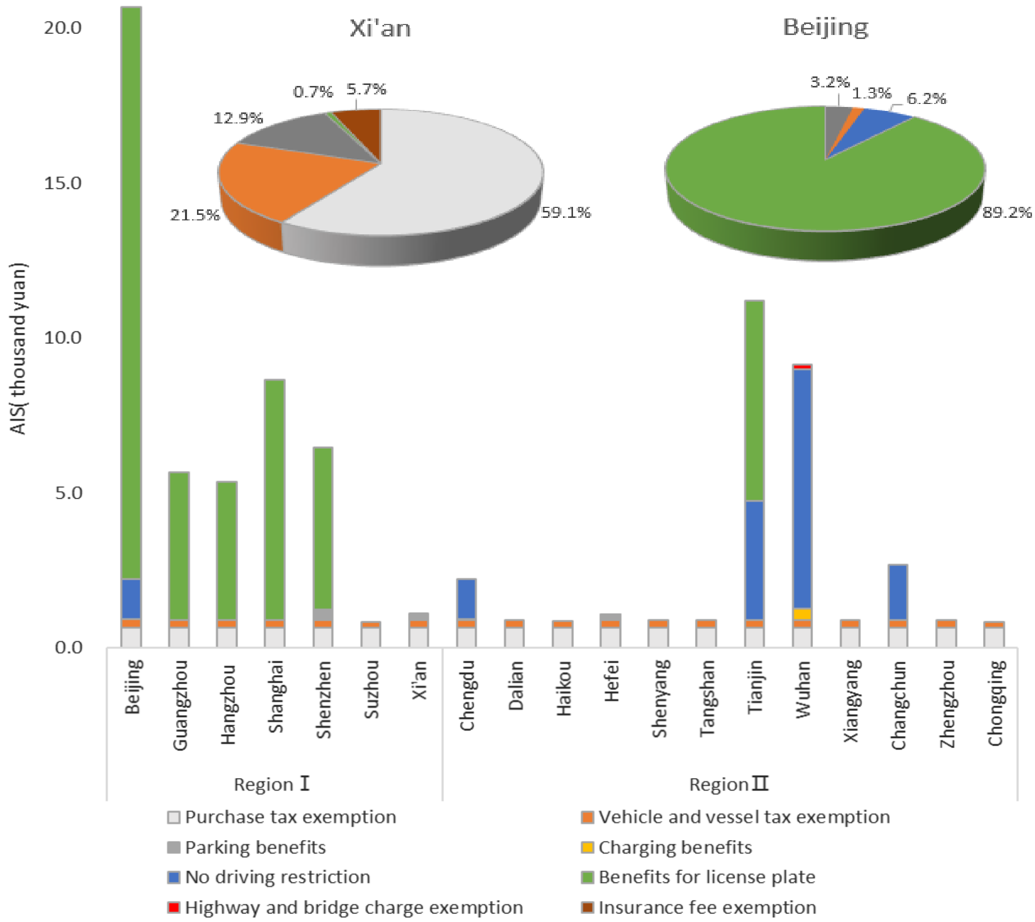


**Figure 5.** AIS in 19 cities

Among implicit policies, PTE and VVTE benefit NEV consumers in all cities with a fixed subsidy value. BLP and NDR are the main reasons for the difference in AIS between cities. Take Beijing and Xi' an, two cities in region I, as an example. BLP was the most important implicit policy in Beijing, which accounted for about 90% of AIS (206,900 CNY), but in Xi'an, BLP accounted for less than 1% of AIS (11,200 CNY). It's because the specific forms of BLP in the two cities were different: Beijing restricted the distribution of motor vehicles license plates while providing lottery preference for NEVs. The subsidy from BLP was greater than 200,000 CNY. In contrast, Xi'an did not restrict motor vehicle owners to apply for license plates and BLP only exempted the material cost of license plates for NEVs, for which the subsidy was about 125 CNY. That is, in the cities that restrict motor vehicle license plates, the cost of obtaining license plates is higher, which makes the strength of BLP stronger and eventually result in a higher AIS Therefore, although both Beijing and Xi'an belong to region I, the difference in BLP strength caused a significant difference in their AISs.

Among the cities that used BLP, the subsidy of BLP in Beijing was about 185,000 CNY which was far larger than those in the other cities. It was followed by that in Shanghai (about 78,000 CNY). In addition, BLPs in Hangzhou, Guangzhou, Shenzhen and Tianjin were in the range of 45,000 to 69,000 CNY, greatly reducing the consumption cost of NEVs.

Additionally, NDR is also an important reason for the difference in AIS between cities. For example, during 2013 to 2015, the private vehicles in Wuhan encountered driving restrictions every three days. The annual subsidy benefiting from NDR was about 77,000 CNY, which greatly increased the utility of consumers with NEVs.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0028

## 5. CONCLUSIONS AND POLICY SUGGESTIONS

By exploring 19 large- and medium-sized cities in China, we have analyzed the incentive policies for NEVs issued by both the central and the local governments during 2010 to 2015. The results show that: (1) Explicit policies were implemented early across a wide area with high strength, and mainly appeared as PS; (2) Implicit policies were implemented late and were implemented over a narrow range with weak strength, but the incentive modes were diversified. (2) BLP and NDR are the main reasons for the difference in the strength of implicit policies among cities.

To promote the NEVs, the following policy suggestions are proposed based on the aforementioned conclusions:

Firstly, enrich the incentive modes of explicit policy. At present, PS is the major incentive mode of explicit policy. However, the influence of monetary subsidy is temporary and it is difficult to engender a long-term incentivizing effect (Wang et al., 2017c). Kwon et al.(2018) proves that PS shows a certain effect on NEV consumers while its effect is less significant than that of the subsidies in the part of using NEVs. Therefore, enriching the incentive modes of explicit policies is meaningful to stimulate consumers to purchase NEVs.

Secondly, expand the applying area of implicit policies. Implicit policies in China are only implemented within a small range, and the strength of them is much lower than that of explicit policies. But implicit policies decrease the cost of NEVs consuming and improve the convenience of using NEV. Therefore, it is necessary to further improve the application of implicit policies.

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