Efficiency Evaluation of New Energy Light-duty Truck Policy in Major Cities of China

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Abstract. The electrification level of commercial vehicles in China has achieved remarkable development with the support of fiscal and tax policies. In this paper, 15 major cities are selected as samples, and the combined effect of national and local fiscal and tax policies is carefully assessed using the DEA model. The results show that: (1) the comprehensive efficiency of the sample cities is high, indicating that the current policy portfolio has achieved great efficiency in general. (2) Shenzhen, Chengdu and Shanghai are taking the lead in the promotion and penetration of new energy trucks, but the 3 cities fail to achieve the best overall efficiency, with lower scale efficiency and diminished returns to scale. (3) Most of the cities suffer input redundancy, and should further optimize the policy structure and synergy to ensure the efficient implementation of various policies.

1. Introduction

The parc of commercial vehicles in China is low but share of vehicle energy consumption and carbon emission is quite high. According to the internal estimation of Automotive Data of China, the carbon emission of vehicles in use in 2021 was about 900 million tons, of which emissions by commercial vehicles accounted for more than 50%. Accelerating the transformation of commercial vehicles into electric vehicles is an important technical path to save energy and reduce carbon emission in the transportation sector.

China has officially started the journey of vehicle electrification transformation from the campaign of promoting 1,000 NEVs in each of the 10 cities in 2009, and the national fiscal policy has always been an important driving force behind the transformation of commercial vehicle electrification. After the subsidy policy was withdrawn in 2018, the new energy truck segment began shrinking significantly. Thanks to the intensified strength of local policies such as traffic restriction and operating subsidies in the past 2 years, the market rebounded in 2021. As a whole, China's new energy commercial vehicle segment is still dominated by national and local policies, and the level of market-oriented development is still insufficient.

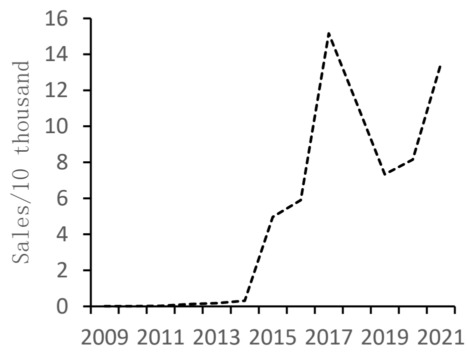

Fig. 1. Sales Trend of New Energy Trucks from 2009 to 2021 [**Source**:Owner-drawing]

At the nation level, the fiscal and taxation policies can benefit most people, mainly including the policies of subsidy, exemption from purchase tax and exemption from vehicle and vessel tax. At the local level, the overall planning, policy tools and strength of transformation of commercial vehicle electrification are also differentiated due to the different levels of economic development and city-based governance in each region. Among them, what has affected the electrification of commercial vehicles most include operation subsidies, electricity charge subsidies, right-of-way concession, infrastructure construction, etc.

As for the development of auto industry under the influence of policies, scholars both at home and abroad have conducted more extensive studies. An Tongliang et al. (2009) used a dynamic asymmetric information game model between enterprises and R&D subsidy policy makers to determine the incentive effect of R&D subsidies[1]. Yu Yingzhe (2015) analyzed the impact of policies upon technological innovation under the withdrawal of subsidy policy[2]; Li Shaoping (2016) used a multiple regression analysis model to study the R&D investments made by

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listed NEV enterprises under the influence of China's tax incentive policies[3]; Ma Liang (2018) established a corporate production decision model to analyze the impact of subsidy and restrictive policies upon the auto market, and the results showed that the joint effect of the restrictive policy and subsidy policy might lead to a decrease in the effect of subsidy policy, and the restrictive policy could be used as an alternative policy after the subsidy was withdrawn[4]. Hardman et al. (2017) compared and analyzed the relationship between fiscal and tax policies and NEV sales, and the results showed that the effect of tax relief was better than that of financial subsidies[5]. Sierzchula et al. (2014) studied various European countries and the result showed that active industrial policies and enhanced construction of infrastructure could play a significant role in boosting the EV (electric vehicle) market[6].

Previous studies have provided valuable references. However, the policy efficiency of various nation-level fiscal and local policies to promote the electrification transformation of commercial vehicles has been rarely studied. This, coupled with the fact that commercial vehicles, as a means of production, are extremely market sensitive, has made it necessary to carefully study the impact of various policies upon the commercial vehicle electrification market through researches.

Data Envelopment Analysis (DEA) is a non-parametric technical efficiency analysis method based on the relative comparison among evaluated objects, which is mainly divided into CCR model that assumes the returns to scale is invariable and BCC model that assumes the returns to scale is variable. This paper mainly adopts the DEA-BCC model to evaluate the policy input efficiency of 15 cities for the promotion of new energy trucks nationwide, with a view to provide references for the optimization of national and local decision-making and governance, and thus promoting the healthy and efficient development of new energy commercial vehicles in China.

2. Indicator Selection and Data Source

2.1. Indicator Selection

In this paper, 15 cities are used as the decision making units (DMU) of the DEA model to evaluate the efficiency of each city's NEV promotion policies. The input indicator refers to the input to the purchase incentive policy and use promotion policy when NEVs are promoted in a city. Output indicator refers to the marketization process of NEVs.

Table 1. Input and Output Evaluation Indicators

[**Source**:Owner-drawing]

Type	Tier-1 Indicator	Tier-2 Indicator	Indicator Description
Input Indicator	National Subsidy for the Promotion and Application of NEVs X1	—	∑Number of Vehicles * Subsidy per Vehicle
	National Purchase Tax Credit X2	—	∑Number of Vehicles* Purchase Tax per Vehicle
	National Preference of Vehicle and Vessel Tax X3	—	∑Number of Vehicles * Vehicle and Vessel Tax per Vehicle
	Local Policy Support X4	Operation Subsidy	Incentive funds granted by some local governments based on the number of new energy trucks and actual driving range.
		Right of Way Favor	∑Number of Vehicles * Average Freight Revenue per Hour * No Restriction on the Operating Duration of New Energy Trucks * Total Days of Traffic Restriction in a Year
		Reduction and Exemption of Electricity Charge	∑Number of Vehicles * Annual Charging Degree * Electricity Charge Discount
	Infrastructure X5	—	Construction Density of Charging Infrastructure
Output Indicator	Promotion Volume of New Energy Light-duty Trucks Y1	—	Annual Sales of Local New Energy Trucks
	Penetration Rate of New Energy Light-duty Trucks Y2	—	Annual Penetration Rate of Local New Energy Trucks

To propel the promotion of new energy light-duty trucks, the indicators of policy input include:

(1) National subsidies for the promotion and application of NEVs, which refers to the total amount of subsidies for promotion and application provided by the central government in accordance with the number of new energy light-duty trucks that are promoted by a city.

(2) National purchase tax credit, which refers to the exemption of purchase tax in accordance with the number of new energy light-duty trucks that are promoted by a city.

(3) National vehicle and vessel tax credit, which refers to the exemption of vehicle and vessel tax in accordance with the number of new energy light-duty trucks that are promoted by a city.

(4) Local policy support, which refers to the total investment of differentiated local policies in accordance with the number of new energy light-duty trucks that are promoted by a city, including the local operating subsidies, right-of-way concession and electricity charge reduction. The amount of local operating subsidies can be obtained according to the instruction indicated in the official

website of each city; right-of-way concession is measured according to the operating income obtained by new energy light-duty trucks that enjoy the differential right-of-way, and electricity charge reduction is measured according to the product of annual average kilowatt hours a new energy light-duty truck charges in a local city and discount for 1kWh electricity.

(5) Infrastructure, which refers to the density of infrastructure construction, and it mainly reflects the overall investment of national and local policies in creating a friendly environment for customers to use the new energy trucks.

Output Indicators Include:

(1) Number of new energy light-duty trucks that are promoted, and sales of new energy trucks in sample cities in 2021.

(2) Penetration rate of new energy light-duty trucks, and penetration rate of sample cities in the electrification of trucks in 2021.

2.2. Data Source

Currently, light-duty trucks play a very important role in electrification transformation. This paper selects the new energy trucks whose gross mass is not heavier than 4.5 tons as the research object, and takes the sales data as the number of vehicles in the region over the current year. For the amount of national finance and taxation, refer to the *Notice on Further Improving the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles (Caijian [2020] No. 593), Notice on Policies Related to the Exemption of Purchase Tax of New Energy Vehicles and Notice on the Policies Related to the Exemption of Vehicle and Vessel Tax of Energy-saving and New Energy Vehicles (Caijian [2018] No. 74)*. Local policies integrate local operating subsidies, right-of-way concession, and electricity charge subsidies. Construction data of charging infrastructure is based on the *2022 Annual Monitoring Report on the Charging Infrastructure of Major Cities across China*.

3. Empirical Analysis

3.1. Sample Data

This paper takes the new energy trucks as the main evaluation object of promotion policies. In order to reasonably evaluate the policy efficiency of different cities and objectively reflect the different policy effects of each city, the following 15 cities are selected based on the number of new energy trucks promoted in each city and support policies that have been released. The relevant policies and data collected according to the selected cities and corresponding indicators for accounting the inputs and outputs are shown in Table 2.

Table 2. Input and Output Data of New Energy Light-duty Trucks in Sample Cities in 2021

[**Source**:Owner-drawing]

No.	Application Cities	Input					Output	
		X1-National Subsidy/ RMB10,000	X2-Purchase Tax /RMB10,000	X3-Vehicle and Vessel Tax /RMB10,000	X4-Local Input /RMB10,000	X5-Infrastructure /(Unit/m^2)	Y1-Volume /Vehicle	Y2-Penetration Rate
1	Shenzhen	26379.23	16743.99	294.55	12382.62	118.6	16512	9.4%
2	Chengdu	18310.37	11653.08	200.68	8607.5	19	10329	11.9%
3	Guangzhou	12031.58	7642.56	147.66	7508.33	34.4	9010	5.5%
4	Shanghai	12628.43	8035.29	162.19	8676	49.9	8676	12.6%
5	Chongqing	10375.63	6602.10	114.26	8256.93	14.3	7062	6.9%
6	Suzhou	7793.65	4950.52	94.88	1887.98	9	5544	7.5%
7	Kunming	6327.19	4017.34	71.26	1642.05	12.7	3972	3.1%
8	Beijing	8977.07	5721.26	96.3	6066.67	19.4	3719	8.3%
9	Xi'an	5068.61	3212.02	57.99	1134.42	27.6	3167	4.5%
10	Xiamen	4005.95	2543.38	41.86	2955	24.5	2955	11.8%
11	Changsha	5329.755	3389.53	61.71	5766	32	2883	7.3%
12	Tianjin	3716.00	2370.09	43.47	3875.71	21.4	2713	2.7%
13	Zhengzhou	5142.17	3272.75	57.83	7800	20.5	2340	4.8%
14	Hangzhou	856.40	544.88	9.51	1812	23.2	604	1.4%
15	Jinan	373.01	241.76	4.3	6913	8.1	203	3.1%

3.2. Result Analysis

The calculation results are shown in Table 3 and Table 4. The average comprehensive efficiency of policy inputs of the 15 selected cities is 0.907, indicating that the policy input of these cities for new energy trucks are effective on the whole, and the average technical efficiency and average scale efficiency are 0.939 and 0.967 respectively, which are both at the high level.

(1) From the perspective of comprehensive efficiency of each city, the level of comprehensive efficiency among

different cities is quite different. Among them, 5 cities have the comprehensive efficiency of 1; they are Guangzhou, Chongqing, Suzhou, Xiamen and Jinan, boasting the highest policy efficiency and highly efficient DEA. The other 10 cities have the comprehensive efficiency of less than 1. Zhengzhou has the lowest comprehensive efficiency, which was only 0.622 and the policy effectiveness is lowest. In addition, Beijing and Changsha has the comprehensive efficiency of less than 0.8. The other cities are between 0.8 and 1.

(2) From the perspective of technical efficiency of each city alone, 11 of the 15 selected cities, including Shenzhen, Chengdu and Guangzhou, boast a technical efficiency of 1, indicating that various policy inputs have been highly utilized and key factors reasonably used in these cities. However, the technical efficiency of such 4 cities as Zhengzhou, Beijing, Changsha and Tianjin is less than 1. The current policy inputs of the 4 cities have failed to be effectively allocated and as a result unable to achieve the best output effect; among them, Beijing, Changsha and Zhengzhou saw their technical efficiency less than 0.8 and lower than the scale efficiency, indicating that it is necessary to enhance policy inputs in order to boost the promotion of new energy trucks. The technical efficiency of Tianjin is 0.995 and higher than its scale efficiency. It clearly indicates that Tianjin suffers a certain degree of resource redundancy, and it has failed to achieve the optimal allocation of policy inputs and outputs, therefore necessary to optimize the policy input structure so that the efficiency of policy input can be enhanced and promotion of new energy trucks can be furthered boosted.

(3) From the perspective of scale efficiency of each city alone, Guangzhou, Chongqing, Suzhou and Xiamen have a scale efficiency of 1, indicating that these 4 cities have reached the optimal returns to scale. The scale efficiency of 11 cities like Shenzhen and Chengdu is not optimal, among which, three cities, Shenzhen, Chengdu, and Shanghai, saw their returns to scale decreasing, indicating that the multiplier of output increase in these 3 cities is smaller than that of input increase, so they should appropriately reduce the scale of policy input and turn their attention to optimization of policy structure in order to achieve the optimal returns to scale; 7 cities, i.e. Kunming, Beijing, Xi'an, Changsha, Tianjin, Zhengzhou, and Hangzhou have increased their returns to scale, indicating that these cities may have insufficient input factors or unreasonable input structure, thus weakening the effectiveness of policy inputs. Therefore, they should appropriately enhance the scale of policy inputs or optimize the structure of policy inputs to further enhance the scale efficiency.

Table 3. Efficiency Values of Policy Effects of Sample Cities

[**Source**:Owner-drawing]

City	Technical Efficiency TE	Scale Efficiency SE(k)	Comprehensive Efficiency OE(θ)	Rewards to Scale
Shenzhen	1.000	0.879	0.879	Returns to Scale Diminishing
Chengdu	1.000	0.883	0.883	Returns to Scale Diminishing
Guangzhou	1.000	1.000	1.000	Returns to Scale Fixed
Shanghai	1.000	0.921	0.921	Returns to Scale Diminishing
Chongqing	1.000	1.000	1.000	Returns to Scale Fixed
Suzhou	1.000	1.000	1.000	Returns to Scale Fixed
Kunming	1.000	0.942	0.942	Returns to Scale Increasing
Beijing	0.704	0.994	0.700	Returns to Scale Increasing
Xi'an	1.000	0.998	0.998	Returns to Scale Increasing
Xiamen	1.000	1.000	1.000	Returns to Scale Fixed
Changsha	0.733	0.995	0.729	Returns to Scale Increasing
Tianjin	0.995	0.984	0.980	Returns to Scale Increasing
Zhengzhou	0.649	0.959	0.622	Returns to Scale Increasing
Hangzhou	1.000	0.951	0.951	Returns to Scale Increasing
Jinan	1.000	1.000	1.000	Returns to Scale Fixed
Mean Value	0.939	0.967	0.907	—

(4) From the perspective of input redundancy analysis, among the 10 non-DEA effective cities, Shenzhen and Kunming mainly have the input redundancy in 2 dimensions of national subsidy and purchase tax, with the amount of funds above RMB6 million, while 5 regions, i.e. Shanghai, Changsha, Tianjin, Zhengzhou and Hangzhou mainly suffer the problem of excessive local inputs, so they may reduce the strength of local policies appropriately in a short period of time and adopt the national fiscal policy as the main motivating measures, and with the withdrawal of subsidies, the local governments can enhance their inputs in capital investments and right-of-way so that the optimal efficiency can be achieved. 2 cities, Chengdu and Beijing, have redundancy in both national fiscal and taxation and local inputs, so it is necessary to further reduce policy strength and coordinate between local and national policies. From the perspective of output, the market promotion strength in Beijing seems slightly insufficient in the current year, while other regions have all done a very good job; Shenzhen, Chengdu and Kunming still need to make progresses in the penetration rate of NEVs.

(5) From the perspective of charging infrastructure construction, there is a certain redundancy in the investment of public charging piles in Shenzhen, and similar problems have also taken place in cities such as Xi'an and Hangzhou.

Table 4. Input Redundancy and Insufficient Output in Non-effective Cities

[**Source**:Owner-drawing]

	Input Redundancy-Analysis					Insufficient Output-Analysis	
City	X1-National Sub-sidy/RMB10,000	X2-Purchase Tax/RMB10,000	X3-Vehicle and Vessel Tax/RMB10,000	X4-Local Input/RMB10,000	X5-Infrastructure/(Unit/m^2)	Y1-Volume/Vehicle	Y2-Penetration Rate
Shenzhen	387.162	238.553	0.000	0.000	24.246	0.000	0.340
Chengdu	1638.915	1060.763	0.333	4078.794	0.000	0.000	0.021
Shanghai	0.000	13.436	11.972	399.785	3.170	0.000	0.000
Kunming	389.717	246.079	0.000	0.000	3.553	0.000	0.030
Beijing	548.067	361.873	0.000	2162.374	0.000	397.741	0.000
Xi'an	611.398	380.850	3.926	0.000	21.864	0.000	0.000
Changsha	0.000	3.624	1.352	1525.455	4.981	0.000	0.000
Tianjin	0.000	9.808	0.000	1394.561	6.819	0.000	0.018
Zhengzhou	0.000	3.748	0.000	2596.418	0.000	0.000	0.002
Hangzhou	0.000	1.013	0.000	1155.589	18.034	0.000	0.003

4. Conclusions

Avoid blind policy investment and drive the promotion of new energy trucks precisely and effectively. According to the conclusion of the model, the quantity of new energy trucks promoted in Shenzhen, Chengdu and Shanghai and their penetration rate are both taking the lead among 15 cities, but the 3 cities have all failed to achieve the optimal comprehensive efficiency, with low scale efficiency and diminishing returns to scale, and compared with other cities, they suffer the problem of policy input redundancy and failure to achieve the maximum policy input efficiency. Therefore, during the implementation of the follow-up policies, it is necessary to attach great importance to the evaluation of policy input efficiency, in order to make sure "precision irrigation".

Introduce the combination of central and local policies to boost the promotion of new energy trucks in a coordinated and efficient manner. In this study, the comprehensive efficiency of the 15 cities are all at a higher level, indicating that the current policy combination of "national fiscal and taxation support + local policy input" has achieved higher policy efficiency. As a result, the central and local governments still need to make concerted efforts, with a view to further accelerate the promotion of new energy trucks.

Adhere to the local conditions and take multiple measures to propel the promotion of new energy trucks. First, from the perspective of input redundancy analysis of the model, the redundancy can be found in the local policy inputs among the 10 cities whose comprehensive efficiency is less than 1, and one of the main reasons is that the structure of local policy input is unreasonable. Second, take Tianjin as an example. The city's technical efficiency is less than 1 but higher than its scale efficiency, mainly caused by its failure to make sure optimal allocation in its policy input structure compared to other cities. Therefore, in the purchase and using links, each local government should develop a more flexible and effective policy to promote the new energy trucks according to the real local situation.

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