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Efficiency Evaluation of New Energy Vehicles Policy in Major Cities of China Based on DEA

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Abstract. With the energy crisis and environmental problems becoming serious, the new energy vehicle industry has become one of the seven strategic emerging industries in China. Based on the input and output data of the NEV policy, this paper uses DEA method to quantitatively evaluate the relative input and output efficiency of the NEV policy in the selected 10 cities of NEV promotion and application. Through comparative analysis, it is found that Beijing, Shanghai and other cities have not achieved the optimal relative policy efficiency, and some suggestions are put forward to improve the policy efficiency.

1. Overview
As one of the seven strategic emerging industries, China's NEV industry has shown leapfrog development and has stably ranked No.1 in global sales volume for four consecutive years. At this stage, the brilliant achievements of China's NEV industry are inseparable from the huge policy inputs. Under the background of the prosperity of China's NEV industry, the promotion of NEVs in different cities is widely divergent due to the different environment and policy inputs between different provinces and cities. Therefore, the study of the relative efficiency of NEV policy inputs between cities is of great significance to lead the orderly, healthy and sustainable development of China's NEV market.

2. Index system construction

2.1 Selection of evaluation methods
Data Envelopment Analysis (abbr. DEA) is a common method used by experts and scholars at home and abroad to measure the efficiency, especially suitable for the efficiency evaluation of multi-variable inputs and outputs. When using DEA analysis method, there is no need to make assumptions on functions and distributions before analysis, nor does it need to give weight to various input and output variables, thus reducing the impact of subjective judgment on the results. Therefore, this paper also chooses DEA method to evaluate the policy efficiency of the NEV industry for analysis.

2.2 Design of evaluation system
The evaluation basis of DEA method is the input and output data of the decision-making unit. This paper mainly evaluates the efficiency of the NEV promotion policies in various cities. Therefore, the input index refers to the inputs of purchase incentive policies and use promotion policies when cities are promoting the use of NEVs. The output index refers to the marketization process, promotion and application environment and social derivative effect of NEVs.
Table 1. Evaluation Index System for NEV Policy Efficiency

| Category                  | Tier-1 index                                                                 | Tier-2 index                                                                 | Index meaning                                                                                     |
|---------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
|                            | Purchase incentive policy                                                   | Total vehicle purchase subsidy E1                                               | $\sum$ (the cumulative sales of vehicles meeting subsidy criteria * the subsidy per vehicle)        |
| Input index               | Purchase incentive policy                                                   | Total amount of vehicle and vessel tax exempted E2                            | $\sum$ (the cumulative sales of vehicles meeting the criteria of exemption from vehicle and vessel tax * the amount of vehicle and vessel tax exempted per vehicle) |
|                            | Use promotion policy                                                       | Total charging facility awards E3                                              | The total award amount for charging facilities is the award funds granted by the state to support the construction of charging infrastructure according to the number of NEVs promoted. |
|                            | Use promotion policy                                                       | Earnings from unlimited license plate and travel E4                           | Earnings from unlimited license plate = the cumulative amount of NEVs in cities with limited purchase policy * the lowest bid price of license plates |
|                            | Use promotion policy                                                       | Earnings from unlimited travel E4                                              | Earnings from unlimited travel = $\sum$ (the cumulative amount of NEVs in cities with limited purchase policy * the average daily driving range of NEVs * the cost of taxi ride per kilometer) |
| Output index              | Marketization process                                                      | NEV promotion scale F1                                                         | The cumulative promotion amount of NEVs                                                           |
|                            | Marketization process                                                      | NEV market penetration F2                                                      | The proportion of NEVs sales in total vehicle sales                                               |
|                            | Promotion and application environment                                       | Number of charging piles F3                                                    | The number of public charging infrastructure constructed by the end of 2017                      |
|                            | Promotion and application environment                                       | Pile-vehicle ratio F4                                                          | The ratio of the number of charging infrastructure constructed to the number of NEVs promoted     |

The input indexes for the purchase incentive policies include:

1) Total vehicle purchase subsidy, it refers to the total subsidy funds provided by the city to promote NEVs, including state subsidies and local subsidies.
2) Total amount of vehicle and vessel tax exempted, it refers to the total amount of vehicle and vessel tax exempted by local cities to promote NEVs.

The indexes for the use promotion policies include:

1) The total award amount for charging facilities, it refers to the award funds granted by the state to support the construction of charging infrastructure according to the number of NEVs promoted.
2) The earnings from the unlimited travel and purchase policy are divided into two parts, among which the benefit for NEV licensing is the exemption of NEVs from bidding for license plate and licensing cost; the earnings from unlimited travel of NEVs refers to the earnings brought by the unrestricted of NEVs from limited travel policy.

The output indexes of this study include the process of marketization and the promotion and application environment. For the specific indexes, see Table 1.

3. Empirical study on policy efficiency of NEVs in cities

3.1 City selection and data collection
This paper takes the efficiency of the NEV promotion policies as the main evaluation object. In order to scientifically evaluate the policy effect of different cities and objectively reflect different policy effects, this paper selects cities based on the following dimensions: 1) cities that have issued relevant support policies; 2) cities that have a certain amount of NEVs promoted. According to the data availability, the following 10 cities are selected as the research objects.

Table 2. City Selection for Policy Efficiency Evaluation

| City     | Characteristics                                                                 |
|----------|---------------------------------------------------------------------------------|
| Shanghai | Large promotion volume, limited license and travel policy, comprehensive policies, key area for air pollution prevention and control |
| Beijing  | Large promotion volume, limited license and travel policy, comprehensive policies, key area for air pollution prevention and control |
| Shenzhen | Large promotion volume, limited license and travel policy, comprehensive policies, key area for air pollution prevention and control |
| Hangzhou | Large promotion volume, limited license and travel policy, comprehensive policies, key area for air pollution prevention and control |
| Tianjin  | Large promotion volume, limited license and travel policy, comprehensive policies, and key area for air pollution prevention and control |
| Guangzhou| Medium promotion volume, limited license policy, comprehensive policies, and key area for air pollution prevention and control |
| Qingdao  | Medium promotion volume, developed economy, and comprehensive policies            |
| Changsha | Medium promotion volume, comprehensive policies                                  |
| Xi'an    | Medium promotion volume, comprehensive policies                                  |
| Chengdu  | Medium promotion volume, comprehensive policies                                  |

According to the selected NEV promotion cities, the input and output data of vehicle policies for cities by the end of 2017 are collected. For details, see Table 3.

3.2 Results analysis of policy efficiency

As shown in Table 4, it can be seen from the results that the average comprehensive efficiency of policy inputs in 10 cities is 0.929, which is 92.9% of the ideal efficiency, indicating that the NEV policy inputs in these cities are generally effective. The average of pure technical efficiency to scale efficiency is 0.983 and 0.946 respectively, both of which are at a higher level.

(1) From the perspective of pure technical efficiency, there are certain differences among cities, indicating that the development of NEVs in each city is not balanced. With the exception of Tianjin, the pure technical efficiency of other cities has reached the optimal level, indicating that the policies of these cities are already in an effective state for technological upgrading. The pure technical efficiency of Tianjin is 0.830, indicating that the city has some shortcomings in the structure of policy inputs and some resources waste of policy inputs.

Table 3. Inputs of NEVs Policy in Cities by 2017

| City    | Input index | Output index                  |
|---------|-------------|-------------------------------|
|         | Purchase incentive policy | Use promotion policy | Marketization process | Promotion and application environment |
|         | E1 (k RMB)  | E2 (k RMB)                  | E3 (k RMB)         | E4 (k RMB) | F1 (units) | F2 (%) | F3 (units) | F4  |
| Shanghai| 18017530    | 118520                      | 120000            | 12321200   | 171479     | 4.78    | 26314      | 0.15|
| Beijing | 21003900    | 135350                      | 120000            | 17873800   | 165864     | 2.94    | 30363      | 0.18|
(2) From the perspective of scale efficiency, there is also a certain difference between cities. The scale efficiency values of Shenzhen, Hangzhou, Qingdao, Changsha and Chengdu are all 1, indicating that the input-output scale efficiency of these cities is optimal. The scale efficiency of Shanghai, Beijing, Tianjin, Guangzhou and Xi'an is not optimal, among which Shanghai, Beijing and Tianjin are facing diminishing rewards to scale, indicating that the city's policy inputs exceed the optimal scale. It means that the multiple of output increase is smaller than the multiple of input increase. Attention should be paid to appropriately reducing the scale of industrial policy and turning to the optimization of industrial policy structure. However, Xi'an and Guangzhou are facing increasing scale efficiency, that is, the multiple of output increase is greater than the multiple of input increase, indicating that the industrial scale is small. The two cities should focus on strengthening the scale construction of the NEV industry, and then improve the scale efficiency of their NEV industry.

| City     | Comprehensive efficiency | Pure technical efficiency | Scale efficiency | Rewards to scale |
|----------|--------------------------|----------------------------|-----------------|------------------|
| Shanghai | 0.921                    | 1                          | 0.921           | drs              |
| Beijing  | 0.765                    | 1                          | 0.765           | drs              |
| Shenzhen | 1                        | 1                          | 1               | -                |
| Hangzhou | 1                        | 1                          | 1               | -                |
| Tianjin  | 0.797                    | 0.83                       | 0.96            | drs              |
| Guangzhou| 0.884                    | 1                          | 0.884           | irs              |
| Qingdao  | 1                        | 1                          | 1               | -                |
| Changsha | 1                        | 1                          | 1               | -                |
| Xi'an    | 0.927                    | 1                          | 0.927           | irs              |
| Chengdu  | 1                        | 1                          | 1               | -                |
| Grand average | 0.929          | 0.983                     | 0.946           | -                |
Table 5. Input Redundancy and Output Deficiency of Non-DEA Effective Cities

| City     | Input redundancy | Output deficiency |
|----------|------------------|-------------------|
|          | E1   | E2   | E3   | E4   | F1   | F2   | F3   | F4   |
| Shanghai | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Beijing  | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |
| Tianjin  | 0    | 112  | 8207 | 0    | 0    | 0.376| 3388 | 0.068|
| Guangzhou| 264746| 222  | 74062| 4292 | 0.12 | 6557 | 0.1  |
| Xi'an    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

(3) The comprehensive efficiency of Shanghai, Beijing, Tianjin, Guangzhou and Chengdu have not achieved the optimal DEA efficiency. Among them, Beijing has the lowest comprehensive efficiency, so it should reduce input in industrial scale policy and optimize the input structure of industrial policy to improve comprehensive efficiency. Tianjin's comprehensive efficiency is only 0.797. There exists input redundancy in the two policies of charging infrastructure award funds and the exemption of vehicle and vessel tax, and there is insufficient output in the market penetration of NEVs, public charging infrastructure construction and pile-car ratio. Guangzhou's comprehensive efficiency is not high, and it is within the range of increasing rewards to scale. Therefore, we should adjust the structure of policy input, reduce policy input on vehicle purchase subsidies and benefits from unlimited travel and purchase, and enhance other policy inputs that support the industrial scale more effectively, so as to improve the comprehensive efficiency of policy input and output. The comprehensive efficiency of Shanghai and Xi'an is similar, but the difference is that Shanghai is within the range of diminishing rewards to scale while Xi'an is within the range of increasing rewards to scale. Therefore, different strategies should be adopted to improve the efficiency of industrial policies according to local actual conditions.

4. Conclusions and policy recommendations

4.1 The quantity and strength of policies are only positively related to the policy effect, but not positively related to the policy efficiency

The first-tier cities including Beijing, Shanghai and Shenzhen are leading the country in terms of the number and strength of policies to promote NEVs, producing positive effects on the promotion of NEVs, with the promotion volume and market penetration indexes of NEVs leading the country. However, from the perspective of policy efficiency, the promotion policies of NEVs in Beijing and Shanghai have not achieved the optimal DEA efficiency. On the other hand, in second-tier cities such as Qingdao, Changsha and Chengdu, the number and strength of policies to promote NEVs as well as the NEV promotion effect lag far behind that of the first-tier cities such as Beijing and Shanghai, but the efficiency of the promotion policies is optimal. This phenomenon explains that the unit output of policy input in the five cities of Beijing, Shanghai, Tianjin, Guangzhou and Xi'an is lower than that in the other five cities. Therefore, the quantity and strength of policies are only positively related to the policy effect, but not positively related to the policy efficiency.

4.2 Policies should be adapted to local conditions

From the previous data analysis, it can be found that the ten cities have given support to the national and local dual subsidy policies, and the subsidy policies have also produced great policy benefits for the promotion of NEVs. However, there are still great differences in the total promotion amount and market penetration of NEVs, indicating that in some cities, the policies that produce the biggest monetary incentive benefits to private consumers are not local purchase subsidies, but indirect incentive policies such as NEV licensing benefits. Especially in Beijing and Shanghai, the equivalent
monetary incentive brought by NEV licensing benefits is as high as 80,000 to 130,000 yuan, which greatly stimulates private buyers' willingness to purchase NEVs.

4.3 Only a reasonable policy combination can enhance policy efficiency

Shanghai and Beijing both have huge inputs in subsidy and unlimited travel and license plate benefits, and have achieved good promotion results, but compared with other cities, the output efficiency is lower. Policy in Beijing has given rise to many NEV purchase demands, and the NEV license plate has brought huge benefits to consumers. On the other hand, Beijing has set up a local catalog and PHEV can't be defined as NEVs have greatly weakened the effect of the promotion policy. At the same time, policies such as the total amount control of NEV license plates have also restricted the large-scale development of NEVs, resulting in the redundant inputs and insufficient outputs of unlimited travel and license plate policies.

Therefore, each city should set up an effective policy combination in order to improve the efficiency of comprehensive policies, maximize the income from policy input and avoid waste of resources.

4.3.1 The government aspect: it should formulate corresponding policies to guide industrial inputs to 1) supervise the direction of industrial development and prevent the waste of resources caused by blindly rapid development and unreasonable resource allocation; 2) reasonably control the industrial scale to match the input-output scale.

4.3.2 The city aspect: we can see that there are great differences in policy efficiency between cities, so we should guide the flow of various elements of industrial development among cities and break down local protection restrictions. Due to the differences in economy, technology, environment and infrastructure, the inputs in NEVs policy in different cities are not balanced.

4.3.3 Other aspects: each city should formulate NEV policies according to local conditions, carry out targeted policy inputs in combination with factors such as local market environment, consumption level and infrastructure, and guide the innovation of business model to improve the efficiency of NEV policy inputs.

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