Simulation analysis of short-term electric energy policy in electric vehicle field

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Abstract. As an important field of electric power substitution process, it is of great significance to study the influence of electric power substitution policy on electric vehicle sales and electric power substitution. This paper establishes an electric power substitution time series intervening analysis model to simulate the sales data of new energy vehicles, and quantitatively analyzes the impact of short-term policies on electric vehicle sales and electric energy substitution. In view of the change of short-term subsidy policy, the sensitivity analysis is carried out, and the influence of the subsidy policy on the sales of new energy vehicles and the substitution of electricity are obtained under different rates of subsidy.

Key words. Electric power Substitution; Electric vehicle; Policy simulation Analysis

1. Introduction

In the field of electric power substitution, electric power substitution indicators will be affected by events, such as policy orientation, industrial structure, technological progress, etc. [1] some policy interventions have a short duration of impact and only affect things within a year. [2,3] To assess the impact of these policies on normal time series, a time series intervention analysis model is introduced to assess the impact of emergencies on variables. Widely used in the field of economic and finance, time series analysis is used to analyze social and economic phenomena, and to discover the inherent changes law by analyzing the statistical data of a certain indicator. [4-6] in the economic field, when a government policy intervention or a serious natural disaster and other emergencies occurs, it will inevitably have different degrees of impact on the relevant economic sectors. Intervention analysis model is introduced in time series analysis to evaluate the impact of policy intervention or emergencies on the economy from the perspective of quantitative analysis.

In this paper, the electric power substitution policy is regarded as an intervention event in the process of electric power substitution operation, and an intervening analysis model of electric power substitution time series is established. By intervention analyzing the implementation of the electric power
substitution policy on growth rule of electric power substitution, it can quantitatively describe the structural changes in the growth trend of electricity substitution quantity and provide a large amount of valuable information for the energy sector, which can help them make better decisions on power grid planning, operation optimization and improvement of operation and service efficiency.

2. Short-term policy intervention model

2.1. Time series modeling

The interventions analysis of short-term policy impact assumes that intervention influences the process by changing the mean function or trend of the sequence in a short time scale. Considering a policy intervention, after appropriate transformation, the general model of time series \( \{Y_t\} \) can be expressed as follows:

\[
Y_t = \begin{cases} 
N_t, & t < T \\
m_t + N_t, & t \geq T 
\end{cases}
\]  

(1)

Where \( m_t \): influence of external intervention; \( N_t \): electric power substitution index not influenced by electric power substitution policy. It is assumed that the policy is implemented at time T, that is, the time series of power substitution index is subject to policy intervention at time T. Before time T, \( \{Y_t\} \) is the electric power substitution time series without intervention, which can be used to identify the electric energy substitution model before the implementation of the electric power substitution policy. Due to the short duration of the short-term policy, the monthly interval is often selected as the unit time length in the time scale of the short-term policy intervention model.

2.2. Policy intervention modeling

The basic variable of the electric power substitution policy intervention analysis model is the electric power substitution policy intervention variable. The policy intervention variable is 1 when the intervention occurs, and the intervention variable is 0 when the intervention does not occur. The electric power substitution policy intervention variable can be expressed as the impulse function as follows:

\[
P_t^{(T)} = \begin{cases} 
0, & t \neq T \\
1, & t = T 
\end{cases}
\]  

(2)

This formula indicates that the intervention occurs at time T, and only affects a short time. For example, the initial price subsidy for the electric energy substitution does not last long. The intervention variable is the basic element in the intervention analysis model. It can only indicate the moment of intervention, and it does not fully reflect the degree of intervention and the gradual impact process. Sometimes, after the intervention occurs, it does not immediately affect the original sequence, and there is a lag period. Sometimes, after the intervention, the original sequence may gradually rise or fall, may return to the original level, or may reach a new level. Intervention variables need to be processed in the form of intervention events.

A typical case of an intervention event is that the effect suddenly occurs and then gradually weakens to disappear. In the short-term electric power substitution price and subsidy policies, the initial electricity price policies or subsidy policies are often highly preferential. However, due to the financial problems of government and power grid companies, such policies gradually reduce support and subsidies after short-term effects. The model of such policy event simulation is calculated as follows:
\[ Y_t = \frac{\omega B}{1-\delta B} P_t^{(T)}, 0 < \delta < 1 \]  

The impact of intervention policy event is shown in Fig 1.

Figure 1. Impact of intervention policy event.

3. Case study

3.1. Basic data

For new energy vehicles, relevant subsidy policies have been introduced in various provinces and cities in China at this stage to subsidize various types of vehicles. Considering the current subsidy policies of various provinces, the subsidy for new energy vehicles is generally about 50%. In the current policy, there is a maximum subsidy of 22,000 yuan per vehicle for pure electric passenger vehicles.[7,8] In order to meet the statistical requirements, this section analyzes the subsidy policy of 20,000 yuan per vehicle.

The monthly sales of new energy vehicles in 2017 were selected to analyze the sales impact of new energy electric vehicles subsidies. According to the data of CPCA, the sales figures of new energy electric vehicles in 2017 are shown in Fig 2.

Figure 2. Sales charts of various new energy vehicles in 2017.

It can be seen from the Fig 2 that sales of new energy vehicles surged after October 2017, with sales of vehicles doubling in November and doubling in December. The surge has been driven largely by short-term fiscal and tax policies, which have prompted a large number of users to choose to purchase new energy vehicles rather than petrol-powered cars.

The sales of all kinds of new energy vehicles is used to study the short-term energy alternative policy intervention impact. Firstly, without short-term policy impact, the sales volume of various new energy vehicles from January to October in 2017 is analyzed, and a time series analysis model is established, and the data is simulated with the time series model. The results are shown in Fig 3.
Through the above model, the sales results of various new energy vehicles from November to December 2017 are simulated, as shown in Tab 1.

Table 1. Actual and predicted value of various new energy vehicles from November to December in 2017.

| Types                  | New energy vehicles | Electric vehicles | Plug-in Hybrid Electric Vehicles |
|------------------------|---------------------|-------------------|---------------------------------|
| Month                  | 2017.11             | 2017.12           | 2017.11                         |
| Actual value           | 98022               | 196132            | 81303                           |
| Predictive value       | 52339               | 148363            | 42349                           |
| Difference value       | -45683              | -47769            | -38954                          |

Starting from November 2017, considering the impact of short-term fiscal subsidies, an electric energy substitution policy intervention model is established. As the power substitution policy of the new energy vehicle industry is a short-term fiscal and tax policy, its impact on the sales of new energy electric vehicles is a form of short-term rapid increase. The sales of new energy vehicles are simulated by the formula, as shown in Fig 4.

Figure 3. Fitting chart for the sales of new energy vehicles from January to October 2017.

Figure 4. New energy vehicle sales under the policy intervention model.
It can be seen from Fig 4 that the simulation effect is more in line with the actual value after the policy intervention is added. After the stimulus of short-term fiscal and tax policies, the sales volume of new energy vehicles increases significantly.

After considering the impact of the policy, this section estimates the amount of electricity substitution generated by the policy. Taking into account the general private cars, taxis, special vehicles and other models, based on the average 15-day travel per vehicle per month and the consumption of 20 kWh per day, the electric vehicle substitution quantity in November 2017 and December 2017 and the environmental benefits brought by the electric vehicle subsidies policy can be calculated. The estimation of new energy vehicle policy impact and electric power substitution are shown in Tab 2.

**Table 2.** The estimation of new energy vehicle policy impact and energy substitution.

| Month       | Policy impact on new energy vehicle sales estimate | Estimation of electric power substitution (million kWh) |
|-------------|--------------------------------------------------|-------------------------------------------------------|
| 2017.11     | 90,911                                           | 27.27                                                 |
| 2017.12     | 97,269                                           | 29.18                                                 |

**Figure 5.** Estimation of policy intervention.

Through quantitative analysis of policy simulations, under the consideration of the short-term subsidy policy of 20,000 yuan for electric vehicles, the sales of 90,911 electric vehicles and 97,269 electric vehicles were increased, and the electric power substitution capacity was increased to 27.27 million kWh and 29.18 million kWh in November and December of 2017, respectively. Short-term fiscal and taxation policies can achieve the effect of short-term rapid stimulus.

### 3.2. Sensitivity analysis

In view of the change of short-term subsidy policy, sensitivity analysis of new energy vehicles is conducted in this section on the basis of the subsidy of 20,000 yuan per vehicle, and its sensitivity analysis settings are shown in Tab 3.
Table 3. Quantitative analysis of sensitivity of new energy vehicle subsidy policy.

| Subsidies proportion | 40% | 45% | 50% | 55% | 60% |
|----------------------|-----|-----|-----|-----|-----|
| Subsidies value(thousand yuan per vehicle) | 16  | 18  | 20  | 22  | 24  |
| Policy impact on new energy vehicle sales estimate | November 2017 |
| Regard | 87072 | 88656 | 90911 | 93176 | 95489 |
| Estimation of electric power substitution (million kWh) | 26.12 | 26.59 | 27.27 | 27.95 | 28.64 |
| December 2017 |
| Policy impact on new energy vehicle sales estimate | 94563 | 95154 | 97269 | 98940 | 10106 |
| Estimation of electric power substitution (million kWh) | 28.36 | 28.54 | 29.18 | 29.68 | 30.31 |

By calculation, the sensitivity factor is 0.25, which is a positive correlation coefficient. That is, for every 1 unit increase of subsidy rate on the basis of 50%, the electric energy substitution quantity can be increased by 0.25 unit.

4. Conclusion

In this paper, the electric energy substitution policy is regarded as an intervention event of the power substitution operation process, and an electric energy substitution time series intervention analysis model is established to simulate the sales data of new energy vehicles. The impact of short-term policy on electric vehicle sales and electric energy substitution is analyzed quantitatively by using electric energy substitution time series intervention analysis model. In view of the change of short-term subsidy policy, the sensitivity analysis is carried out, and the influence of the subsidy policy on the sales of new energy vehicles and the substitution of electricity are obtained under different rates of subsidy. Through the simulation analysis of short-term electricity substitution policy in the field of electric vehicles, it can quantitatively describe the structural changes in the growth trend of electricity substitution quantity and provide a large amount of valuable information for the energy sector, which can help them make better decisions on power grid planning, operation optimization and improvement of operation and service efficiency.

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