Sales Forecasting of New Energy Vehicles in China: under the Subsidy Recession and Carbon Credits

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Keywords: Forecast, Gray NGM model, New energy vehicle.

Abstract. As one of China's strategic emerging industries, the new energy automotive industry is not only one of the key industries to deal with energy security, climate change and environmental protection, but also an important breakthrough in the upgrading of the automobile industry. In this paper, based on the actual sales of new energy vehicles in China, the improved gray model (NGM model) are used to predict the cumulative sales of new energy vehicles in China by 2020. The forecast result shows that while the sales of NEVs will continue to rise, the declining of subsidies will have some impact on the growth rate. Based on the basic prediction, the article draws on the United States carbon credits (ZEV policy) to analyze and research on China's carbon credits policy.

Introduction

The development of the global economy and science as well as technology has brought social development and prosperity, but it also brings serious environmental pollution. Therefore, all countries in the world are exploring the use of clean energy instead of traditional energy sources. Electric vehicles, as a typical representative of clean energy applications, have been rapidly developed.

In recent years, the government has issued the “Guiding Opinions on Accelerating the Promotion and Application of New Energy Vehicle” and the “National Strategic Emerging Industry Development Plan for the Thirteenth Five-year Plan” to set the requirements for the development of the new energy automobile industry. According to the official announcement of “Energy-saving and New Energy Vehicle Industry Development Plan (2012-2020)”, the cumulative sales volume of new energy vehicles would reach 500,000 by 2015, and it also has to increase to 5 million by 2020. With the support of many national policies, China's new energy automotive industry has witnessed rapid development.

Despite the significant progress of existing technologies and policy support, whether the goal to promote 5 million vehicles by 2020 can be achieved in the future is still unknown, which is not only related to the continuous introduction of national strategic policies, but also to the sustainable development of the new energy automobile industry as well as the major automobile enterprises to set their strategic planning. Consequently, forecasting the future market of new energy vehicles not only helps the authority to adopt timely regulatory measures to promote the industry, but also helps all car companies seize the opportunities in the market to make innovations and promote the virtuous cycle of the new energy automotive industry.

Literature Review

The quantitative forecasting methods used in market forecasting are time series method, multiple regression analysis, gray model prediction and neural network. Time series, also known as the historical extension method, predicts the future development based on the past trend of the market and highlights the important position of the time factor in the forecasting activities. Gray model is efficient to establish mathematical model and forecast through a small amount of incomplete information. It is mainly applied to the case of short time series and few statistical data, so it has been widely used. The method of neural networks requires a large amount of data, and its prediction
Li [1] used the gray model GM (1, 1) to predict the private car ownership in China, and obtained the trend of car ownership in the future. Chinese scholar Shi [2] considered the seasonal variations in the sales of new energy vehicles and put forward the seasonal variation index improved gray prediction model, which was more accurate to forecast the sales data in China. Zhang [3] made use of the first-order gray model and the improved second-order model to predict the demand, supply and freight rates of the international shipping market. According to the relationship between passenger flow volume and time, Ma [4] used a linear dynamic forecasting model with gray system theory to discuss the prediction of the number of tourists in the future. Seval Ene [5] utilized the improved OGM model to forecast the number of scrapped vehicles and recyclable vehicles on the market, which provided a reference for the study of vehicle policies in various regions of Turkey. Coskun Hamzacebi [6] predicted the annual electricity consumption of Turkey in the future by the optimal gray model, and put forward some policy suggestions on the safety of electricity supply.

This article adopts the national sales volume of new energy vehicles since 2010 as the basic data for the prediction, and draws on gray theory to build a mathematical model to forecast the national electric cars ownership by 2020. Furthermore, the paper will analyze the simulation results in order to benefit the future development of new energy automotive industry.

Methodology
The gray prediction model is a method to forecast through a small amount of incomplete information and its prediction is based on the past and present objective laws and describes the future development trend through scientific methods to form a scientific judgment [7].

New energy vehicle’s sales volume is affected by policy, technology and other factors, which makes the change in sales show a complex nonlinear characteristic. Gray prediction model can reflect the overall trend of time series, but it cannot reflect the fluctuation of external factors well. Financial subsidy is the main and the most significant promotion measure to increase sales volume [8, 9]. Therefore, the impact of subsidy recession on the cumulative sales cannot be ignored. Considering the influence of subsidy policy, this paper utilizes the improved gray model—NGM (1, 2) model to forecast the sales volume, and explores whether China can reach the set goal in 2020 under the background of subsidy recession.

According to the gray system theory and referring to the literature [10, 11, 12], the original data should be carried out buffer operator mathematical operation before modeling in order to exclude the external influence of the uncertain factors. (Eq. 1 and Eq. 2)

\[
xd=[x(1)d, x(2)d, \ldots x(n-1)d, x(n),] 
\]

\[
x(k)d=\frac{1}{n-k+1}[x(0)(k)+x(0)(k+1)+\ldots+x(0)(n)] \quad (k=1,2,\ldots n) 
\]

Eq. 3 is set as a system feature data sequence, and Eq. 4 is a related factor sequence. \(x_1^{(1)}\) is a cumulative sequence of \(x_0^{(1)}\) \(i=1,2,\ldots n\), \(z_1^{(1)}\) is an adjacent mean sequence of \(x_1^{(1)}\), and then we can construct NGM(1, n) model (Eq. 5).

\[
x_1^{(0)}=(x_1^{(0)}(1),x_1^{(0)}(2),x_1^{(0)}(3),\ldots,x_1^{(0)}(n)) 
\]

\[
x_2^{(0)}=(x_2^{(0)}(1),x_2^{(0)}(2),x_2^{(0)}(3),\ldots,x_2^{(0)}(n)) 
\]

\[
\vdots 
\]

\[
x_n^{(0)}=(x_n^{(0)}(1),x_n^{(0)}(2),x_n^{(0)}(3),\ldots,x_n^{(0)}(n)) 
\]

\[
x_1^{(0)}(k)+az_1^{(1)}(k)=\sum_{i=2}^{N}b_i (x_1^{(1)}(k))^i 
\]

Considering the properties of \(x_1^{(0)}\) (Eq. 6), we can combine Eq. 6 and Eq. 5, then the final model can be available (Eq. 7).
\[ z^{(1)}_1(k) = 0.5x^{(1)}_1(k-1) + 0.5x^{(1)}_1(k-2) + 0.5x^{(0)}_1(k) = x^{(1)}_1(k-1) + 0.5x^{(0)}_1(k) \]  \hspace{1cm} (6)

\[ x^{(0)}_1(k) = \sum_{i=2}^{N} \frac{b_i}{1+0.5a} \left( x^{(1)}_i(k) \right)^{\gamma_i} - \frac{a}{1+0.5a}x^{(1)}_1(k-1) \]  \hspace{1cm} (7)

For a given system, the variables of behavioral sequences and related factors are often characterized by complex nonlinear relationships. The correct power exponent \( \gamma_i \) in the differential equations of NGM (1, n) reflects that \( x^{(1)}_i(i=2,3\ldots n) \) has a nonlinear effect on \( x^{(0)}_1 \). In the modeling process, the specific values of these parameters must be determined in advance to estimate the structural parameters and then solve the model's time response function. In this paper, from the perspective of improving the accuracy of modeling and aiming at minimizing mean error, the following parameters are used as constraints to establish the following nonlinear optimization model (Eq. 8):

\[
\begin{align*}
\min_{\gamma_i} \quad & \frac{1}{n-1} \sum_{k=2}^{n} \left| \frac{\hat{x}^{(0)}_1(k) - x^{(0)}_1(k)}{x^{(0)}_1(k)} \right|, \quad i=2,3,\ldots,n \\
\text{s.t.} \quad & \hat{x}^{(0)}_1(k) = \sum_{i=2}^{N} \frac{b_i}{1+0.5a} \left( x^{(1)}_i(k) \right)^{\gamma_i} - \frac{a}{1+0.5a}x^{(1)}_1(k-1) \\
& \hat{a} = [a,b_1,b_2,\ldots,b_n]^T 
\end{align*}
\]  \hspace{1cm} (8)

**Results and Analysis**

This paper selects the subsidy data from 2013 to 2017 using MATLAB software to establish multivariable nonlinear gray prediction of NGM (1, 2) model. The result shows that the error is 0.2377, which is less than 0.3, so it has a certain reference value.

Figure 1 presents that although the overall development trend is on the rise and the popularization of new energy vehicles is increasing year by year, its growth rate has slowed down from 2018 to 2020. And the cumulative sales in 2020 cannot reach the expected level, only about 4.9 million.

![Figure 1. New energy vehicle forecasting data](image-url)

The gray model combines the influence of policy factors, and it presents the change of subsidy policy affects the promotion of new energy automotive industry. However, the factors influencing the development of the automobile industry are various, such as population and economic factors. Although the economic development is stable from 2012 to the present, the impact of other factors (such as technical barriers and charging facilities layout) will also play a role in the promotion of new energy vehicles.

Compared to 2015, the purchasing subsidies for new energy vehicles have slightly declined,
which to a certain extent hurt the enthusiasm of consumers. For the implementation of the new standard in 2017, the government has set new restrictions for vehicle energy consumption requirements, mileage and safety performance, limiting some types of cars to enjoy financial subsidies. In order to achieve the goal set in the plan, it is necessary to motivate the enthusiasm of consumers while maintaining and enhancing the productivity of automobile enterprises. Therefore, in order to reduce the excessive dependence on government financial subsidies for the development of new energy vehicles, the "carbon credit" system is imperative. China's carbon credit system refers to "zero-emission car plan" proposed by California's government and the Chinese authority has put forward its own guidelines for action drawing on the foreign laws and regulations.

In August, 2016, NDRC (National Development and Reform Commission) promulgated a draft, called “Measures for the Administration of Carbon Quotas for New Energy Vehicles” and put forward the concept of carbon credit [13]. To be specific, according to the scale of the enterprises and the sales volume of fuel cars to set carbon quotas, enterprises produce and sell new energy vehicles to generate carbon credits to meet the target requirements.

In our country, the implementation of carbon quota management, which is an important warranty for the healthy development of automotive filed under the background of subsidy recession, can not only effectively motivate automobile companies, but also can make the traditional fuel vehicles to assist the development of new energy industry.

In September, 2017, a regulation called "Passenger Vehicle Enterprise Average Fuel Consumption and New Energy Vehicle Carbon Credits Parallel Administrative Measures" was officially promulgated, it indicates the companies whose annual imports and exports of traditional energy vehicles are less than 30,000 will not set carbon ratio requirements, but if the number reaches 30,000 or more, the enterprises should set the proportion of new energy vehicles carbon requirements from 2019. In 2019 and 2020, the proportion of new energy car carbon standards will be 10% and 12% respectively. The main objective of a company's average fuel consumption point (CAFC) is to control the overall energy consumption of the automobile industry [14], especially oil consumption, while new energy vehicle carbon credits (NEV) is intended to boost the market for the new energy vehicle industry operation mechanism [15], this two jointly promote enterprises to participate into the new energy automotive industry.

From the current situation, the CAFC management system only considers the carbon emissions of vehicles in the process of production and utilization, and its essence is the same as the NEV system. However, its core is to view the development of the automobile industry from the perspective of carbon emissions, promoting product innovation and technological changes, and the goal is to reduce carbon emissions in the automotive industry and the entire country so as to ultimately achieve green, sustainable development.

Paralleling carbon quota policy and carbon credit policy promotes automobile manufacturing enterprises to set about the layout of new energy industry pattern from the national level [16]. Therefore, in order to profit and meet the legal requirements of the mandatory policies, companies will increase investment in production and marketing of new energy vehicles. According to the implementation effect of the "Zero Emission Scheme" in the United States [17, 18], until April 2014, American car makers have successively launched 24 different types of ZEV models and the sales volume of domestic ZEV models exceeded 20 ten thousand, which doubled in 2013. Thus, the effect of ZEV program is obvious. With reference to the result of the implementation of the ZEV plan in the United States and the predictions of gray model, we can see that with the dual promotion of CAFC management and NEV policy, the sales volume of new energy vehicles will show a substantial increase, with great hope for achieving the government's goal.

**Conclusion**

With the support of national and local industrial policies, the new energy automotive industry which is one of national strategic emerging industries is developing rapidly. Considering the subsidy policy and carbon credits policy, the article studies whether the sales volume by 2020 can achieve the promotion target of 5 million. Based on the actual sales of new energy vehicles in China, the
paper predicts the cumulative sales by 2020 with an improved gray model (NGM), and concludes that the cumulative sales of new energy vehicles will reach 4.9 million by 2020, and there is a certain gap between the predictive result and the promotion goal. Furthermore, this paper draws lessons from the experience of ZEV plan in the United States and explores the future trend as well as the impact of the implementation of carbon credit policy on the sales volume in the market. From this we can see that under the policy stimulus, there is great promise for achieving the planned goal by 2020 although subsidy recession.

Acknowledgement
This research was financially supported by the National Social Science Foundation.

References

