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Analyze the Development Trend and Influencing Factors of the Electric Vehicle Battery Market from New Energy Raw Materials

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Abstract: New energy vehicle is a very popular item in China in recent years, and the battery is the biggest difference between new energy vehicles and fuel vehicles. This work started from the market of raw materials and collected a lot of price data of raw materials of new energy vehicles, especially the battery part. In addition, this work involves the national policy and measures for electric vehicles and the mechanism of product pricing by companies. After obtaining this information, Tesla's price data are used as an example and a statistical gray model is used to build a mathematical model to make up for some of the data deficiencies. After that, this work analyzed the impact of price, policy measures, companies, and market mechanisms on EV battery prices. Through the model, this work roughly predicts the future trend of electric vehicle development.

Keywords: electric vehicles, grey model, the market of raw material, national policy

1. Introduction

Under the influence of various factors, the development of fuel vehicles needs to face the dual tests of environmental pollution and energy crisis. New energy vehicles are the most important strategic measure to achieve energy saving and emission reduction in automobiles. In recent years, the world's major auto-producing countries have taken the development of new energy vehicles as a major measure to improve their industrial competitiveness. China has given full support in terms of policies, subsidies, infrastructure, and other aspects, aiming to realize the goal of a low-carbon economy as soon as possible. Considering people’s willingness to buy an electric vehicle, a lot of people care about the price most. When companies are setting the price of an electric car, the main factor they will think about is the cost of producing the products. In addition, the price of raw materials which are used in production plays a non-negligible role in determining the cost of making the vehicle, and many expensive materials are used to make batteries. The battery accounts for a large part of the cost of producing electric vehicles, which takes up about 40%. Nowadays, there are mainly two types of battery that are widely used. One type is the ternary lithium battery, the other type is the lithium iron phosphate battery. Although the percentage that phosphate battery

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takes up in the market is increasing, there are still a lot of ternary lithium batteries being produced and used because of their high energy density. Most of the electric cars we can see on the streets are still using ternary lithium batteries. Since ternary lithium battery uses a lot of rare metals which are expensive or their prices will change a lot in the future, like cobalt, the cost of producing ternary lithium battery will fluctuate.

2. Methodology

This work uses the grey model (GM) to predict the selling price of the power electric battery packs.

2.1. Definition

The system with all the information fully known is called the WHITE SYSTEM; the system with none of the information known is called the BLACK SYSTEM. The GREY SYSTEM represents the system with part of the information known while other information remains unknown. Generally speaking, the social system, economic system, and ecosystem are all grey systems. The grey model is a gray differential prediction model with a small amount of incomplete information to make a fuzzy long-term description of the development pattern of things. For example, in the price system, there are lots of factors that may affect the price, but only a few of these are aware; thus, we could use the grey model to predict the future price [1,2].

2.2. Characteristics & Advantages

1. It only has to use a few pieces of information.
2. High accuracy
3. Simple and useful
4. Do not require regular data

2.3. Theory

Let the original sequence of 2016,2017,2018,2019,2020,2021 these six years to be $x_1^{(0)}, x_2^{(0)}, x_3^{(0)}, x_4^{(0)}, x_5^{(0)}, x_6^{(0)}$. Accumulate to generate a new sequence,$x_1^{(1)}, x_2^{(1)}, x_3^{(1)}, x_4^{(1)}, x_5^{(1)}, x_6^{(1)}$:

$$x_k^{(1)} = \sum_{i=1}^{k} x_i^{(0)}, k = 1,2,3,4,5,6 \ldots \quad (1)$$

The sequence of means is then generated:$z_k^{(1)} = \alpha x_k^{(1)} + (1-\alpha)x_{k-1}^{(1)}, k = 2,3,4,5,6$
In the equation, $0 \leq \alpha \leq 1$, stands for weight. Then create the grey differential equation:

$$x_k^{(0)} + az_k^{(1)} = b, k = 2,3,4,5,6 \ldots \quad (2)$$

The corresponding GM(1,1) white differential equation is:

$$\frac{dx^{(1)}}{dt} + ax_t^{(1)} = b, k = 2,3,4,5,6 \ldots \quad (3)$$

Shifting the terms of the grey differential equation yields:

$$-az_k^{(1)} + b = x_k^{(0)}, k = 2,3,4,5,6 \ldots \quad (4)$$

a,b are undetermined parameters, the above equation can be written as a matrix in the form of:

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$$\begin{bmatrix} -z_2^{(1)} & 1 \\ \vdots & \vdots \\ -z_6^{(1)} & 1 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} x_2^{(0)} \\ \vdots \\ x_6^{(0)} \end{bmatrix} \ldots \quad (5)$$

And that is $X\beta = Y$. using the ordinary least squares can determine the estimation of the β of the parameter matrix:

$$\hat{\beta} = (X^T X)^{-1} X^T Y \ldots \quad (6)$$

This gives an estimate of the parameters a, b, and brings in the white equation to get the general solution of the sequence $x_k^{(1)}$:

$$\widehat{x_k^{(1)}} = \left(x_1^{(0)} - \frac{b}{a}\right) e^{-\alpha(k-1)} + \frac{b}{a}, k = 2,3,4,5,6 \ldots \quad (7)$$

Restore to the original sequence to get the prediction function:

$$\widehat{x_k^{(0)}} = \left(x_1^{(0)} - \frac{b}{a}\right) e^{-\alpha(k-1)}(1 - e^a), k = 2,3,4,5,6 \ldots \quad (8)$$

2.4. Prediction

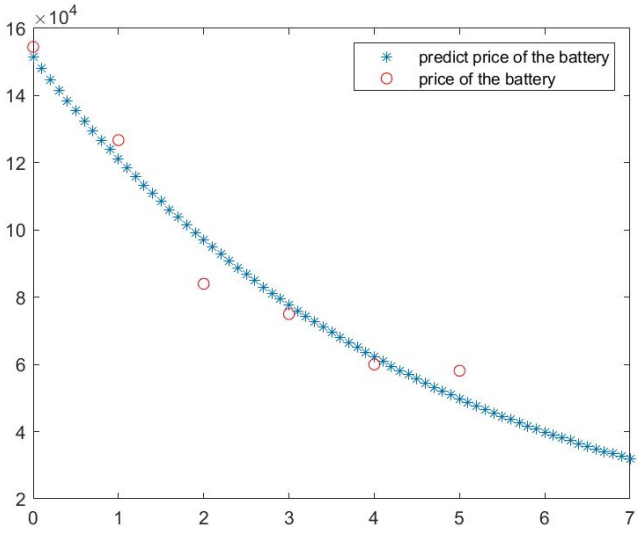

Figure 1: Predicted prices of battery (price from 2016 to 2023) [Owner-draw].

Table 1: Predicted prices of battery (price from 2016 to 2023) [Owner-draw].

y3	1	2	3	…	68	69	70	71
price	151409	148079	144822	…	34119	33369	32635	31917

Price of the battery in 2023 is ￥31916.9231511097, while the price of it in 2022 is ￥39866.7732255940

(31916.92315-39866.77323)/ 39866.77323=-0.19941

Compared with price of the battery in 2022, the price of the battery reduces by about 20%.

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3. Data

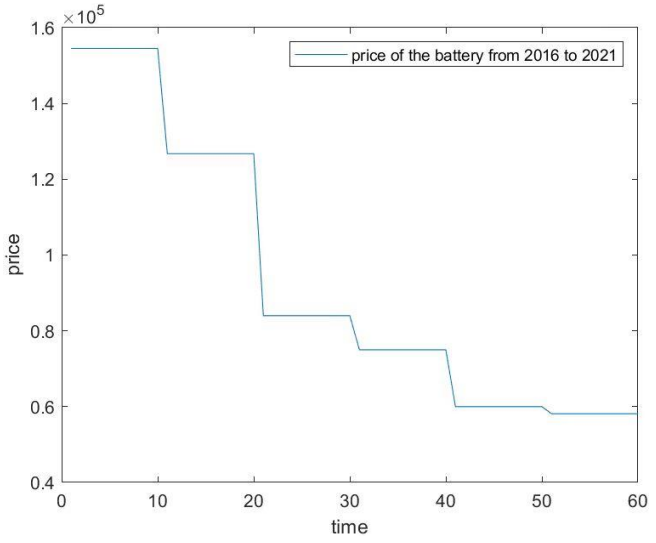

Figure 2: Price of ternary lithium battery from 2016-2021[Owner-draw].

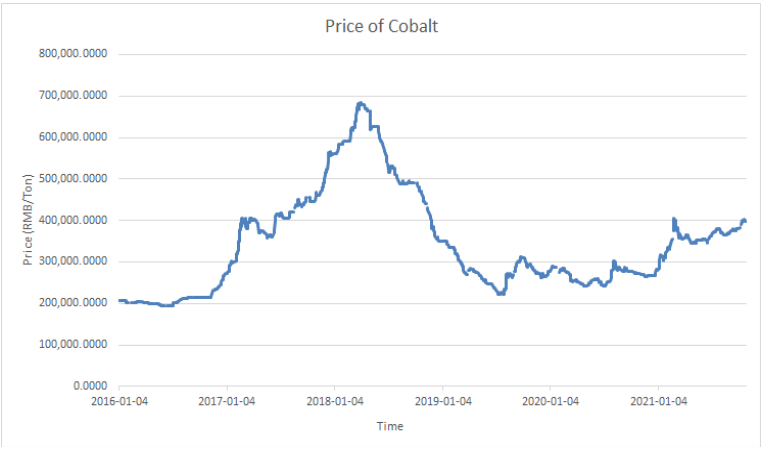

Figure 3: Average price of cobalt from 2016-2021[Owner-draw].

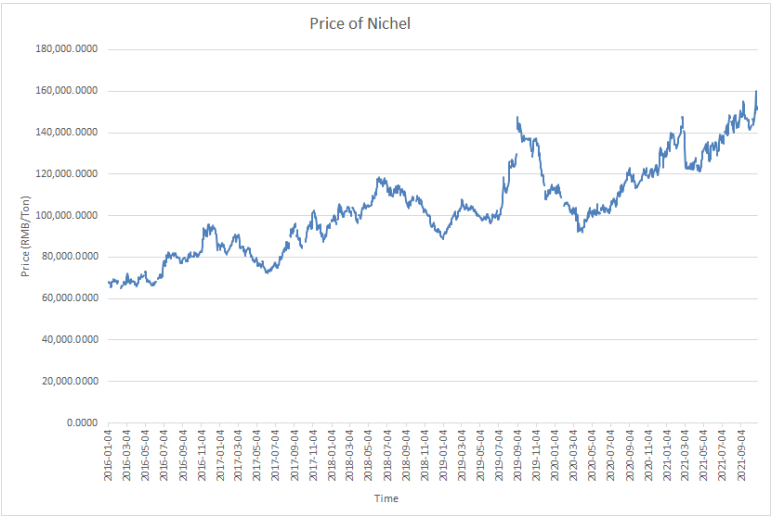

Figure 4: Average price of nickel from 2016-2021[Owner-draw].

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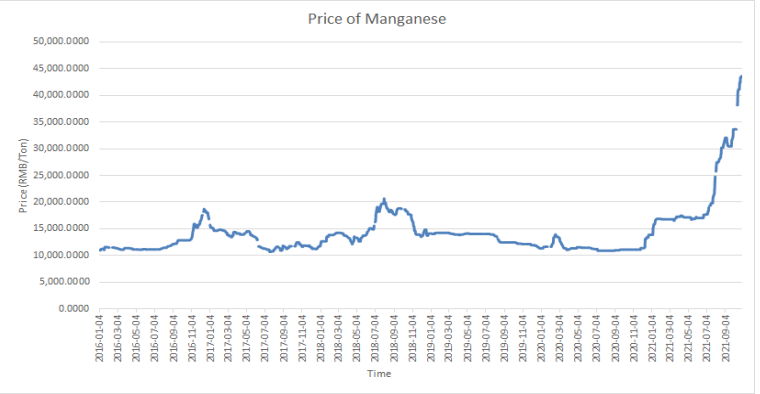

Figure 5: Average price of manganese from 2016-2021[Owner-draw].

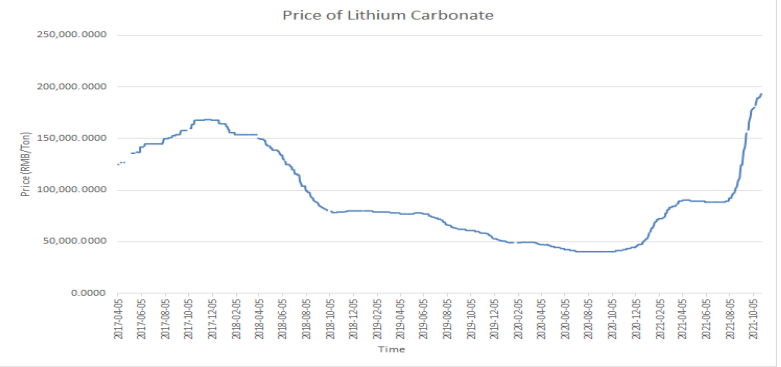

Figure 6: Average price of Lithium Carbonate from 2016-2021[Owner-draw].

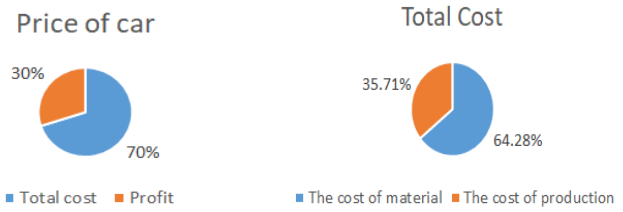

Figure 7: Cost ratio of the model3 [Owner-draw].

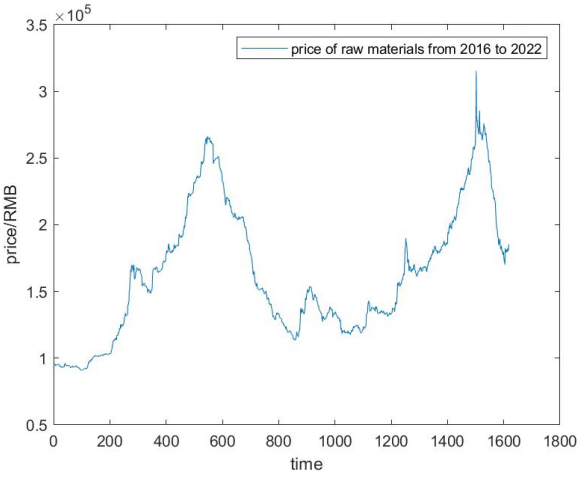

Figure 8: Prices of raw materials of the ternary lithium battery [Owner-draw].

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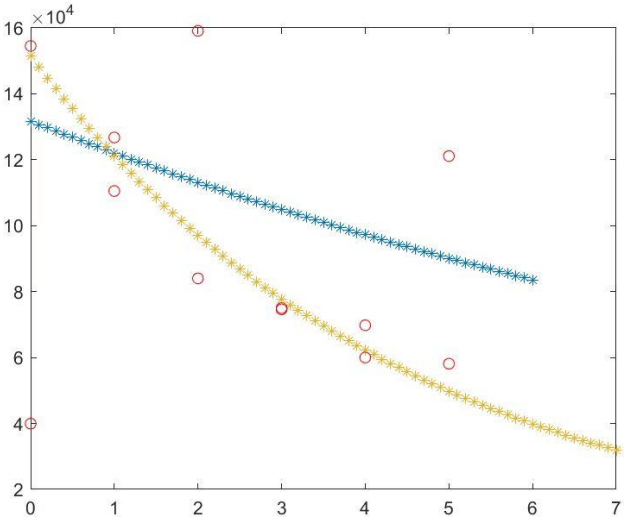

Figure 9: Predicted price of the battery and price of raw materials [Owner-draw].

4. Results

Figure 1 and Table 1 show the predicted values and each "*" on the graph is one of the predicted prices. The 61st are the prices of the ternary lithium battery in the future, and the 71st column shows the price of the ternary lithium battery in 2023.The prices of raw materials of the ternary lithium battery is shown in Figure 9, the blue points are the prices of raw materials that are calculated from the Grey Model while the yellow points are the prices of the ternary lithium battery. The data are from 2016 to 2021 and the prices of the same year have the same x-coordinate. Both the lines have the tendency of decreasing, which indicates the phenomenon of a sustained decrease in the prices of the raw materials and the ternary lithium battery. So, a guess could be hazarded that the prices of raw materials have a direct impact on the prices of the ternary lithium battery. However, the blue 'o's, which are the real prices of raw materials for each year, are separated from each other and fluctuate during these years while the real prices of the ternary lithium battery can better match the predicted function. According to this, the results come that the batteries' prices will not change frequently. It will remain constant for some time instead and change with the overall tendency of the prices of raw materials.

From Figure 7, results can be calculated that the costs of materials accounted for 64.28% and the costs of production constituted 35.71% [3]. So, the costs of raw materials are closely related to the cost of a new energy car. The costs of a car almost determined the price of a car, especially in the new energy market, which involves the production of batteries. The data from Figure 3, Figure 4, Figure 5, Figure 6 are used to build the model for raw materials.

5. Discussion

5.1. Economies of Scale Effect

According to Figure 2 and Figure 8, the work shows that the price of ternary lithium batteries is not continuously changing but remains the same for a period before changing. Even Figure 9 shows that the price of raw materials for ternary lithium batteries is changing frequently and irregularly. This phenomenon can be explained by the difficulties that a producer will have while changing their price. There will be difficulties in discussing, calculating, and announcing the new price. Producers bought the raw materials once in a short-run situation to enjoy the discount for bulk buying. So, before they use all the bought materials, they will not have to be concerned about the price of

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materials and they can observe the tendency of the price of the raw materials and supplement their reserve at a low price. What is more, the price change needs time to be put into use. Producers will have to calculate accurately since this will directly affect their revenue, which means that they must solve the problem of whether and how they will change their expenditure on other factors of production (such as wages). Also, the information requires time to let all the consumers be aware of.

In Figure 9, the work shows that the linear tendency of the price of the ternary lithium battery is steeper than the linear tendency of the price of raw materials. This means that the price of the ternary lithium battery is reducing at a faster rate than the price of the raw materials. This could be attributed to the effect of the economy of scale. There could be many economies of scale that exist in this situation. As the companies that produce the ternary lithium battery are all large firms and they produce the ternary lithium battery in significantly large quantities. So, they will buy raw materials in bulk and place large orders for capital equipment usually receiving a discount. So, they will pay less for each raw material they purchased and they may also be treated uniquely by being provided with items of higher quality. So, the long-run average cost will reduce.

The total cost of processing orders, packing the goods, and transporting them does not rise in line with the number of orders. What is more, large firms can afford to employ specialist staff in key posts as they can spread their payments over a high number of units. Employing specialist buyers, accountants, human resource managers, and designers can increase the firm’s efficiency, reduce costs of production, and raise demand and revenue. Moreover, large firms can engage in the division of labor among their staff. For example, among all the workers that produce the ternary lithium battery, the process of production can be divided into different parts and train certain workers to be specialized in the part that they do. Thus, productivity could increase and the long-run average cost will be lower. Accordingly, the cost of production could be reduced while the cost of raw materials increases, so the price of ternary lithium batteries will not always be directly related to the price of raw materials [4].

5.2. The Reason for Economies of Scale

About the cause of Economies of Scale, the increase in battery production, this work analyzes that this phenomenon is due to the influence of national policies and measures.

5.2.1. On the Aspect of Infrastructure and Service Improvement

By the end of 2019, China's charging infrastructure reached 1.2 million, an increase of 500,000 from the end of the previous year. In addition, the structure of charging piles has been further optimized, including 500,000 public piles, with a slower growth rate, and 700,000 private piles, maintaining a high growth trend. This reflects that the market of electric vehicles is transforming with increasing speed from policy-driven to market-driven. People's willingness to buy electric vehicles is increasing, and the market demand for batteries is also increasing, which leads to an increase in battery production.

5.2.2. On the Aspect of Financial Subsidies

The Ministry of Finance clarified that the subsidy standard for electric vehicles in 2021 will be lower by 10% from 2020, and no transition period has been set, which will be implemented from January 1, 2021. China has slowed down the speed of subsidy withdrawal. Originally, the subsidy standard in 2020-2022 retreated by 10%, 20%, and 30% based on the previous year. This policy, to some extent, alleviated the cost pressure of enterprises at all levels and encouraged more consumers to buy electric vehicles, thus leading to an increase in the production of batteries.

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5.2.3. On the Aspect of Technology

Contemporary Amperex Technology Co., Limited's CTP and BYD's blade technology have improved the safety performance of batteries (energy density has increased significantly and cost has been reduced), and the technology of electric vehicles has been upgraded and safety has been guaranteed. Consumers are willing to buy electric vehicles, the demand for batteries increases, and battery production increases. China now has more other policy support and subsidies for electric vehicles, but the vast majority of these have increased the willingness to buy electric vehicles, thus explaining the rise in battery demand [5-8].

6. Conclusions

This work has got a relatively accurate prediction about the change in battery price in the next few years. Since the price of the battery will decrease by about 20% in 2023, the cost of making a car will also decrease by about 8%, which will cause the price of the car to decrease and increase the willingness of people want to buy an electric vehicle. As a result, the market share of electric vehicles will continue to rise for more than two years [9,10].

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Yiwen Liu, Ziyou Tang, Erji Sang contributed equally to this work and should be considered co-first authors.

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Appendix

```
x0=[154500,126750,84000,75000,60000,58125];%raw data
   n=length(x0);%accumulate data
   x1=zeros(1,n);
   x1(1)=x0(1);
   for i= 2:n
   x1(i)=x0(i)+x1(i-1);
```

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```
end
%smoothing, with a weight of 0.4
af=0.63;
z1=zeros(1,n);
z1(1)=0;
for i=2:n
z1(i)=x1(i)*af+(1-af)*x1(i-1);
end
%Construct the equation matrix
%X is a 2-column matrix composed of Z1 (K) and 1
%Y is a first-order column matrix
%B is the solution matrix of a and b.
%use the ordinary least squares to find the optimum solution
Y=zeros(n-1,1);
X=zeros(n-1,2);
for i=2:n
Y(i-1)=x0(i);
X(i-1)=-z1(i);
X(i-1,2)=1;
end
%Solve the parameter matrix, 'inv' is the inverse operation
B=inv(X'*X)*X'*Y;
a=B(1);
b=B(2);
%solve the equation of year n+1
pred_n_1=(x0(1)-b/a)*exp(-a*n)*(1-exp(a));
x=0:0.1:7;
y3=(x0(1)-b/a).*exp(-a.*x).*(1-exp(a));
plot(x,y3,'*')
hold on
n0=0:5;
plot(n0,x0,'ro')
legend('predict price of the battery','price of the battery')
```