A Study on Forecasting Sales of New Energy Vehicles in China Based on Time Series Analysis

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Abstract. Combining the methods of multiple linear regression and time series analysis, this paper forecasts the sales trend of China's new energy electric vehicles in the next 10 years by using the data of new energy electric vehicle sales from 2013-2022, and comprehensively analyzes the impact of multiple factors, such as policy, technology, economy, market, and environment, on China's new energy electric vehicle sales. The study selected 16 secondary indicators including government subsidies, vehicle sales, number of charging piles, GDP per capita, consumer satisfaction, carbon emissions, etc. for data analysis, highlighting the key role of technological factors in the development of the industry. The study concludes that China's new energy electric vehicle industry is expected to usher in a period of sustained growth as technology continues to advance and the market matures.

Keywords: New Energy Electric Vehicles, Traditional Energy Vehicles, Multiple Linear Regression, Time Series ARIMA Analysis Model, Sales Forecast.

1. Introduction

In order to realize the sustainable development of China's economy, it is crucial to promote the development of green and low-carbon industries, advocate green consumption, coordinate the planning of industrial structural adjustment, and accelerate the green transformation of the mode of development. As an important pillar of China's national economy, the new energy automobile industry shoulders the important responsibility of promoting the development of green economy, realizing the goal of "double carbon", and accelerating the construction of a new pattern of double-cycle development at home and abroad [1]. Accompanied by the increasingly serious problems of climate change and environmental pollution, the high-frequency use of fuel vehicles is gradually being diluted by new energy vehicles. According to statistics, in 2022, the production and sales of new energy vehicles in China will reach 7,058,000 and 6,887,000 respectively, with a year-on-year growth rate of 96.9% and 93.4%, respectively, and the share of new energy vehicles in the Chinese market will also further increase to 25.6%, which means that the new energy vehicles in the whole automobile industry The influence of the new energy vehicles has increased dramatically, and with the alternative of new energy vehicles, the global environment and pollution problems can be better improved [2]. New energy vehicle technology research and development is being emphasized by all countries, especially China as a populous country, as a leading country in the global automobile sales share, the development of new energy and technological innovation has also become a benchmark for the rapid development of the world, not only for the rapid development of the economy, but also in terms of environmental and energy security for the entire population to contribute to the development of the new energy automobile industry, and the Chinese government has launched a variety of to promote the development of new energy automobile industry policies, such as reducing automobile purchase tax, lowering the cost of car purchase, and building charging infrastructure [3].

The development of new energy vehicles is actually influenced by a variety of factors, technological innovation, the expansion of technological fields, cost compression, the pursuit of popularization, a large amount of research and development costs, as well as the government's policy support. Chinese car companies also in the market demand for research and development of new battery technology, reduce the use of cost at the same time, but also let the new energy vehicle range increased significantly, but also more consumers are willing to pay for it, the climate and environmental changes have also made more countries began to develop a long-term carbon neutral target, new energy vehicles are also in this emerging field, play an absolutely important role [4]. Therefore, this paper will deeply analyze the key factors affecting the development of China's new energy automobile industry, predict the sales of China's new energy automobile in the next 10 years and put forward the corresponding improvement measures, with a view to providing useful references for the scientific and reasonable policy support and industrial development of the new energy automobile industry.

2. Literature review

As an emerging industry, new energy vehicles have achieved remarkable results in the past time and have gained wide attention and rapid development globally. Forecasting the development trend of China's new energy electric vehicles in the next 10 years is of great strategic significance for promoting the transformation and upgrading of the automobile industry and realizing the sustainable development of the economy and society. Currently, the research on China's new energy vehicle sales forecast is mainly divided into two parts: forecasting method and the construction of evaluation index system of influencing factors.

(1) Forecasting method

(i) SSA-SVR model. Liang Yaling, Chen Yingwei and Liu Sijia (2023) established the SSA-SVR model to predict the monthly sales of domestic new energy vehicles in 2023. Their study utilized historical sales data from 2014 to 2022 and provided the industry with insights and recommendations on future sales trends through the model prediction results [5].

(ii) Gray forecasting model. Cheng (2022), on the other hand, used a gray forecasting model GM (1,1) to predict the sales of pure electric vehicles in China from 2021 to 2025. This study was based on the sales data from 2016 to 2020 and found that the sales showed an upward trend and predicted that the sales would reach 2,308,000 units by 2025, and this prediction provided an important reference for industry planning [6].

(iii) ARIMA model. Miao Hui, Tang Chentian and Luo Lulu (2020) used the ARIMA model to analyze the time series of China's monthly sales of new energy vehicles from January 2014 to May 2019, and constructed an optimal ARIMA model to forecast sales. Their study not only provided an in-depth understanding of past sales data, but also provided forecasts and comparisons for the future growth of the new energy vehicle industry [7].

(2) Influential factors evaluation index system construction

In exploring the key factors affecting the development of new energy vehicles in China and the relationship between these factors, Wang Na (2017) proposed four first-level indicators, such as government factors, market factors, consumer factors and environmental factors, as well as 12 second-level indicators, such as the price of oil [8]. Huang Ruijin and Gu Gaofeng (2021) considered the factors influencing domestic consumers' electric vehicle purchase preferences from four aspects: personal attributes, vehicle attributes, charging infrastructure, and incentives for purchasing and using vehicles, and found that range, charging speed, vehicle licenses, charging pile facilities, and financial subsidies play a more significant role in influencing consumers [9].Theo L, Silke M and Sven H's study showed that price, range, performance, reliability, and battery maintenance are factors that consumers pay more attention to when purchasing new energy electric vehicles [10]. In summary, these studies provide diverse methods and insights for forecasting and analyzing the sales of new energy vehicles, which help industry participants better understand and respond to market changes.

Therefore, this paper refines the indicators from five aspects: policy, technology, economy, market, and environment, and creates the average governmental single-vehicle subsidy amount for new energy vehicles, the number of new energy vehicle policies, the total national automobile sales volume, new energy vehicle ownership, the cumulative number of recharging piles, the average range of new energy vehicles, the number of power batteries produced, the average per capita GDP, the average per capita disposable income, the price of oil, the new energy electric vehicle the 16 secondary indicators, including market share, consumer satisfaction, urbanization level, number of registered enterprises related to new energy electric vehicles, carbon emissions, crude oil production, etc., are aimed at exploring the main factors affecting the development of new energy electric vehicles, so as to better predict China's sales of new energy electric vehicles in the next 10 years.

3. Research Methods

(1) Multiple linear regression analysis modeling

Linear regression is a statistical analysis method that uses regression analysis in mathematical statistics to determine the interdependent quantitative relationship between two or more variables [11]. In the actual problem of the development of new energy electric vehicles in China, there is often more than one independent variable that affects the development of the industry, but there is more than one independent variable, so a multiple linear regression analysis model with one dependent variable and multiple independent variables is established.

(2) Autoregressive moving average model

The full name of ARIMA model is Autoregressive Integrated Moving Average Model. ARIMA model is mainly composed of three parts, which are autoregressive model (AR), differential process (I) and moving average model (MA) [12]. The basic idea is to use the historical information of the data itself to predict the future.

The autoregressive (AR) model is given by:

$$\text{AR}: Y_t = c + \varphi_1 T_{t-1} + \varphi_2 Y_{t-2} + \ldots + \varphi_p Y_{t-p} + \xi_t \tag{1}$$

The moving average model (MA) is given by the formula:

$$\text{MA}: Y_t = \mu + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \ldots + \theta_q \epsilon_{t-p} \tag{2}$$

If we disregard the difference for the time being (i.e., assuming d = 0), then the ARIMA model can be viewed as a direct combination of the AR model and the MA model, and the formula for the ARIMA model can be expressed as:

$$Y_t = c + \varphi_1 Y_{t-1} + \varphi_2 Y_{t-2} + \ldots + \varphi_p Y_{t-p} + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \ldots + \theta_q \epsilon_{t-q} + \epsilon_t \tag{3}$$

Where Y_t is the time series data we are considering; φ_1 to φ_p are parameters of the AR model, which are used to characterize the relationship between the current value and the past p time values; θ_1 to θ_q are parameters of the MA model, which are used to characterize the relationship between the current value and the error at the past q time points; ε_t is the error term at time point t; c is a constant term; and ξ_t is white noise.

Also, this formula basically assumes that the time series we are dealing with is smooth so that we can just use the model with, but if the time series is non-smooth then we have to consider the I part of the ARIMA model, which means that we have to perform the differencing process.

The above model is called ARIMA (p,d,q) model, where p and q can be set to different values, and d is the order of the difference needed in ARIMA model, and the d-order difference can be expressed as $d = (1 - B)^d Y_t$.

B is the lag operation. When we set d equal to a certain value in the ARIMA model, we are telling the model how many lag operations we have applied to smooth the data. p represents the autoregressive part, which expresses the value of lagged values used in the model. q represents the moving average part, which describes the lagged value of the error term used in the model.

The process of constructing the ARIMA model is shown in Figure 1:

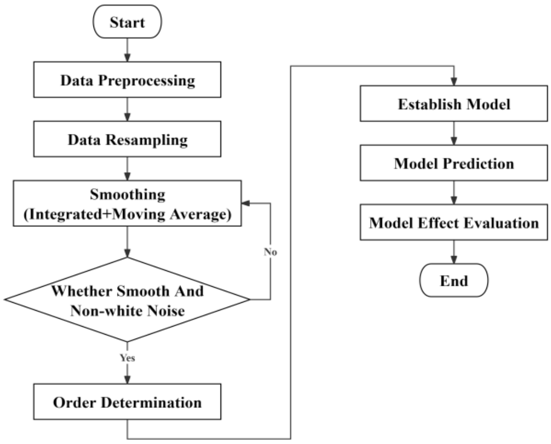

Figure 1. ARIMA Modelling Process

4. Establishment and Solution of Influence Factor Analysis Model Based on Multiple Linear Regression

4.1. Selection of Indicators

In this paper, five aspects of policy, technology, economy, market and environment are selected as level 1 indicators, of which the policy indicators are characterized by the average amount of governmental subsidies for new energy vehicles per unit, the number of policies for new energy vehicles, the total vechile sales volume, and the ownership of new energy vehicles; the technical indicators are characterized by the cumulative number of charging piles, the average mileage of new energy vehicles, and the number of power batteries output; and the economic indicators are characterized by the GDP per capita, disposable income per capita, and oil price; market indicators are characterized by the market share of new energy electric vehicles, consumer satisfaction, urbanization level, and the number of registered enterprises related to new energy electric vehicles; and environmental indicators are characterized by carbon emissions and crude oil production, so as to illustrate the impact of these factors on the development of new energy electric vehicles in China. The specific evaluation index system is shown in Figure 2:

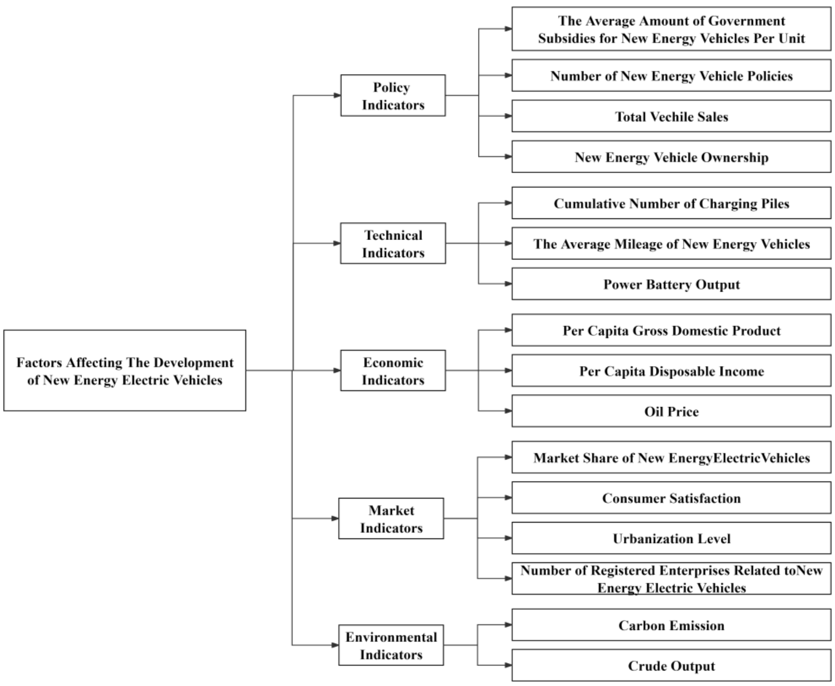

Figure 2. Evaluation Indicator System

4.2. Multiple linear regression modeling

(1) The model is generally determined by $y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k$:

$$\begin{cases} Y = X\beta + \epsilon \\ E(\epsilon) = 0, COV(\epsilon, \epsilon) = \sigma^2 I_n \end{cases} \quad (4)$$

Where k is the number of independent variables, β is the regression coefficient, $\in$ is the error term, $E(\in)$is the expected value of the error term, COV is the covariance of the error term, and I_n is the nth order unit matrix.

The above equation is a k-element linear regression model and is notated as $(Y, X\beta, \sigma^2 I_n)$.

If there are n sample values, then:

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_n \end{bmatrix}, X = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1k} \\ 1 & x_{21} & x_{22} & \cdots & x_{2k} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix}, \beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \cdots \\ \beta_k \end{bmatrix}, \epsilon = \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \cdots \\ \epsilon_n \end{bmatrix} \quad (5)$$

$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k$becomes the regression plane equation.

(2) Once the equations are established, point estimates are first made for the parameters$\beta$and$\sigma^2$to establish the quantitative relationship between y and $x_1, x_2, \ldots, x_k$.

Find the estimates of $\beta_0, \ldots, \beta_k$ by least squares:

$$Q = \sum_{i=1}^{n} (y_i - \beta_1 x_{i1} - \cdots - \beta_k x_{ik})^2 \quad (6)$$

Choose $\beta_0, \ldots, \beta_k$ to minimize Q. Solve for the estimate $\hat{\beta} = (X^T X)^{-1}(X^T Y)$,and substitute the resulting $\hat{\beta}_i$ into the regression plane equation yields:

$$y = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \cdots + \hat{\beta}_k x_k \quad (7)$$

The above equation is called the empirical regression plane equation and $\hat{\beta}_i$ is called the empirical regression coefficient.

(3) Regression coefficient tests for multiple linear regression models.

(i) r-test method

$$U = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2 \quad (8)$$

$$Q_e = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \quad (9)$$

$$R = \sqrt{\frac{U}{L_{yy}}} = \sqrt{\frac{U}{U + Q_e}} \quad (10)$$

Where U is the regression sum of squares, Q_e is the residual sum of squares, and R is called the multivariate correlation coefficient between y and $x_1, \ldots, x_k$, ranging from 0-1, with the closer R is to 1, the better the correlation is; the closer R is to 0, the worse the correlation is.

(4) Predictions from multiple linear regression model.

(i) Point forecast

Find the regression equation $\hat{y} = \beta_0 + \beta_1 x_1 + \cdots + \hat{\beta}_k x_k$, and for a given value of the point independent variable $x_1, \ldots, x_k$, predict $y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \epsilon$ using $\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \cdots + \hat{\beta}_k x_k$, call $\hat{y}$ the point prediction of y.

In this paper, there are 16 independent variables, new energy electric vehicle single-vehicle average government subsidy amount for x_1, the number of new energy vehicle policies for x_2, China's total vehicle sales for x_3, new energy vehicle ownership for x_4, the cumulative number of charging piles for x_5, the average mileage of new energy vehicles for x_6, the power battery output for x_7, the per capita gross domestic product for x_8, the per capita disposable income is x_9, oil price is x_{10}, market share of new energy vehicles is x_{11}, consumer satisfaction is x_{12}, urbanization level is x_{13}, the number of registered enterprises related to new energy electric vehicles is x_{14}, carbon emission is x_{15}, and the production of crude output is x_{16}. The sales volume of new energy electric vehicles is the dependent variable Y.

4.3. Display of solution result

4.3.1 Correlation analysis

In this paper, the sales volume of new energy electric vehicles is chosen to describe the development of the industry, and after processing the data, the Pearson correlation coefficient of each index is calculated to determine whether there is a linear relationship between it and the sales volume.

Pearson's correlation coefficient, usually denoted by the letter r, is used to measure the linear relationship between two variables. The output ranges between -1 and 1, where 0 means no correlation, negative values represent negative correlation, positive values represent positive correlation, and the closer to 1 and -1, the stronger the correlation. The overall Pearson correlation coefficient between two variables is defined as the quotient of the product of the covariance and standard deviation between the two variables, usually denoted by ρ,with the following formula:

$$\rho = \frac{\mathrm{Cov}(X,Y)}{\sqrt{D(X)}\sqrt{D(Y)}} = \frac{E(X-EX)(Y-EY)}{\sqrt{D(X)\sqrt{D(Y)}}} \tag{11}$$

The Table 1 is a preliminary determination of the degree of relevance:

Table 1. ρ value of each indicator

Indicator	ρ	Indicator	ρ
The average amount of government subsidies for NEV per unit(x_1)	-0.74	PCDI(x_9)	0.82
Number of NEV policies at national level(x)	0.73	Oil Price(x_{10})	0.36
Total vechile sales(x_3)	0.29	Market Share Of NEEV(x_{11})	1.00
The number of NEV(x_4)	0.98	NEV consumer satisfaction(x_{12})	0.66
Cumulative number of charging piles(x_5)	0.99	Urbanization Level(x_{13})	0.80
The average mileage of NEV(x_6)	0.76	Number of registered enterprises related to NEEV(x_{14})	0.98
Power battery output(x_7)	0.99	Carbon Emission(x_{15})	-0.23
PCGDP(x_8)	0.84	Crude Output(x_{16})	0.70

Table 1 was visualized to produce a heat map for each indicator as shown in Figure 3:

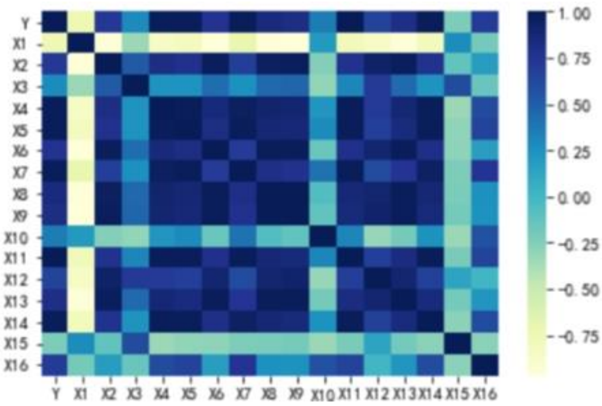

Figure 3. Correlation Heat Map

Through the data in Table 1 and the heat map, it can be seen that China's automobile sales, carbon dioxide emissions and oil prices are weakly correlated, and the rest of the indicators have a strong correlation with the development of the new energy electric vehicle industry. Among them, the number of charging piles, power battery production, new energy vehicle market share and the number of enterprises correlation index tends to be close to 1, showing strong linear correlation, which has a great influence on the development of new energy vehicle industry.

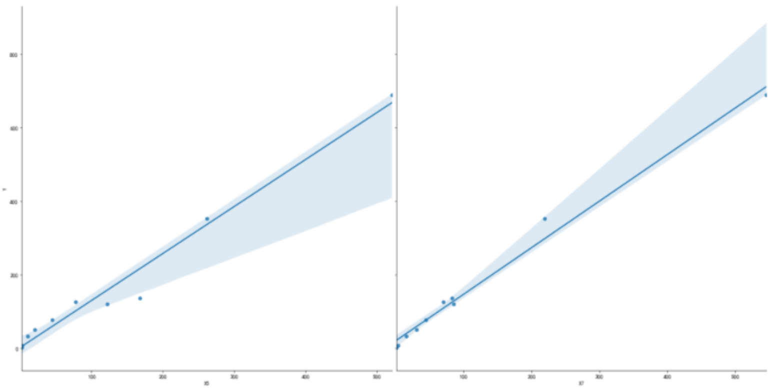

Figure 4. Scatter plot of China's car sales and oil price and Scatter plot of China's car sales and carbon emissions

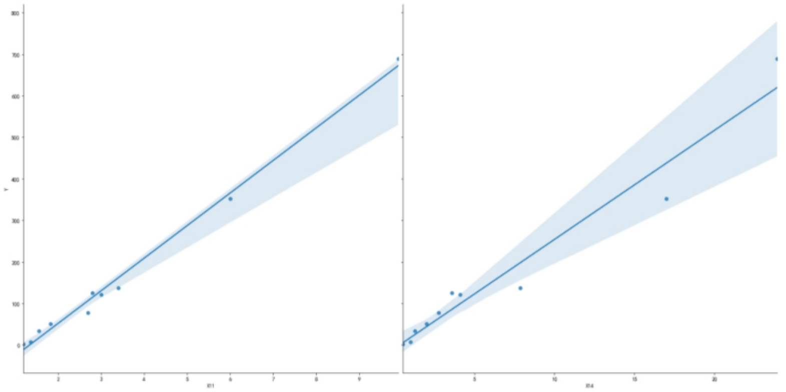

Figure 5. Scatter plot of China's car sales and carbon emissions and Scatterplot of China's car sales and power battery production

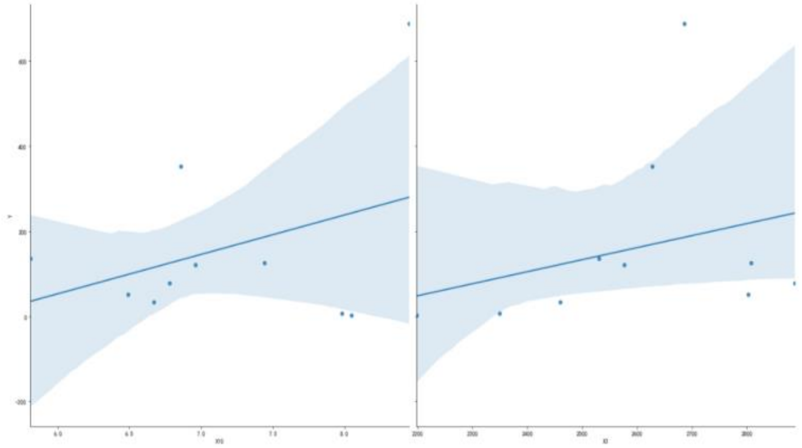

Figure 6. Scatter plot of China's car sales and market share of new energy vehicles and Scatter plot of China's car sales and the number of new energy electric vehicle enterprises

4.3.2 Multiple linear regression

On the basis of the above analysis, the paper excluded the indicators with low correlation and low linear fit and selected the remaining 8 indicators to carry out multiple linear regression analysis using Python software. The relationship between NEEV sales and other indicators can be obtained as follows:

$$y = -5.166 - 0.092x_1 + 0.009x_2 + 0.001x_3 + 0.008x_8 - 0.383x_9 + 0.003x_{12} + 0.791x_{13} + 0.087x_{16} \quad (12)$$

After regression, R^2 is 0.996, F-value is 301 and a Durbin Watson value is 2.767, which is between 0 and 4, and the model fits well. The effect is shown in Figure 7:

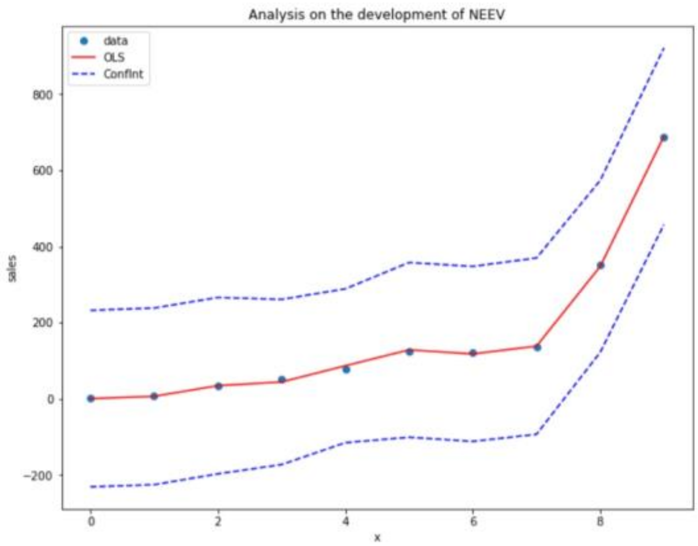

Figure 7. Multiple linear regression fitting graph.

From the above data, it can be concluded that the average amount of government subsidies per EV and per capita disposable income have a negative impact on the industry development, i.e., the decline of the first two will lead to the reduction of new energy vehicle sales, which may cause some obstacles to the further development of the industry in the future. The remaining factors, such as GDP and urbanization level, have a positive impact on industry development.

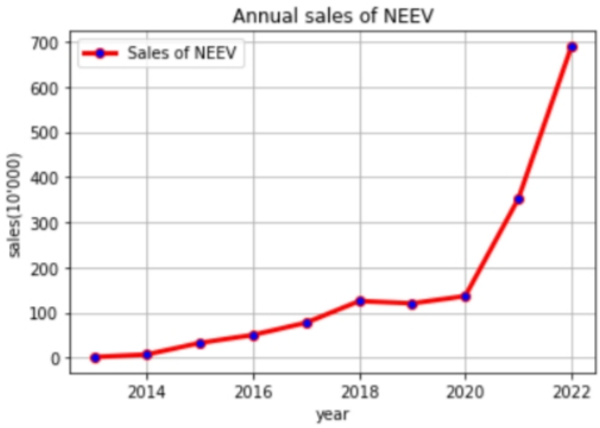

Figure 8. 2013-2022 China New Energy Electric Vehicle Sales Graph

Figure 8 shows the sales volume of new energy electric vehicles in China in the past ten years, with an overall upward trend and good prospects for market development. As of now, the development of new energy electric vehicle industry is mainly affected by technology, national policy and current market development, of which a larger proportion is the technical factor. Therefore, China should improve the technology of new energy electric vehicles, accelerate the improvement and coverage of basic charging facilities by increasing the number of public charging piles, etc., and at the same time, it can also increase the subsidies and support in terms of policy.

5. Establishment and solution of a time series-based sales volume forecasting model

5.1. Data collection

According to the data collected on the development of new energy electric vehicles is shown in Table 2:

Table 2. New Energy Electric Vehicle Development Data Display

Year	Sales	NEV Output	Charging Piles	PCGDP x_8	Power Battery Output(Gwh) x_7	Number of Registered Enterprises Related to NEEV x_{14}	The Average Mileage of NEV x_6	Urbanization Level x_{13}
2013	1.75	1.76	2.25	59.30	1.4	0.51	124	0.54
2014	7.50	7.85	3.10	64.36	3.7	0.98	158	0.55
2015	33.11	34.05	10.23	68.89	15.7	1.26	186	0.56
2016	50.70	51.70	20.40	74.64	30.8	2.00	209	0.57
2017	77.70	79.40	44.60	83.20	44.5	2.74	249	0.59
2018	125.60	127.00	77.70	91.93	70.6	3.58	332	0.60
2019	120.60	124.20	121.90	98.65	85.4	4.10	381	0.61
2020	124.60	136.60	168.10	101.36	83.4	7.86	411	0.64
2021	352.10	354.50	261.70	114.92	219.7	17.00	429	0.65
2022	688.70	705.80	521.00	121.02	545.9	23.94	454	0.65

5.2. Solving a time series-based sales forecasting model

5.2.1 Solution process

Time series model solution process

Step1 Visualizing and analyzing time-series data

Step2 Observe whether the sequence is smooth

Step3 Plot ACF/PACF graph to find optimal parameters

Step4 Modeling Differential Autoregressive Moving Average (ARIMA)

Step5 Perform data forecasting

Step6 Result Output

5.2.2 Display of solution result

This paper takes the sales volume of new energy electric vehicles as an indicator to measure the future development of the industry and selects the following seven indicators with strong correlation with sales volume data for analysis: NEV output, Cumulative number of charging piles, PCGDP, Power battery output, Number of registered enterprises related to NEEV, the average mileage of NEV, Urbanization level.

Firstly, the ADF test was performed on the series by Python software to determine whether it is smooth or not, and the results were obtained as shown in Table 3:

Table 3. ADF test list

varite	sequence	t	P	Critical value		
				1%	5%	10%
Sales of NEEV	Primitive sequence	2.7242	0.9991	-5.3543	-3.6462	-2.9012

The query shows that the ADF value, i.e. t-value, is less than 1%, 5% and 10% at the same time means that the original hypothesis is very well rejected. The t-value in this data is 2.72442, which is greater than three levels of statistics. p-value needs to be less than 0.05, but the result shows 0.9991. In summary, we conclude that the series is not a smooth series and needs to be processed for differentiation.

After two differential treatments of the series and finally turning it into a smooth series, we calculate the values of ACF and PACF, determine the values of p and q, and finally build the ARMA (p,q) model. As shown in Figure 9, from the ACF and PACF plots, it can be seen that the values of p and q are both 1.

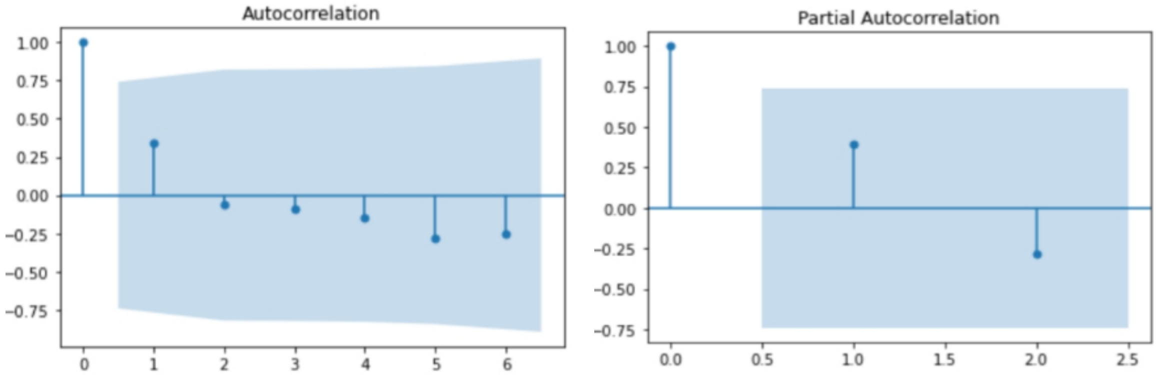

Figure 9. Sales Autocorrelation Chart and Sales Partial Autocorrelation Chart

After establishing the final model, the sales volume of new energy electric vehicles in the next 10 years is again predicted by python software, and the results are shown in Table 4:

Table 4. Sales forecast of NEEN in the next 10 years

Year	Sales of NEEV (Ten thousand units)
2023	933.753
2024	1097.434
2025	1206.765
2026	1279.793
2027	1328.572
2028	1361.154
2029	1382.917
2030	1397.453
2031	1407.163
2032	1413.649

From the data in Table 4, it can be seen that the sales of new energy electric vehicles in China will grow steadily in the next 10 years, and the industry has a very good prospect for development.

6. Conclusion

This study assessed the key factors affecting the development of new energy vehicles by constructing a multiple linear regression model containing indicators of multiple dimensions such as policy, technology, economy, market and environment. The analysis results show that the development of the new energy vehicle industry has a significant positive correlation with the number of charging piles, power battery production, market share and the number of enterprises, while the correlation with total vehicle sales, carbon dioxide emissions and oil prices is weak. This indicates that technology and policy factors play a decisive role in promoting the development of new energy vehicles.

Further, through the time series model forecast, we predicted the sales of new energy vehicles in China in the next 10 years. The forecast data shows that new energy vehicle sales will continue to grow and are expected to maintain a steady upward trend in the coming years. Specifically, it increases from 9,337,530,000 units in 2023 to 14,136,490,000 units in 2032. This forecast result reflects, to some extent, the optimistic outlook and long-term growth potential of the new energy vehicle market.

Based on the above findings, this paper suggests that the Chinese government and enterprises should continue to increase their R&D investment in new energy vehicle technology and improve their technological level and innovation capability in order to enhance the competitiveness and market attractiveness of new energy vehicles. At the same time, the construction of charging infrastructure should be accelerated and improved, and the number of public charging piles should be increased to provide consumers with more convenient charging services, thus promoting the popularization and application of new energy vehicles. In addition, the government should continue to introduce and implement a series of targeted policy measures, such as subsidies and support policies, to stimulate market demand and promote the healthy and sustainable development of the new energy vehicle industry.

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