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Study on the Development Status and Future Trends of New Energy Electric Vehicles in China

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Abstract: In recent years, energy shortage and environmental problems have become increasingly serious, and the development of new energy electric vehicles has become a new breakthrough. China's new energy electric vehicle market has entered a new stage of explosive growth, with significant growth in the proportion of private consumption and market share. However, the driving and inhibiting factors about the development of new energy automobile industry are still unclear; how the future trend of China's new energy industry development will be has not yet been fully answered; is it really a substitution relationship between new energy electric vehicles and traditional energy vehicles? How can China quickly capture market share in the complex and changing global market? To what extent does the popularization of new energy vehicles have an impact on the environment? Solving these problems will be of great significance to China's new energy development strategy. To address the above issues, this paper constructs the corresponding model and solves them. Finally, the constructed model is briefly evaluated and further discussed.

Keywords: New energy electric vehicles; AHP hierarchical analysis; ARIMA time series analysis; Policy resistance.

1. Introduction

1.1. Background of the issue

In recent years, the scale of China's new energy electric vehicle industry has been expanding, and has achieved world-renowned results. According to the Ministry of Industry and Information Technology disclosure data show that in 2022, China's new energy electric vehicle production and sales were completed 7,058,000 and 6,887,000 vehicles, an increase of 96.9% and 93.4%, respectively, the market penetration rate of 25.6%, the production and sales exceeded 1 million vehicles for five consecutive years, ranking first in the world for eight consecutive years. However, under the goal of promoting the transformation from a large automobile country to a strong automobile country, the development of China's new energy electric vehicle industry is still facing a lot of problems, affected by various factors, and the relationship between the influencing factors is intricately linked. It is of practical significance to deeply investigate the factors affecting the development of China's new energy electric vehicle industry and their internal mechanisms, and to clarify the influence of each factor on the development of the new energy industry in order to enhance its competitiveness and influence, and to realize the goal of high-quality development.

1.2. Restatement of issues

Considering the background information and constraints identified in the problem statement, we need to address the following questions.

Q1: There are many factors affecting the development of new energy electric vehicles in China, how to categorize these many factors and construct an evaluation system for the level of development of new energy electric vehicles is the primary problem, and how to determine the weighting agreement of each of these intricate influencing factors among these influencing factors after establishing the evaluation system is also important.

Q2: If we want to describe and predict the development of China's new energy electric vehicles in the next ten years, collecting past data is the first task, but in the prediction, since the data is only the annual trend data, the amount of data is small, and it is not possible to use the machine learning neural network model that requires a large amount of data, so how to choose the time series to analyze the prediction is a crucial issue.

Q3: To analyze the impact of new energy electric vehicles on the global traditional energy automobile industry, the first step is to collect data and preprocess the data. And to get the global sales of traditional cars you need to get the global sales of new energy electric cars, but the new energy electric cars in different countries are not all public, which is the first task of solving problem three.

Q4: Problem 4 is to analyze when foreign countries adopt targeted boycott policies, what kind of impact these policies will have on the development of China's new energy electric vehicles, the main problem encountered in analyzing this problem is how to accurately obtain the specific time nodes of foreign countries adopting these boycott policies and how to accurately express the implementation of the policy as a qualitative variable in the model.

Q5: For question 5, how to quantitatively represent the changes in the ecological environment is the main problem, and since the impact on the environment is to be assessed, then the impact on the environment of new energy electric vehicles and traditional vehicles must be assessed together, so how to unify these two types of vehicles with different metrics?

1.3. Our work

This topic requires us to solve five problems related to the development of new energy electric vehicles and write an open letter to the public. For problem one this paper establishes the AHP hierarchical analysis model; for problem two of the time series forecasting problem this paper uses the

ARIMA model to analyze, through the difference to ensure the smoothness of the time series; in problem three need to model to quantitatively analyze the impact on the traditional energy automobile industry, in order to qualitatively analyze the sales of the traditional energy automobile this study uses the sales of traditional energy automobiles to represent the development of the traditional industry to determine whether the two commodities Whether there is a mutually exclusive relationship.

Question four requires quantitative analysis of the impact of foreign boycott policies on the development of China's new energy electric vehicle industry, this study is mainly through the introduction of dummy variables to achieve the construction of the model; for question five to study the impact of electric vehicle electrification on the environment, this study through the conversion of the electricity consumption of the trolley buses and the fuel consumption of traditional fuel vehicles into the coal consumption of this uniform outline for comparison, through the comparison of the amount of coal consumption to quantitatively compare the environmental impact of the adoption of new energy electric vehicles. We quantitatively compare the environmental impact of adopting new energy electric vehicles by comparing the amount of coal consumption.

2. Symbol Description

The key mathematical notations used in this paper are listed in Table 1.

Table 1. Notations used in this paper

Notation	Description
ω	weight vector
λ	Eigenvalues
CI	Consistency indicator to assess the consistency of comparisons between different factors.
RI	Consistency Ratio
CR	Consistency ratio, used to judge whether the comparison between different factors meets the consistency requirement.
Y_t	Time series data corresponding to time node t
α_i	Regression coefficients in the regression model
β_i	Parameters of the AR model, used to describe the relationship between the current value and the value at the past p time points
θ_i	Parameters of the MA model to describe the relationship between the current values and the errors at the past q time points
ε_t	Error term at time point t
e_i	Recall the random perturbation term in the model
X_{1i}	New energy electric vehicle sales at year t
X_{2i}	Time series with the change of
Y^t	Represents relative energy savings/t standard coal
F	Standard coal fuel consumption for fuel vehicles
E	Electric Vehicle Standard Coal Electricity Consumption
EC	Electric Vehicle Power Consumption
FC	Fuel Vehicle Fuel Consumption
SCE	Standard Coal Equivalent

3. Assumptions and Justifications

Assumption 1: China's new energy electric vehicle production (sales) has shown a positive growth trend over time.

Justification: As the most commonly used vehicle for people to get around, it is almost impossible to give up in daily life, secondly, the car has a phase-out period, in the popularity of the car in the decades, the amount of car phase-out and the amount of holdings are in a relative equilibrium, and the amount of holdings of the new car does not have to be overly considered, in the situation of excessive growth of carbon emissions, new energy electric vehicles have the space to compete with traditional cars, and With the passage of time and technological progress, the production and acceptance of new energy electric vehicles will gradually increase.

Assumption 2: The regression model is linear with zero conditional expectation of the error term, homoscedastic and free of autocorrelation and multicollinearity.

Justification: Model assumptions are justified in that they are consistent with what is common in practical applications, ensure unbiasedness and validity of the model, avoid model overfitting and autocorrelation errors, and ensure stability of the model. These assumptions are considered reasonable in both theoretical and practical applications and provide valid estimates and predictions.

Assumption 3: Sales of conventional energy vehicles is a proxy indicator for the state of the global conventional energy vehicle industry, with the view that the better the sales and ownership, the better the development of related infrastructure and ancillary industries.

Justification: This paper studies the impact of the development of new energy electric vehicles on the traditional energy automobile industry with the sales of traditional energy vehicles as a representative indicator of the state of the global traditional energy automobile industry, because the sales of commodities represent consumer demand and preference, according to the theory of consumer behaviour the sales of a certain commodity can be representative of the development of the industry where the commodity is located.

Assumption 4: As the models, driving conditions and energy sources of various models vary in reality, this paper determines the 100-mile energy consumption of each model based on the Catalogue of New Energy Electric Vehicle Models Exempted from Vehicle Purchase Tax.

Justification: The100-mile energy consumption of each model can be verified by checking the Catalogue of New Energy Electric Vehicle Models Exempted from Vehicle Purchase Tax, and weighting the average energy consumption of various models of different brands.

4. Model Building and Solution of Question 1

4.1. The Establishment of Model 1

Due to the complexity of the economic environment, new energy electric vehicles as a daily use of bulk commodities, the specific impact factors are not clear, in order to explore the impact of the influence of China's new energy electric vehicles influence mechanism, this paper is based on hierarchical analysis AHP (Analytic Hierarchy Process), evaluation model as the construction of the weights of the indicator system.

Hierarchical analysis is fundamentally a scoring method: indicators are identified, different programme indicators are scored, and weights are established for the indicators. It is used to deal with evaluations where the data are unknown. Hierarchical analysis breaks down the problem into its constituent factors and aggregates and combines the factors at different levels according to their correlation, influence and affiliation to form a multilevel structural model of analysis. This ultimately reduces the problem to the determination of the relative importance weights or the ranking of the relative advantages and disadvantages of the lowest level (programmes, measures, etc. for decision-making) in relation to the highest level (the overall objective).

4.2. Establishment of a System of Indicators

Table 2. System of indicators

Level 1 indicators	Secondary indicators	Tertiary indicators
Factors affecting the development of new energy electric vehicles	Policy-related indicators	Number of new energy electric vehicle policies
		Public charging pile holdings (10,000)
		China car sales (10,000 units)
	Technology-related indicators	China's New Energy Electric Vehicle Patent Applications
		Power Battery Company Registrations
		Battery recycling business registrations
		New Energy Electric Vehicle Investment and Financing Events
		Total disclosure of investment and financing in the new energy electric vehicle industry
	Economic-related indicators	GDP per capita
		Consumption level index
		Per capita disposable income of urban residents
		Per capita disposable income of rural residents
	Resource-related environmental indicators	crude oil production
		Road area (10,000 square metres)
		Length of roads (10,000 kilometres)
		Public transport vehicles per 10,000 population (standard units)
		petrol price
		carbon trading price
	Indicators related to social benefits	urbanisation rate
		aging rate
		Gross enrolment ratio in tertiary education
		Number of car drivers

4.3. The Solution of Model 1

In this paper, the main purpose is to establish the AHP evaluation model through Python and refer to related literature to construct the index judgement matrix, also known as the pairwise comparison matrix, which is a comparison of the relative importance of all the factors in this layer against a factor (quasi-side or target) in the previous layer. The element α_{ij} of the pairwise comparison matrix indicates the comparison result of the ith factor relative to the jth factor. This model assumes that each factor is independent of each other, but the actual situation may be more complicated, and the introduction of cross terms of mutual influence can be considered, in order to quantify the five different influences in a more detailed way, this paper selects a more specific three-level indicator.

(1) Consistency test

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \Leftrightarrow \begin{cases} a_{ij} > 0 \\ a_{11} = a_{22} = \cdots = a_{nn} = 1 \\ \left[a_{i1}, \ldots, a_{in}\right] = k_i \left[a_{1n}, \ldots, a_{1n}\right] \end{cases} \quad (1)$$

For a consistent array: then we naturally take the normalized eigenvectors $\{w_1, w_2, \cdots w_n\}$, and $\sum_{i=1}^{n} w_i = 1$ corresponding to the largest characteristic root n, where w_i denotes the weight of the degree of influence of the ith factor in the lower layer on a factor in the upper layer.

Non-consistent array: use the normalized eigenvector corresponding to its largest characteristic root as the weight vector. If $W = \{w_1, w_2, \cdots w_n\}$ then $AW = \lambda W$. The method of determining the weight vector in this way is known as the characteristic root method.

Judging whether the judgement matrix has consistency or not is mainly observed quantitatively through the three consistency indicators CI, RI and CR. If CI=0, there is complete consistency, CI is close to 0, there is satisfactory consistency, the larger CI is, the more serious the inconsistency is, and vice versa if CI is smaller, the higher the consistency is. RI is the corresponding average random consistency index which can be obtained by checking the table.CR is the consistency ratio, if CR<0.1, the consistency of the judgement matrix can be regarded as acceptable, otherwise, it is necessary to correct the judgement matrix.

$$CI = \frac{\lambda - n}{n-1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

(2) Judgement matrix of the five factors of the secondary indicators

A judgment matrix is constructed for the policy factors, technical factors, economic factors, resource environmental factors and social factors of the secondary indicators, and the weights of the matrix are based on the results obtained from the modeling of the gray correlation on the objective data.

$$\begin{pmatrix} 1 & 1.201 & 0.975 & 1.167 & 1.002 \\ 0.832 & 1 & 0.875 & 1.032 & 0.903 \\ 1.026 & 1.142 & 1 & 1.294 & 1.056 \\ 0.856 & 0.968 & 0.772 & 1 & 1.018 \\ 0.998 & 1.107 & 0.946 & 0.982 & 1 \end{pmatrix} \quad (3)$$

The weight vector calculated by the eigenvalue method is: [0.212300450, 184499550, 21915680, 183349460, 20069374]. The CI value of the judgement matrix is: (0.001323+0j): he CR value of the judgement matrix is: (0.001181+0j). Because the CI value of the judgement matrix is very close to 0 so there is a satisfactory consistency to pass the consistency test, and at the same time the CR of the judgement matrix is <0.1 so it can be considered that the consistency of this judgement matrix is acceptable.

Technical Indicator Judgement Matrix:

$$\begin{pmatrix} 1 & 1.210 & 1.232 & 1.201 & 1.351 \\ 0.826 & 1 & 1.023 & 1.014 & 1.054 \\ 0.812 & 0.978 & 1 & 1.023 & 1.045 \\ 0.833 & 0.986 & 0.978 & 1 & 1.051 \\ 0.740 & 0.949 & 0.957 & 0.951 & 1 \end{pmatrix} \tag{4}$$

The weight vector calculated by the eigenvalue method is: [0.23762739, 0.19512, 0.19267392, 0.192475, 0.18210368], the CI value of the judgement matrix is: (0.000152+0j), the CR value of the judgement matrix is: (0.000135+0j), the CI value of the judgement matrix is very close to 0 so there is satisfactory consistency through the consistency test, and at the same time, the CR of the judgement matrix is <0.1 so it can be considered that the consistency of the judgement matrix is acceptable. Pass the consistency test.

Judgement Matrix for Tertiary Economic Indicators:

$$\begin{pmatrix} 1 & 1.023 & 1.021 & 1.032 \\ 0.978 & 1 & 1.213 & 1.264 \\ 0.980 & 0.824 & 1 & 1.192 \\ 0.969 & 0.791 & 0.839 & 1 \end{pmatrix} \tag{5}$$

The weight vector calculated by the eigenvalue method is: [0.25413435, 0.27586627, 0.24677962, 0.22321976]. The CI of the judgement matrix is: (0.002797+0j).The CR of the judgement matrix is: (0.003143+0j).The CI value of the judgement matrix is very close to 0 so there is satisfactory consistency to pass the consistency test and also the CR of the judgement matrix is <0.1 so the consistency of this judgement matrix can be considered acceptable. It passes the consistency test.

Judgement Matrix for Tertiary Social Benefit Indicators:

$$\begin{pmatrix} 1 & 1.015 & 1.034 & 1.076 \\ 0.985 & 1 & 1.023 & 1.067 \\ 0.967 & 0.978 & 1 & 1.027 \\ 0.930 & 0.937 & 0.974 & 1 \end{pmatrix} \tag{6}$$

The weight vector calculated by the eigenvalue method is: [0.25761767, 0.25448977, 0.24806882, 0.23982374], the CI value of the judgement matrix is: (9.844781+0j), the CI value of the judgement matrix is very close to 0 so there is a satisfactory consistency to pass the consistency test, and also the CR of the judgement matrix is <0.1 so it can be considered that the consistency of this judgement matrix is acceptable. Pass the consistency test.

4.4. AHP Weighting Results

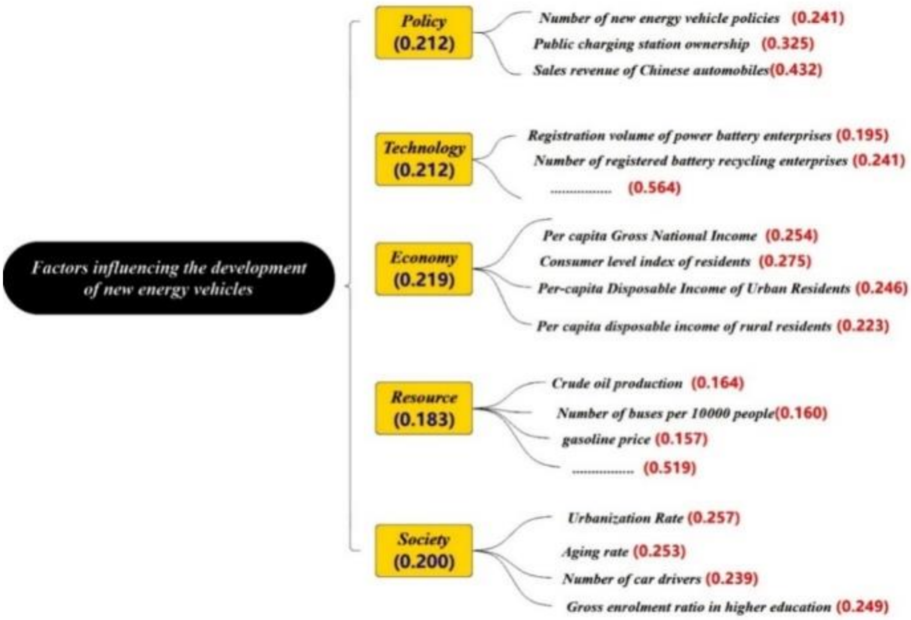

Figure 1. Final System of Indicators

According to the final indicator system, the five major influencing factors of the development of new energy electric vehicles in the economic indicators and policy indicators have a greater impact, the weight of which is 0.219 and 0.212, the social benefit indicators for all the influencing factors of the 1/5, technology related indicators and environment-related indicators account for a smaller proportion, respectively, 0.184 and 0.183.

5. Model Building and Solution of Question 2

5.1. Model Building Ideas

China's new energy electric vehicle development prospects in the next ten years, its actual landing point is the government's policy support, new energy vehicle sales and some infrastructure (charging piles) on the popularity of the policy and other non-numerical dummy variables, in the actual analysis is not good and numerical data together, and for the sales volume, the number of infrastructure, and so on, there are indicators for each year's data, it can be easy to define and modelling and analysis, therefore in Question 2, we choose the sales volume of new energy EVs and charging piles of new energy EVs in China as the projected items to represent the future development of new energy EVs with these two indicators.

In the prediction, because the data only year trend situation, the data volume is small, cannot be used on the data volume requirements of the larger machine learning neural network model, so we choose a more conventional time series analysis prediction model, due to the data does not have a seasonal trend, so this paper selects the ARIMA model to analyse, through the difference to ensure that the smoothness of the time series, and then use the AR and MA model to predict the results.

5.2. Establishment of ARIMA Model

In this paper, the ARIMA model is selected for analysis, and the smoothness of the time series is ensured by differencing, and in using the AR and MA models to predict the results, the model is as follows:

$$Y_t = c + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + ... + \beta_p Y_{t-p} + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + ... + \theta_q \varepsilon_{t-q} + \varepsilon_t \quad (7)$$

The AR model partly indicates that the current value is related to its past value, and the MA model partly indicates that the current value is related to its past error term. The mean value υ, which represents the long term trend in the MA model, does not exist in the formula of the ARIMA model, and the "long term forecasting trend" is performed by the AR model, which replaces the mean value υ, and c can be 0 in the model. The AR model replaces the mean value υ, and c can be zero in the model.

Also, this formula is based on the assumption that the time series we are working with is smooth so that we can apply the AR and MA models directly. If the time series is non-smooth, then we need to consider the I part of the ARIMA model, which is to perform the differencing process. The above model is called ARIMA(p,d,q) model, where p and q have exactly the same meaning as in the original MA and AR models, and p and q can be set to different values, while d is the order of the difference required by the ARIMA model.

5.3. Solution of Question 2

(1) Production forecasts for new energy electric vehicles

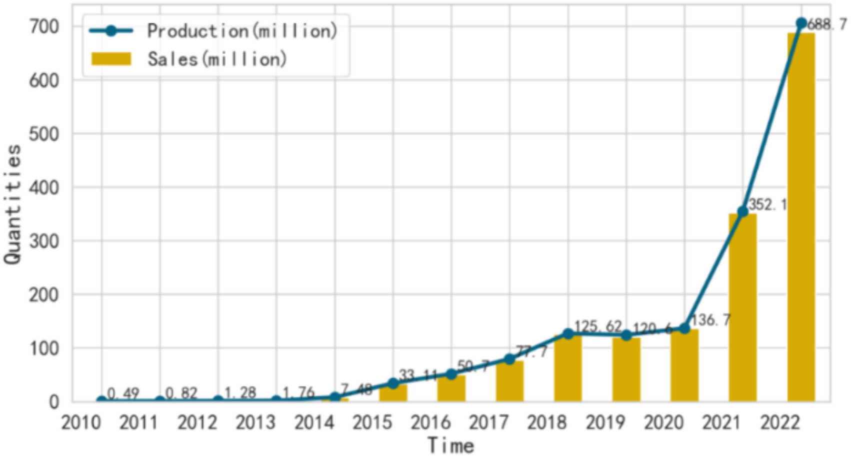

Figure 2. Production and Sales of New Energy Electric Vehicles 2010-2000

In the subsequent analysis, due to the great similarity between the trend of production and sales, this paper only considers the forecast of sales, because sales relative to production can be more responsive to the development of new energy electric vehicles, the national likes, the purchase will be high, the development will be good. In the ARIMA model, a more important place lies in determining the parameters of the ARIMA model, mainly including the order I of the difference, the order p and q of the AR and MA models, and for short series data, at best, the first-order difference, the data will be almost smooth, so we first perform the ADF statistical test, and if it's not smooth, then carry out the first-order difference p and q of the order of the determination of the model is mainly through the AIC index to determine, because the data is small does not exist training time-consuming problem, so we choose to iterate p and q from 1 to 4, respectively, select the minimum value of AIC as the optimal ARIMA model, and then lose the prediction results.

For the sales ARIMA model, the optimal p, d, and q are 0, 1, and 3, respectively. Because the ADF test found that the time series was not smooth, it was differenced.

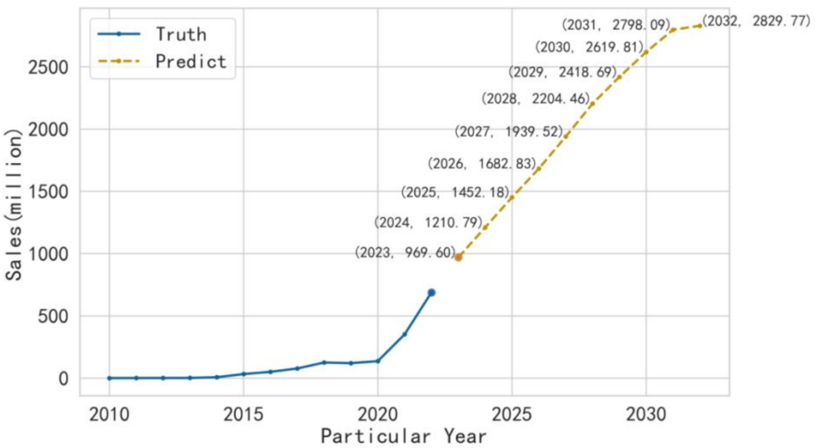

Figure 3. Forecast of New Energy Electric Vehicle Sales for the Next Ten Years

The prediction results can be obtained by bringing in the parameters as follows figure:

As can be seen from the figure from 2023 to 2031 new energy electric vehicle sales are growing rapidly, it is expected that new energy electric vehicle sales will increase from 9,696,000 units in 2023 to 27,980,900 units in 2031, but from 2031 onwards China's new energy electric vehicle sales began to slow down. It is predicted that the sales of new energy electric vehicles in 2032 will only be 28,297,700 units, a growth rate of 1 per cent, which is much lower than the previous growth rate of 6 per cent.

At the same time, also in line with the reality of the situation, when the sales growth to a certain extent, the market share of each manufacturer tends to stabilise consumer demand is no longer rapid growth, these phenomena will lead to, new energy electric vehicle sales began to slow down.

(2) Forecast of the number of charging stations

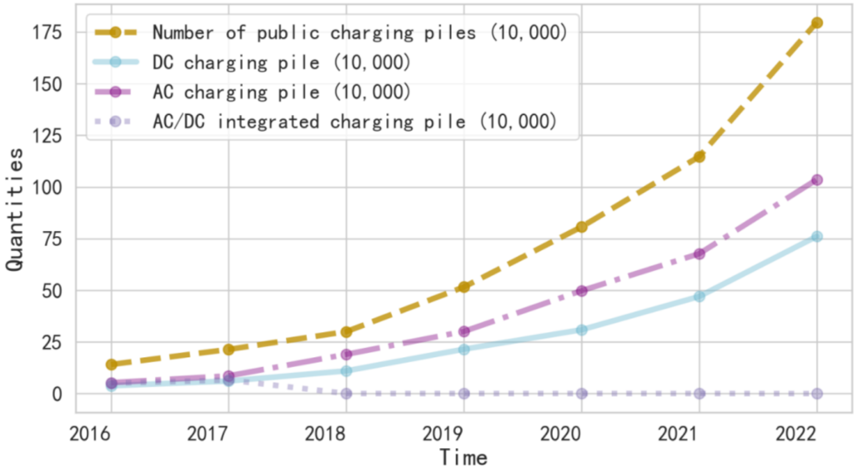

Figure 4. Comparison of Number of Charging Piles

For charging stations, we only perform modelling of all charging piles, after processing and importing the data use ADF to test whether the data is stable or not, if it is not stable perform first-order differencing and print the plots of the data before and after differencing. Then normalise the processed data and print the normalised plots, finally determine the ARIMA parameters by AIC, print the autocorrelation coefficient plots and partial autocorrelation coefficient plots for the original and post-differential data, and print the residual plots after determining the parameters.

Test Statistic: 7.835749, p-value: 1.000000, min ACI:(1, 1, 0) were obtained, and the optimal p, d, q for the ARIMA model of charging piles was 1,1,0 respectively. Because the ADF test found that the time series was not smooth, a first-order differencing process was required. The prediction results can be obtained after bringing in each parameter:

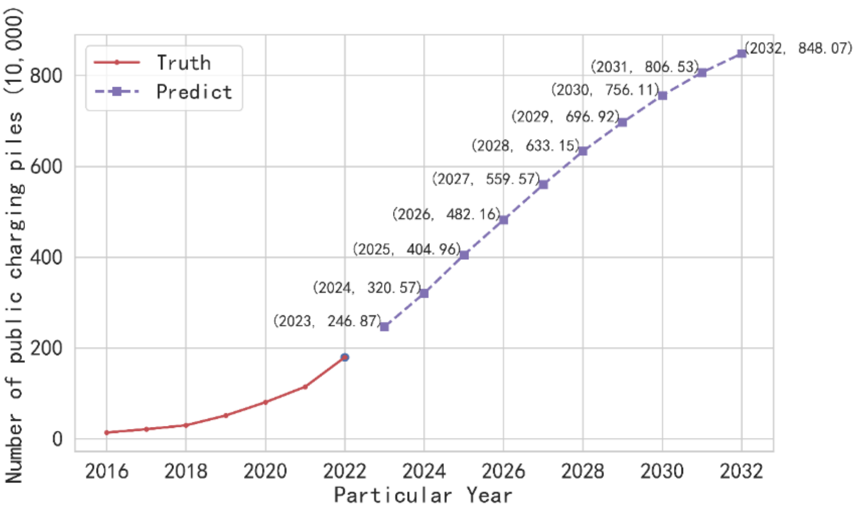

Figure 5. Forecast of the number of public charging posts in the next ten years

6. Model Building and Solution of Question 3

6.1. Model Building Ideas

Problem analysis: the impact of new energy electric vehicles on the global conventional energy automotive industry:

This study takes the sales of traditional energy vehicles as a representative indicator of the state of the global traditional energy vehicle industry, and argues that the better the sales and ownership, the better the development of related infrastructure and affiliated industries. Therefore, this study is to prove that the sales of new energy electric vehicles and the sales of traditional energy vehicles are mutually exclusive and substitutive, thus indicating that the development of new energy electric vehicles has a significant impact on the global traditional energy automobile industry. Then, this study will also examine whether the development of new energy electric vehicles has a positive or negative impact on the global traditional energy automobile industry.

6.2. Data Processing

Collect data and preprocess the data. Due to the limitation of data acquisition, this paper only collects the global stock of new energy electric vehicles and the global sales of automobiles, while to obtain the global sales of traditional automobiles it is necessary to obtain the global sales of new energy electric vehicles, but the new energy electric vehicles in different countries are not all publicly available.

Based on this, we based on the global stock of new energy electric vehicles, to get the new stock each year, and then based on the access to data, assuming that the discount rate of 0.95, you can get each year damage to the new energy electric vehicles, so as to invert the new energy electric vehicle sales each year, and then use the sales volume minus the global sales volume of automobiles and then get the sales volume of traditional cars in the new energy electric vehicles, collect the data including China, the European Union and the United States in the national car sales, collect the data including China, the United States, Japan, Germany, South Korea and India. In the new energy electric vehicles, the data collected include China, the European Union and the United States in the national car sales, the data collected include China, the United States, Japan, Germany, South Korea and India we need to extract the intersection of which, taking into account that the United States and China are the world's GDP of the first and the second largest countries, we assume that the new energy electric vehicles and traditional automobile situation in these two countries can reflect the global situation.

6.3. Establishment and Solution of Regression Model

A linear regression model based on the time factor is established after obtaining the global sales volume or ownership of new energy electric vehicles and the global sales volume or ownership of traditional energy vehicles. Using Y_i represents the sales of traditional cars, X_{1i} represents the sales of new energy electric cars and X_{2i} represents the time, and the OLS method is used to solve the regression model. The regression results were obtained to see whether the p-value was significant and the positive and negative relationships of the regression coefficients.

If the model is significant at the 5% level of significance can be proved that the impact of new energy electric vehicles is significant, and at the same time to observe the regression coefficients X_1 positive and negative relationship if the sign is positive indicates that new energy electric vehicle sales on the sales of traditional cars is the impact of promoting the relationship, there is no substitution, if the sign is negative indicates that new energy electric vehicle sales on the sales of traditional cars is the impact of inhibiting the relationship, there is a substitution relationship. If the sign is negative, it means that the sales of new energy electric vehicles are inhibiting the sales of conventional vehicles and there is a substitution relationship.

As mentioned earlier, we try to build a model based on this in the following form.

$$Y_i = \hat{\alpha}_0 + \hat{\alpha}_1 X_{1i} + \hat{\alpha}_2 X_{2i} + e_i \tag{8}$$

We make:

$$\min Q = \min \sum_{i=1}^{9} (Y_i - \hat{Y}_i)^2 = \min \sum_{i=1}^{9} [Y_i - (\hat{\alpha}_0 + \hat{\alpha}_1 X_{1i} + \hat{\alpha}_2 X_{2i})]^2 \tag{9}$$

In order to get the best fit for the equations, it is therefore necessary to minimize the value of Q taken, i.e., to find minQ such that the following system of equations holds.

$$\begin{cases} \dfrac{\partial Q}{\partial \hat{\alpha}_0} = -2\sum_{i=1}^{9}[Y_i - (\hat{\alpha}_0 + \hat{\alpha}_1 X_{1i} + \hat{\alpha}_2 X_{2i})] = 0 \\ \dfrac{\partial Q}{\partial \hat{\alpha}_1} = -2\sum_{i=1}^{9}[Y_i - (\hat{\alpha}_0 + \hat{\alpha}_1 X_{1i} + \hat{\alpha}_2 X_{2i})]X_{1i} = 0 \\ \dfrac{\partial Q}{\partial \hat{\alpha}_2} = -2\sum_{i=1}^{9}[Y_i - (\hat{\alpha}_0 + \hat{\alpha}_1 X_{1i} + \hat{\alpha}_2 X_{2i})]X_{2i} = 0 \end{cases} \tag{10}$$

We can calculate the values of the coefficients programmatically in Python

Table 3. The value of each coefficient

Parameter	$\hat{\alpha}_0$	$\hat{\alpha}_1$	$\hat{\alpha}_2$
Estimated Value	-3.967e+05	-2.1108	198.7645

Also observe the t-test value of X_1 and its p-value probability:

Table 4. Coefficient of T test

	t	P>|t|
X_1	-3.858	0.008
X2	3.007	0.022

Where, X_1 denotes the new energy electric vehicle sales, X_2 denotes the time, and the p-value of X_1 is 0.008, which indicates that the effect of new energy electric vehicle sales on conventional vehicle sales is significant at the 5% significant level, and it has a coefficient of -2.1108, which indicates a negative impact relationship.

The reason why X_2 year should be included in the test is because with the development of the year the country's economy is also developing, which means that the increase in income and purchasing power, the impact on the traditional car may also be significant, and it has been proved that it is indeed also significant. Meanwhile the R-squared of the whole model is 0.740, which means that to explain the industrial situation of traditional automobiles, the use of new energy electric vehicle sales and year can explain more than 70 per cent of the traditional industrial situation, and in the follow-up, more variables can be considered to be included to get a better model fitting effect.

7. Model Building and Solution of Question 4

7.1. Model Building Ideas

Problem analysis: the impact of foreign boycott policies on the development of new energy electric vehicles in China:

Firstly, by searching the website of China Association of Automobile Manufacturers (CAAM), searching for China's new energy export policies in the past two years, we find that there are actually some policies enacted every month, so the new energy boosting policies are continuous, and we only consider the foreign boycott policies. We set the policy boycott variable, if there is a policy boycott, mark the bit 1, otherwise mark the bit 0. Assuming that China's new energy electric vehicle exports grow naturally over time, the fluctuations should be due to the various policies, so we set the independent variables as the year and policy boycott variables, and the dependent variable as China's exports, to determine the impact of the policy boycott on the volume of exports, again modelled according to Problem 3 and perform regression analysis.

7.2. Establishment and Solution of Regression Model

Construct the following model based on the above ideas

$$Y^x{}_i = \hat{\beta}_0 + \hat{\beta}_1 P_{1i} + \hat{\beta}_2 T_{2i} + e_i \quad (11)$$

$Y^x{}_i$ denotes the export volume of new energy electric vehicles、P_{1i} denotes a dummy variable for the implementation of the boycott policy and X_2 denotes time.

Step 1: Collect the number of new energy electric vehicles exported in different time periods as shown in the figure:

It can be seen that the export quantity of new energy electric vehicles fluctuates in different time periods, but the overall tendency is upward.

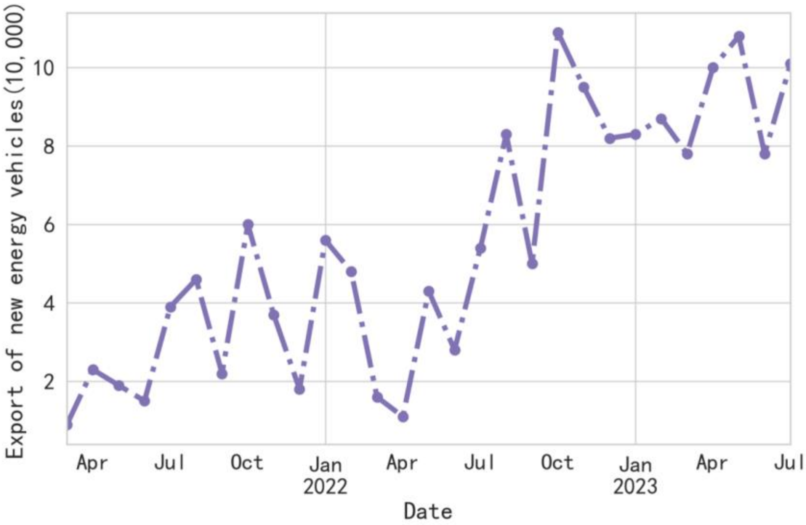

Figure 6. Number of New Energy Electric Vehicle Exports by Time Period

Step 2: Organise the important time points of the boycott policy as shown in the table:

Table 5. Resistance Policy Timeline

Jun 2022	The German-Japanese government is strongly opposed to new energy sources!
Sep 2022	U.S. passes bloat abatement bill
Mar 2023	New Energy Vehicle Spontaneously Combusts Multiple Times
Jun 2023	Competition failed to lead a boycott of China's new energy vehicles, the Japanese auto industry to the backbone of the fast lost!

The implementation of the boycott policy in this study is mainly concentrated in the two years of 2022 and 2023, which corresponds to the export volume of the statistics in the figure above, and can be compared and observed to get a rough conclusion. It is found that in the month of the implementation of the boycott policy in China's new energy electric vehicle export volume decreased significantly, if the modelling results do not meet the reality can be considered whether it is a model construction error, which can be taken as a corroboration of the results.

Step 3: Bring in the data to regress for parameters based on the constructed model.

We can calculate the values of the coefficients programmatically in Python

Table 6. The value of each coefficient

Parameter	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$
Estimated Value	0.6254	-2.1108	0.3480

According to the coefficients of each parameter obtained, the equation can be obtained by bringing them into the original model. $\hat{\beta}_0$ is the coefficient of -0.6254, which is the intercept term that is not discussed much in this model, $\hat{\beta}_1$ is the coefficient of -2.1108, which is the coefficient of the dummy variable for the implementation of the boycott policy, and the positivity or negativity of the coefficient has a direct impact on the final results.

$$Y^x{}_i = 0.6254 - 2.1108 P_{1i} + 0.3480 T_{2i} + e_i \quad (12)$$

Also observe the t-test value of X_1 and its p-value probability:

Table 7. Coefficient of T test

	t	P>|t|
P_{1i}	8.675	0.000
T_{2i}	8.675	0.000

It can be seen that $\hat{\beta}_1$ is -2.1108 is a negative value and the p-value is 0.019, indicating that the significance level of 5% is very significant, also combined with China's exports of new energy electric vehicles in the last two years of the line graphs can be found when the implementation of the boycott policy, China's exports of new energy electric vehicles also have a significant drop

In summary, we can draw a further conclusion that the policy boycott on the development of China's new energy electric vehicles is a very significant negative impact, our country should strengthen the cooperation and communication with the world to achieve the common progress of the world.

8. Model Building and Solution of Question 5

8.1. Model Building Ideas

Problem analysis: analyse the ecological impact of electrification of new urban energy electric vehicles:

First of all how to quantify the impact on the ecological environment, here by introducing the relative energy savings (relative energy savings = standard coal fuel consumption of fuel vehicles / standard coal power consumption of electric vehicles) as a relative indicator for quantitative analysis, but at the same time also faced with the problem of inconsistency of the quantitative outline, so in order to solve this problem can be used in the equivalent unit of energy, usually kilowatt-hours (kWh) and litres or gallons. The following is a simple conversion method that gives us the results we need.

Electricity consumption of an electric vehicle: The energy consumption of an electric vehicle is usually expressed in kilowatt hours per 100 kilometres (kWh/100 km) or miles per 100 miles (kWh/100 miles). Fuel consumption of fuel-efficient vehicles: The fuel consumption of fuel-efficient vehicles is usually expressed in litres per 100 km (L/100 km) or miles per gallon (mpg). For comparison purposes, we can use the following conversion relation: 1kWh = 3.6M_j, the energy of 1 litre of petrol is approximately equal to 31.536 kWh.

8.2. Establishment and Solution of Regression Model

In this paper, Y represents the relative energy saving/t standard coal, F represents the standard coal fuel consumption of fuel vehicles, E represents the standard coal power consumption of electric vehicles, EC represents the power consumption of electric vehicles, and FC represents the fuel consumption of fuel vehicles.

$$Y^t = \frac{F}{E} \tag{13}$$

$$E = EC * 0.1229 \tag{14}$$

$$F = FC * 1.4714 * 0.725 \tag{15}$$

To calculate the relative energy savings, it is first necessary to convert the energy consumption of electric and fuel vehicles to Standard Coal Equivalent (SCE). The Standard Coal Equivalent (SCE) factor represents the amount of standard coal equivalent per unit mass of fuel or electricity.

For Formula 14 to calculate E, that is, the standard coal consumption of electric vehicles, as long as the power consumption of electric vehicles multiplied by the electric energy dis-count standard coal factor can be, that is, the form shown in Formula 15. Formula 16 is also the same, to calculate F that is, the standard coal fuel consumption of fuel vehicles, as long as the fuel consumption of fuel vehicles multiplied by the fuel folding standard coal coefficient (1.4714kg) and the density of automotive oil products (0.725kg / L).

Table 8. Catalogue of New Energy Electric Vehicle Models Exempted from Vehicle Purchase Taxes

vehicle type	Electric vehicles (kW-h/100km)	Fuel vehicle (L/100km)
town bus	110	30
(Taiwan) rental car	20	10
logistic vehicle	50	20
tour bus	110	30
sanitation vehicle	40	20
private car	20	10

Due to the reality of various models of models, driving conditions and energy sources and different, each model corresponding to the power consumption and fuel consumption are also different, so in order to quantitative data processing and easy to compare, this paper according to the "exemption from vehicle purchase tax of new energy electric vehicle models catalogue" for each model of the 100 miles of energy consumption data, put forward the following assumptions specific content of the following table:

Since question 5 needs to be further quantified based on a population of 1 million, this paper chooses to analyse the ecological impact of electrification in an urban environment of 1 million people, using the population of 3.896 million and the total number of vehicles in Yichang City in 2020 as a proxy.

Firstly, we need to know the population of Yichang City and the total number of related vehicles. According to the data, the population of Yichang City in 2020 is 3,896,000 people. At the same time, we also need to obtain data on the total number of vehicles in the city. These data will provide the basis for our quantitative measurement.

Next, we will use this data to analyse the ecological impact of electrification. Electrification is the process of converting traditional fuel-powered vehicles to those that use electricity. This shift reduces dependence on fossil fuels, thereby reducing air pollution and green-house gas emissions. By comparing the extent of electrification in Yichang City at different population sizes, we can assess the ecological impact of electrification.

Table 9. Yichang City 2020 Population Size and Associated Vehicle Totals

Vehicle type	Number of Yichang	Number of cities with 1 million
town bus	2039	523
(Taiwan) rental car	3198	820
logistic vehicle	25524	6551
tour bus	1192	305
sanitation vehicle	475	121
private car	93757	24064

In this study, according to the classification standards and relevant rules in the General Rules for Calculating Comprehensive Energy Consumption (GB/T2589-2008), we compare the fuel consumption of fuel vehicles with the electricity consumption of new energy electric vehicles by converting them to standard coal, which results in the following data as shown in the table 9.

Table 10. General Principles for the Calculation of Integrated Energy Consumption

vehicle type	Electricity consumption of electric vehicle models / 10,000kWh	Fuel consumption/kL for corresponding fuel model
town bus	1.1	30
(Taiwan) rental car	3.0	15
logistic vehicle	5.0	20
tour bus	8.8	24
sanitation vehicle	2.0	10
private car	0.4	2

By combining Table 8, Table 9 and Table 10, the relative energy savings for each vehicle type can be obtained by taking the relevant data into Equations 14, 15 and 16, which can calculate the power consumption of electric vehicles and the fuel consumption of fuel models for all vehicle types of the urban population of 1 million people, and then calculate the relative energy savings of standard coal, so that we can compare the environmental impacts of the various vehicle types. Specific data are as following table 11.

Table 11. Relative Energy Savings by Vehicle Type

Vehicle type	Electricity consumption of electric vehicle models / 10,000kWh	Fuel consumption/kL for corresponding fuel model	Relative energy savings/t standard coal
town bus	575.3	15690	236725.7194
(Taiwan) rental car	2460	12300	43399.71522
logistic vehicle	32755	131020	34719.77217
tour bus	2684	7320	23672.57194
sanitation vehicle	242	1210	43399.71522
private car	9625.6	48128	43399.71522
add up the total	48341.9	215668	425317.2091

According to the statistical data in the table, assuming an urban population of 1 million, the relative energy saving for buses is 236725.7194 tonnes of standard coal, for taxis is 43,399.71522 tonnes of standard coal, for logistic trucks is 34,719.77217 tonnes of standard coal, for sanitation trucks is 43,399.71522 tonnes of standard coal, for private cars is 43,399.71522 tonnes of standard coal, and the total of each data can be summed up to get the electrification at the same level of the same level of standard coal. for sanitation vehicles is 43,399.71522 tonnes of standard coal, and the relative energy saving for private cars is 43,399.71522 tonnes of standard coal, which can be summed up to get the amount of standard coal saved by electrification at the same level.

To sum up, after summing up the amount of coal for buses, taxis, logistics vehicles, tourist vehicles, sanitation vehicles and private vehicles, we get that the amount of standard coal saved in the same level of moblisation is about 425317.2091 tonnes of standard coal.

9. Model Evaluation and Further Discussion

9.1. Advantages of the Model

Advantages of AHP hierarchical analysis: First, it is a systematic analysis method, which can decompose and combine the decision-making problems according to the levels of objectives, guidelines, and prgrammes, which is in line with people's thinking habits and logical relations, second, it is a concise and practical decision-making method, which can organically combine qualitative and quantitative factors, and make subjective judgments by using the scale method of 1-9, which simplifies the complex computation process and is easy to understand and operate, third, it requires less quantitative data information, which can deal with some unstructured or difficult-to-quantify problems and operation. Thirdly, it requires less quantitative data information, can deal with some unstructured or difficult to quantify decision-making problems, and reflects the subjective will and preference of decision-makers by using the experience and knowledge of experts.

Advantages of ARIMA model: It can deal with non-stationary time series, eliminating the trend and seasonal variations of the time series by means of differencing, so as to make it stable. Able to consider both the autoregressive part and the moving average part of the time series, capturing the historical trend and random fluctuations of the data, and improving the accuracy and stability of forecasts

9.2. Advantages of the Model

Disadvantages of AHP hierarchical analysis: first, the large amount of data statistics when there are too many indicators, and the weights are difficult to determine, when the decision-making problem involves more factors, it is necessary to construct a large-scale judgement matrix, which increases the complexity of the calculation and error, and also reduces the consistency and reliability of the judgement, secondly, the exact method of finding the eigenvalue and the eigenvectors is more complicated, and when the order of the judgement matrix is higher, it is necessary to use a high degree of linear algebra knowledge and skills, which may not be easy to grasp and understand for general decision makers.

Disadvantages of ARIMA model: It requires smoothness test and difference processing of time series, which increases the complexity and difficulty of analysis. Need to determine the appropriate model parameters (p,d,q), which often rely on empirical judgement and experimental selection, there is no uniform standard and method. It cannot handle time series with nonlinear characteristics well, and is not sensitive and adaptable enough to some sudden outliers or structural changes.

9.3. Improvement and Promotion of the Model

Improvement and extension of AHP hierarchical analysis: firstly, some improved methods, such as scaling only the lower or upper triangle of the judgment matrix, or using fuzzy hierarchical analysis or network hierarchical analysis, to improve the consistency and reasonableness of the judgment matrix, and secondly, some extended methods, such as combining the grey theory, the theory of innovation, or intelligent algorithms, in order to generate new scenarios or optimize the existing scenarios.

Improvement and extension of ARIMA model: firstly, some improvement methods, such as adopting nonlinear ARIMA model, generalised ARIMA model or fractal ARIMA model, to adapt to the characteristics of nonlinear time series, secondly, some extension methods, such as adopting SARIMA model, STARIMA model or TARIMA model, to deal with the time series with seasonality, spatial correlation or threshold variation time series.

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