Research on the Impact of Policies under the Bayesian Network Model on the Consumption Behavior of New Energy Vehicles

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Abstract. Based on the Bayesian network, this paper uses consumer models to extract several factors that affect the consumption behavior of new energy vehicles, and combines principal component analysis to extract the main factors to construct the model. Using the past sales changes of various models under various policy environments, this paper assigns probabilities to the model, and uses genetic algorithms to find the value of each factor when the predicted value of new energy vehicle sales growth is the highest. Through correlation analysis, the relevant information of each factor is analyzed, and it is concluded that subsidies have a greater impact on the consumption of new energy vehicles. In the car itself, people pay more attention to the durability of the battery than the performance of the car. Combining the predicted value of the model with the current policy background, it puts forward recommendations on loans, batteries, environmental awareness, and charging infrastructure for new energy vehicle policies.

1. Introduction
As a major country in the production and sales of automobiles in the world, in the process of continuous development of the automobile industry, China's energy and environmental pollution problems have become issues of general concern to all sectors of society. The state has continuously increased its investment in the development of new energy vehicles. The development of the industry has become one of the important strategies for the smooth realization of energy saving, emission reduction and low-carbon economic development. Since new energy vehicles are mainly powered by unconventional vehicle fuels, the advanced vehicle power control and drive technology adopted by them is automotive. The adjustment of the industrial structure provides new opportunities. Relevant policies can not only continuously promote the development of new energy vehicles from the end of the car company and enhance the innovation capabilities of new energy car companies, but also promote consumer consumption through some preferential policies. It can promote the development of the new energy vehicle industry to achieve ecological civilization construction. Therefore, research on new energy vehicle policies and their impact on consumers is particularly important.

Based on the Bayesian model, this paper will build a model of the impact of policies on consumers, combining the policy background and the latest developments, following the development trend of new energy vehicles, to further analyze the impact of policies on consumers from multiple factors, while considering the impact on new energy vehicles. The impact of manufacturing, the impact of constructing policies on consumer behavior of new energy vehicles, verifying the accuracy of the model, using the
model to predict the impact of policies on consumers, and giving recommendations based on the prediction results.

2. Literature review
As a large energy-consuming country, China has an urgent need for the development and utilization of new energy. The emergence of new energy vehicles has given people one more choice in green travel, and people’s research on the consumption of new energy vehicles has continued to deepen. In recent years, with the continuous development of theoretical knowledge, research models have also been enriched. Cao Guohua and Yang Junjie (2016) used a game theory model and a dynamic evolution method to propose that the government should actively guide companies to invest in the construction of new energy infrastructure through financial subsidies, implement a subsidy retreat mechanism, and attach importance to publicity methods. [1] Han Na (2015) based on consumer behavior theory, individual psychological cognition, etc., that the government should standardize green product certification mechanisms, promote new media applications, equip complete service facilities, improve policies and regulations, and establish a comprehensive incentive mechanism. And publicity and education to promote green consumption. [2] Zhou Linying (2020) analyzed the current subsidy policy and marketing status of new energy vehicles in Changsha, from the perspective of increasing customer perceived value, reconstructed marketing strategies for Changsha new energy vehicle companies from innovation, channels, and prices. Provide reference. [3] Zhang Lihui (2020) and others divides motor vehicles into four categories: buses, taxis, passenger cars, and special vehicles. Taking into account the purchase subsidies and construction subsidies on the charging infrastructure of NEVs, this paper proposes an evaluation index, namely, the comprehensive subsidy efficiency, that measures the effectiveness of the two subsidies in reducing emissions of atmospheric pollutants among different NEVs. [4] Shao Chuan (2020) studied the impact of financial policies on a series of social issues such as poverty reduction, education, and pollution control, and concluded that the implementation of green credit can not only control environmental pollution, but also have a significant positive impact on sustainable development. [5] Shen Runjie (2020) and others conducted research and analysis on young consumers’ new energy vehicle purchasing decisions and selection behaviors, combined with the current development status of the new energy passenger vehicle market, and predicted the future market trends to get the future With the dual support of policies and products, the development of new energy vehicles still has a promising development space. [6] Zhu Yueyan (2020) and others studied the British electric vehicle policy and found that it has outstanding characteristics such as focusing on openness, clear long-term goals, and making good use of transportation support policies. Based on the characteristics of British policy and the actual development of China's industry, they put forward suggestions for China to strengthen strategic leadership, Establish a vehicle tax system based on energy-saving and emission reduction indicators, actively explore the feasibility of implementing low-emission zones and other transportation policies, enrich the support methods for charging infrastructure, and strengthen policy tracking and evaluation to promote the healthy and sustainable development of China's new energy vehicles. [7]

People often consider the influence of financial, automobile, marketing and other factors, but they are not comprehensive enough and ignore the connection between different factors. And this article combines the three major factors of finance, non-financial, and auto companies for research and analysis, and uses Bayesian network to analyze the correlation between different factors, and provides a reference for the research method of the impact of policies on new energy vehicles.

3. Data and Methodology

3.1 Factors affecting consumers of new energy vehicles
The impact of policies on consumers can be divided into two aspects: direct policy impact and indirect policy impact. Among them, the direct impact of policies can be studied from two aspects: fiscal policy and non-fiscal policy. The indirect impact mainly refers to the impact of policies on new energy vehicle
companies, which in turn affect consumers. Fiscal policies mainly refer to policies that have monetary subsidies and preferential policies for consumers, while non-fiscal policies refer to policies that can bring consumers non-monetary preferential policies and publicity and promotion policies. In addition, policies can also affect the manufacturing of new energy vehicles by encouraging technology development and limiting emissions from car companies, as shown in Figure 1.

Figure 1. Schematic diagram of factors affecting consumers of new energy vehicles

3.2. Data acquisition and processing methods of the policy's impact on consumers

According to the previous analysis, there are many types of policies, and different types of policies have different characteristics. Fiscal policies can get very direct data, which can be well quantified and compared. It is relatively difficult for non-fiscal policies to be directly good, and indicators are constructed by segmentation or transfer to some other quantifiable factors. The policy of car companies indirectly affects consumer behavior, so we should first consider how the policy will affect car companies and consider the impact of consumers. Combining the previous analysis and constructing an indicator system for the impact of policies on consumers in three levels.

- **Target level:** the impact of policies on consumer promotion
- **Standard level:** fiscal policy, non-fiscal policy, auto company policy
- **Index level:** each criterion is subdivided, and each index can be determined by quantitative methods

3.2.1. Fiscal policies

Fiscal policies include purchase subsidies, purchase taxes, loans, subsidy thresholds, and scope of subsidies. Taking the average value of national policy subsidies (or a certain region) in the past 14 years as the standard, collect data and user comments for each indicator in different time periods, combine them according to a certain proportion, and divide them into high (H) and low (L) Two levels.

3.2.2. Non-financial policies

Non-financial policies cover a lot of content, including charging pile construction, license management, environmental awareness, publicity, etc., and are divided into high and low levels by collecting the hot search index and the number of related articles in the past 14 years. For the construction of charging piles, license plates, etc., by collecting the number of charging pile constructions in each year, related policies, the number of license indicators, and user comments on this, the proportion combination is divided into high (H) and low (L) levels.

3.2.3. Policies for auto companies

The policy of car companies mainly considers the impact of policies on car configuration, including Price, Engine, Battery Capacity, Environmental Protection, Speed, Battery Payload, Maintenance,
Charging, Acceleration, collects various types of car configuration and sales data of each model, and compares the data. After standardization, it is divided into high (H) and low (L) levels based on industry standards or average levels.

Bayesian network, also known as belief network, is an extension of Bayesian method and is currently one of the most effective theoretical models in the field of uncertain knowledge expression and reasoning. The basic principles are as follows:

Bayes' theorem:

\[ P(H|E) = \frac{P(E|H)P(H)}{\sum_{k=1}^{n} P(E|H_k)P(H_k)} \]

Chain rule:

\[ P(X) = \prod_{i=1}^{n} P(x_i|x_{i-1}, \ldots, x_1) = P(x_1)P(x_2|x_1)P(x_3|x_2, x_1) \ldots P(x_n|x_{n-1}, \ldots, x_1) \]

Bayes' theorem chain rule (considering multiple evidence):

\[ P(Y|(X_1, X_2, \ldots, X_k)) = \frac{P((X_1, X_2, \ldots, X_k)|Y)P(Y)}{P(X_1 \land X_2 \land \ldots \land X_k)} \]

\[ = \frac{P(Y)P(X_1|Y)P(X_2|X_1, Y)P(X_3|X_2, X_1, Y) \ldots P(X_k|X_{k-1}, \ldots, X_1, Y)}{P(X_1)P(X_2|X_1)P(X_3|X_2, X_1) \ldots P(X_k|X_{k-1}, \ldots, X_1)} \]

4. Empirical Analysis

When calculating conditional probability, the more secondary indicators under the same primary indicator, the complexity of conditional probability will increase exponentially. Therefore, we should try to reduce the number of secondary indicators under the unified primary indicator, and it is best to control it to about 3. Therefore, we consider adopting the principal component analysis method, firstly we analyze the indicators in the model, and extract the main indicators for analysis and research. Taking policy factors for car companies as an example, the results of principal component analysis of the nine factors affecting car companies are shown in Table 1. The cumulative variance contribution rate of the first seven principal components is 91.157%, which covers most of the data. information. This shows that the first seven principal components can represent the first nine indicators to analyze the influence factors of policies on auto companies, so the first seven indicators can be extracted.

| Component                  | Total Variance Explained | Initial Eigenvalues |
|----------------------------|--------------------------|--------------------|
|                            | Total       | % of Variance | Cumulative % |
| Price                      | 3.073       | 34.15         | 34.15        |
| Engine                     | 1.399       | 15.545        | 49.695       |
| Battery Capacity           | 1.144       | 12.71         | 62.405       |
| Environmental Protection   | 0.833       | 10.259        | 72.664       |
| Speed                      | 0.72        | 9.488         | 82.152       |
| Battery Payload            | 0.694       | 9.005         | 91.157       |
| Maintenance                | 0.473       | 3.789         | 94.946       |
| Charging                   | 0.431       | 2.8           | 97.746       |
Using this method, we discarded the factor of high information repetition, and finally got 11 indicators of consciousness, charging pile, license plate, subsidy amount, subsidy scope, loan, battery life, battery capacity, power, vehicle speed, and environmental protection.

Based on the previous analysis and extraction of the factors affecting the sales of new energy vehicles, the Bayesian network model structure is constructed. On the basis of the preliminary Bayesian network model, some pieces of data are used to train it with the maximum fitting estimation to obtain the trained Bayesian network model as shown in Figure 2.

After completing the model construction, by entering the value of each secondary index, the probability of the value of the predicted node can be obtained. Use some pieces of data to predict the Sales node to verify its accuracy. The available accuracy rate is about 87.3%. The picture shows part of the predicted results and actual results as shown in Table 2. In contrast, the linear regression model based on the principal component analysis method has a prediction accuracy of 61.2%, which proves that the linear model must be more accurate.

After the model is built, we can use some optimization algorithms to find a set of data with the largest sales growth probability (Sal=H). The genetic algorithm is used to find the optimal solution, the sub-optimal solution, etc., and finally the multiple results are sorted to obtain the fastest sales growth rate as shown in Table 3. We can see that based on the prediction results of the Bayesian model network model, when the awareness is high, the license policy is loose, the subsidy is large, the loan discount is large, the battery capacity is large, the battery life is long, the car speed is considerable, and it is more environmentally friendly, Even if there are relatively few charging piles, small subsidies, and mediocre vehicle performance, there is still an 87.53% probability that the sales of new energy vehicles will increase and take the highest value.

### Table 2. Comparison of two prediction results of some data

| A | CP | LP | NF | S | E | C | F | BP | BC | P | EN | SP | B | PE | EP | CA |
|---|----|----|----|---|---|---|---|----|----|---|----|---|---|----|----|----|
| L | L | L | H | L | H | H | H | H | H | H | L | L | H | L | L | H | H | H | H |
| L | L | L | H | H | H | H | H | H | L | L | L | L | L | L | L | H | L | H | L |
| H | L | H | L | H | H | H | H | H | H | H | L | H | H | H | H | L | H | L | L |
| H | H | H | H | H | H | H | H | H | L | H | L | H | L | H | L | L | H | L | L |

### Table 3. Comparison of two prediction results of some data

| A | CP | LP | NF | S | E | C | F | BP | BC | P | EN | SP | B | PE | EP | CA |
|---|----|----|----|---|---|---|---|----|----|---|----|---|---|----|----|----|
| L | L | L | H | L | H | H | H | H | H | H | L | L | H | L | L | H | H | H | H |
| L | L | L | H | H | H | H | H | H | L | L | L | L | L | L | L | H | L | H | L |
| H | L | H | L | H | H | H | H | H | H | H | L | H | H | H | H | L | H | L | L |
| H | H | H | H | H | H | H | H | H | L | H | L | H | L | L | L | H | L | L | L |
Although the sales of new energy vehicles can reach the highest value when the preferential subsidies are strong, based on the current background of the decline in subsidies for new energy vehicles, we need to obtain a strong relationship between each factor and sales based on the prediction results and through correlation analysis. Weak, combined with the forecast results and the current actual background, put forward relevant recommendations for the new energy vehicle policy. By using the Pearson correlation analysis method on the prediction results, the following factors can be ranked in Table 4.

Table 3. Factors affecting the probability of consumption growth

| No. | Component | Pearson Correlation |
|-----|-----------|---------------------|
| 1   | BP        | 0.623               |
| 2   | C         | 0.430               |
| 3   | S         | 0.217               |
| 4   | CP        | 0.210               |
| 5   | BC        | 0.188               |
| 6   | E         | 0.130               |
| 7   | LP        | 0.105               |
5. Conclusion
Based on Bayesian network, combined with principal component analysis and correlation analysis, this paper studies the impact of policies on the consumption behavior of new energy vehicles. Judging from the prediction results, subsidies have a greater impact on the consumption of new energy vehicles. In the car itself, people pay more attention to the durability of the battery than the performance of the car. Through the analysis of the forecast results, combined with the correlation analysis and the current national policy background, the following conclusions and opinions on the new energy vehicle policy are put forward:

1) In the current situation of the decline of new energy vehicle subsidies, we can consider promoting cooperation between auto companies and banks, and increase the policy of new energy vehicle loans to stimulate the sales of new energy vehicles, so as to make up for the negative effects of subsidy decline.

2) The models with good sales volume of new energy vehicles are mainly concentrated in relatively cheap, but sexually usable models, indicating that people will not pay too much attention to the performance of new energy vehicles, but pay more attention to the price.

3) The environmental protection of new energy vehicles makes people have very little desire to buy, which reflects that people's environmental awareness is still very insufficient and needs to continue to be strengthened through publicity and guidance.

4) People are paying more attention to battery performance for new energy vehicles themselves. By promoting battery technology innovation, enhancing battery capacity and endurance, thereby increasing sales of new energy vehicles.

5) In terms of batteries, the construction of charging piles also greatly affects people's decision-making. Although the current construction of charging piles is constantly improving, it still needs to continue to advance, especially the increasing number of new energy vehicles, and the demand for charging piles Will keep increasing.

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