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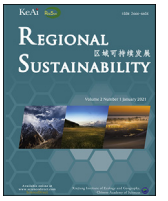

Full Length Article

Purchase willingness of new energy vehicles: A case study in Jinan City of China

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ABSTRACT

Speeding up the promotion of new energy vehicles is an important measure to optimize the energy structure, promote energy conservation and emission reduction, and develop the economy sustainability. The research uses a questionnaire survey to analyze the residents' willingness to purchase new energy vehicles in Jinan City of China, and utilizes the binomial logistic regression model and Global Moran's I to explain the impact of three factors (including respondents' personal characteristics and subjective cognition, products, and social environment) on the purchase willingness of new energy vehicles. According to the survey, 75.12% of the respondents consider buying new energy vehicles in the future, but only 11.66% of the respondents know new energy vehicles well. It can be seen that the respondents in Jinan City generally have an insufficient understanding of new energy vehicles. It may lead to a decline in residents' trust in new energy vehicles, which will in turn affect their purchase willingness. Based on the survey, we find that women who live far from the city center enjoy high incomes and have a low-carbon awareness, generally exhibit a higher willingness to purchase new energy vehicles. Spatial distribution of the purchase willingness has certain aggregation characteristics, showing a positive spatial correlation pattern. Purchase willingness has a certain positive diffusion effect in space, and areas with a higher purchase willingness have a positive driving effect on their surrounding regions. Spatial distribution of the purchase willingness can be used as one of the breakthroughs in promoting new energy vehicles. In addition, safety, price, after-sales service, and infrastructure of new energy vehicles are important determinants of people's purchase willingness. Among the types of subsidies, financial subsidy is most effective on the residents' purchase willingness. Our research provides an important information for the promotion of new energy vehicles in the region.

1. Introduction

With the rapid development of economy, especially in first-tier cities and provincial capitals, the number of private cars owned by citizens is increasing. As an important means of transportation, cars bring us convenience, but they also come with many negative effects, such as traffic congestion and air pollution (Man and Yin, 2015). At the same time, countries around the world are also promulgating policies. For instance, Britain and France have formulated timetables for banning the sales of fuel vehicles. However, for global auto companies, the economic and administrative penalties for non-compliance with emission regulations, such as China's "CAFE regulations" and the stricter emission standards implemented in Europe, have forced various auto companies to take action of banning sales of fuel cars. Therefore, as an emerging product to meet social needs, pollution-free new energy vehicles have received increasing

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attention from both the government and the public (Liu et al., 2018a). The survey on the purchase willingness of new energy vehicles is helpful to understand the public's real thoughts. It displays the related study of its impact mechanism and also puts forward targeted recommendations for the promotion of new energy vehicles.

The entry perspectives of domestic and foreign scholars on the factors affecting the purchase willingness can be roughly divided into three main aspects: consumers, product strategies, and external policies. Many studies, from the perspective of consumers, have investigated the impact of consumer preferences (Lou et al., 2012; Axsen et al., 2015; Cirillo et al., 2017), knowledge of new energy vehicles (Lane and Potter, 2007; Sun, 2017), environmental awareness (Lane and Potter, 2007; Shen and Saijo, 2008; Zhao et al., 2018), and demographic characteristics (Kurani et al., 2008; Shen and Saijo, 2008; Carley et al., 2013; Axsen et al., 2015; Cirillo et al., 2017) on the purchase willingness of new energy vehicles. A survey conducted by Cirillo et al. (2017) in Maryland of USA showed that young people are more likely to buy high-tech vehicles, especially battery electric vehicles (BEV). Well-educated females (bachelor degree or higher) prefer to choose hybrid electric vehicle (HEV), while male equivalents are more likely to buy BEV (Cirillo et al., 2017). A survey of adult drivers in larger US cities found that interests in plug-in hybrid technology are somewhat greater than those in all-electric technology, and consumers, who show early interests in adopting electric vehicles, are typically highly educated (Carley et al., 2013). In addition, Moons and Pelsmacker (2012) indicated that emotion and attitude towards the electric cars are the strongest determinants of people's willingness of diving electric cars, with the subjective norm being the second strongest factor. In terms of product strategy, scholars both at home and abroad have mainly investigated the effects of price (Till et al., 2018), cost (Caulfield et al., 2010; Till et al., 2018), and performance (Caulfield et al., 2010; Xu and Xu, 2010; Skippon and Garwood, 2011; Zhang et al., 2011; Egbue and Long, 2012) on the purchase willingness. Xu and Xu (2010), Zhang et al. (2011), Egbue and Long (2012), and He et al. (2012) pointed out that products with good performance will increase consumers' purchase willingness. And once consumers perceive electric cars to be superior in performance compared with conventional ones, they will possibly be early adopters of electric vehicles. In terms of external policies, domestic and foreign scholars have studied charging standards (Peters et al., 2008), tax incentives (Caulfield et al., 2010; Gallagher and Muehlegger, 2011), and government industrial policies (Yang, 2012). Peters et al. (2008) analyzed whether absolute or relative charging standards would encourage more consumers to switch to those vehicles with lower energy consumption. Gallagher and Muehlegger (2011) studied the relative efficacy of state sales tax waivers, income tax credits, and non-tax incentives and found that the type of tax incentive offered is as important as its generosity. From the government's industrial policy, Yang (2012) pointed out that the government has a significant impact on the consumers' purchase willingness, whether from the research and development stage, the preferential subsidies for taxes and fees at the time of purchase, or the construction of supporting facilities. In addition, some foreign scholars also discussed the impact of electric vehicles on sustainability (Dang et al., 2014). The existing literature, foreign scholars' research on the purchase willingness, is relatively sufficient, while related research is rarely documented in China. Moreover, domestic and foreign scholars mostly start from a certain perspective, so there are few comprehensive studies on multiple perspectives.

Jinan City, the capital of Shandong Province in China and the core city of the Shandong Peninsula urban agglomeration, is an important meeting point between the Circum-Bohai Sea Economic Zone and the Beijing-Shanghai Economic Axis. It is also the leading area which boasts the shift in driving forces for development. In recent years, the haze situation in Jinan City has attracted much attention. Improving the air quality of Jinan City has become an issue that increasingly attracts people's attention and urgently needs to be solved. In addition, the traffic congestion in Jinan City is severe, but the traditional fuel vehicle ownership is still very high, a typical situation in major cities in China. Promoting new energy vehicles will greatly help improve urban air quality and reduce our dependence on fossil fuels. Although new energy vehicles have many benefits and are in line with domestic policy guidance, widespread adoption of new energy vehicles still faces obstacles. One major obstacle is that consumers do not fully trust new energy vehicles. Therefore, the current research was carried out in Jinan City and obtained primary information on the purchase willingness of new energy vehicles through a questionnaire survey, with behavioral psychology, marketing, sociology, geography, and other subject theories integrated. The goal is to conduct questionnaire design and selection of influence factors and to investigate the purchase willingness of new energy vehicles, combining domestic political, economic, and cultural backgrounds. These results can help policy makers to specify promotion strategies of new energy vehicles and can also provide guidance for electric vehicle engineers to enhance consumers' preference in electric vehicle engineering design decisions (Shen and Saijo, 2008).

2. Methods and data sources

2.1. Study area

Jinan City (34°52′12″–37°19′12″N, 116°27′00″–117°34′12″E), also known as "City of Springs", is a sub-provincial city of Shandong Province, China. It is the political, economic, cultural, technological, educational, and financial center and an important transportation hub of Shandong Province. Connected to the circle of economy around the Beijing City in the North and the Yangtze River Delta economic circle in the South, it is an important intersection between the Circum-Bohai Sea Economic Zone and the Beijing-Shanghai Economic Axis, and is also one of the central cities in the Bohai Rim and in the middle and lower reaches of the Yellow River. As of 2019, the city has ten districts and two counties, with a total area of 1.02×10^4 km^2, a built-up area of 0.76×10^3 km^2, a permanent population of 8.91×10^6, an urban population of 6.34×10^6, and an urbanization rate of 71.21%. With the increase of population and economic development in Jinan City, the number of private cars is also increasing. The increase in the number of traditional fuel vehicles has brought heavy energy and atmospheric pressure, which has aggravated environmental problems. Improving air quality in Jinan City has become a growing public attention and an urgent problem.

Starting from 1 December 2016, five cities, including Jinan City, Shanghai City, Nanjing City, Wuxi City, and Shenzhen City, took the lead in launching special license plates for new energy vehicles. According to relevant statistics, in the four years from 2015 to 2018,

China's new energy vehicle subsidies amounted to 224.4 billion CNY, plus the charging facilities, local research funding, purchase tax reduction, and other expenses, the state's investment in the new energy vehicle industry was more than 390.0 billion CNY. In response to the call of the state, Shandong Province also took the lead in issuing the "Air Pollution Prevention and Control Plan Phase III Action Plan". The plan proposes that all public buses, official vehicles, municipal vehicles, sanitation vehicles, and other vehicles purchased with financial funds should give priority to using new energy vehicles.

Despite climate change concerns and the general social agreement for a more sustainable society, the reduction of transportation emissions in urban areas requires methods and infrastructures that have a significant impact on the promotion of new energy vehicles. Consequently, in the following paragraphs, we investigated the residents' willingness to purchase new energy vehicles in Jinan City. Using the binomial logistic regression model and Global Moran's I, we analyzed the influence of various factors on the purchase willingness of new energy vehicles.

2.2. Research methods

2.2.1. Binomial logistic regression

Binomial logistic regression model is a linear regression analysis with the dependent variable being binary. The study took residents' willingness to buy new energy vehicles as the dependent variable to obtain the (0, 1) distribution of purchase and non-purchase, and used this model to carry out a quantitative study of each influencing factor of the purchase willingness. The binomial logistic regression model corresponding to the independent variables is described as follows (He, 2008):

$$p(Y=1)=\frac{\exp(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}{1+\exp(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}, \tag{1}$$

where, β_0 is a constant term (or intercept), and β_i is the partial regression coefficient corresponding to X_i. The probability ratio between the occurrence of the event (p_i) and the non-occurrence ($1–p_i$) is called the odds ratio, which means that under the condition that other independent variables are constant, the independent variable X_n changes by a unit, and the dependent variable corresponding to the odds ratio averages Exp units. Logarithmic transformation of the odds ratio to obtain a linear model of the binomial logistic regression model is as follows (He, 2008):

$$\ln\frac{p_i}{1-p_i}=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n. \tag{2}$$

2.2.2. Global Moran's I (Moran's I)

This indicator reflects whether the distribution of regional attribute values is clustered, discrete, or random. The range of the Moran's I is from −1 to 1, in which the value lower than 0 indicates a negative correlation, the value higher than 0 indicates a positive correlation on the surface, and the value being of 0 indicates no correlation. We used the Moran's I to conduct an autocorrelation analysis of the purchase willingness of the respondents from ten districts and two counties of Jinan City, so as to study the relationship between the spatial distribution of the respondents and the purchase willingness.

The Moran's I statistic for spatial autocorrelation is given as:

$$\mathrm{I}=\frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}w_{i,j}z_iz_j}{S_0\sum_{i=1}^{n}z_i^2}, \tag{3}$$

where z_i is the deviation of an attribute for feature i from its mean, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features, and S_0 is the aggregate of all the spatial weights:

$$S_0=\sum_{i=1}^{n}\sum_{j=1}^{n}w_{i,j}. \tag{4}$$

The z_I score for the statistic is computed as:

$$z_I=\frac{I-E[I]}{\sqrt{V[I]}}, \tag{5}$$

$$\mathrm{E}[I]=-1/(\mathrm{n}-1), \tag{6}$$

$$\mathrm{V}[I]=\mathrm{E}\left[I^2\right]-\mathrm{E}[I]^2, \tag{7}$$

Where z_I is the score of z, I is the Moran's I, E is the mean, V is the variance, and n is equal to the total number of features.

2.3. Data sources

The sample survey targeted residents in Jinan City. A total of 784 paper questionnaires and 1069 online questionnaires were

covered. In order to ensure the validity of the questionnaires, we checked and screened the 1853 questionnaires involved later. The returned questionnaires must meet the following three requirements: (1) the answering time is not less than 3 min; (2) there are no contradictory answers; and (3) there must be less than four consecutive questions with the same options in response. After verification, the effective number of the paper questionnaires was 748, with an effective rate of 95.41%, and the effective number of the online questionnaires was 1065, with an effective rate of 99.63%. So far, 1813 valid questionnaires were collected.

3. Results and discussion

In some countries, such as Norway, there is significant growth in the proportion of BEV among new registrations (Hinnuber et al., 2019). Although the proportion of China's new energy vehicle ownership in the total number of vehicles is increasing year by year, as of June 2019, it only accounted for 1.37%. This disparity raises the questions of what are the main factors hindering consumers from buying new energy vehicles in China and how they are perceived by potential customers. Our survey was launched in Jinan City to analyze the residents' willingness to purchase new energy vehicles. The binomial logistic regression model and Moran's I were used to explain the influence of various factors on the public's purchase willingness.

3.1. Status of voluntary purchase of new energy vehicles

During the survey, the respondents were first asked if they currently owned a private car, and whether they would consider buying a new energy vehicle. The results show that 75.12% of the respondents would buying a new energy vehicle (hereafter referred to as purchase willingness), while only 24.88% of the respondents would not. It can be seen that most of the people have a receptive attitude towards new energy vehicles, and the potential markets and development space are relatively large. According to the questionnaire statistics, 31.29% of the masses do not know about new energy vehicles, 57.06% of the majority have a general understanding, and only 11.66% of the minority have a deep understanding. Therefore, the vast majority of people's cognition of new energy vehicles is still insufficient, lacking detailed understanding of their performance, price, and so on. At present, although the publics are more optimistic about the purchase of new energy vehicles, their ambiguous understanding of new energy vehicles still hinders to some extent, making more citizens lag behind in purchase actions.

3.2. Analysis of influencing factors of mass purchase willingness

The research on the influence mechanism of the purchase willingness (Fig. 1) started from the perspectives of residents, the product itself, and the social environment. With the help of binomial logistic regression model, we used the residents' purchase willingness W (Yes = 1, No = 0) as the explained variable and the influencing factors as explanatory variables, and calculated the model coefficient and odds ratio of each influencing factor. Certain factors appeared in the form of multiple-choice questions in the questionnaires, for example, car performance, and the model coefficients for calculating such influencing factors as a whole cannot accurately reflect the influence of their sub-factors on the purchase willingness. Therefore, the study considered these sub-factors as unordered variables (Appendix A) and the remaining factors as ordinal variables (Appendix B), and calculated the model coefficients and odds ratios of each explanatory variable (Tables 1 and 2). In Tables 1 and 2, B represents the influencing factor of the purchase willingness. Then, the odds ratio Exp(B) indicates that the factor increases by one level, and its corresponding acceptance probability becomes the original Exp(B) times. The study set the confidence interval at 95% level. When the significance value of the influencing factor is less than 0.05, the correlation is significant, that is, the factor has a significant influence on the public's purchase willingness.

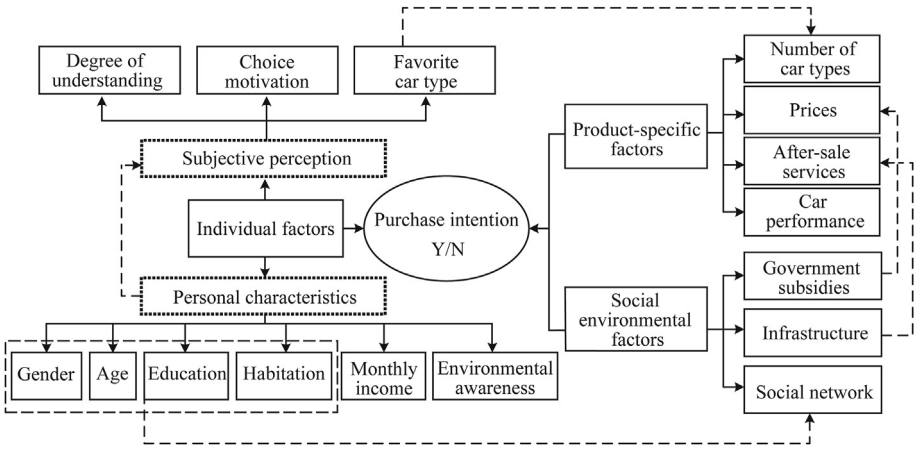

Fig. 1. Research on the influence mechanism of the purchase willingness of new energy vehicles. Y, yes; N, no.

Table 1
Regression results of ordinal variables of influencing factors on purchase willingness of new energy vehicles.

Factor	Model regression coefficient	Exp(*B*)
Gender	−0.899* (0.398)	0.407
Age	−0.446* (0.334)	0.463
Education	0.585 (0.392)	1.794
Habitation	0.586** (0.225)	1.797
Monthly income	0.563* (0.239)	1.695
Environmental awareness	0.441** (0.240)	1.473
Degree of understanding	−0.088 (0.310)	0.916
Price	−0.574* (0.230)	0.190
After-sales services	0.733* (0.210)	1.657
Number of car types	0.632 (0.313)	1.342
Infrastructure	0.416* (0.214)	1.762

Note: *, $P < 0.05$ level; **, $P < 0.01$ level. The value in the parentheses represents the standard error of a single regression. *B* represents the influencing factor of the purchase willingness.

Table 2
Regression results of unordered variables of influencing factors on purchase willingness of new energy vehicles.

Factor	Unordered variable	Model regression coefficient	Exp(*B*)
Social network	Television news	0.325** (0.194)	1.384
	Social communication	−0.342 (0.173)	0.673
	Internet	0.808** (0.211)	1.732
	Adverts	0.412* (0.122)	1.356
Car purchase motivation	Curiosity about new things	0.190 (0.314)	1.027
	Out of low-carbon environmental protection	0.784** (0.187)	1.684
	In line with future trends	0.355* (0.165)	1.433
Government subsidies	Financial subsidy	0.693* (0.144)	1.611
	Free parking fees	0.012* (0.132)	1.023
	Purchase tax exempt	0.243* (0.186)	1.342
	Free number	0.039 (0.343)	1.132
	Hands-free	0.246* (0.231)	1.274
Car performance	Safety	0.743** (0.132)	1.843
	Recharge mileage	0.675* (0.173)	1.694
	Charging time	0.453 (0.432)	1.243
	Accelerate performance	0.124* (0.253)	1.144

Note: *, $P < 0.05$ level; **, $P < 0.01$ level. The value in the parentheses represents the standard error of a single regression. B represents the influencing factor of the purchase willingness.

3.2.1. Personal characteristics of the respondents

From regression results, we found that gender and age are generally negatively correlated with the public's willingness to purchase new energy vehicles (Table 1). The model coefficients are −0.899 and −0.446, respectively, indicating that young women are more willing to purchase new energy vehicles (Liu and Li, 2010; Liu, 2016; Sun et al., 2018). Monthly income is positively correlated with the respondents' willingness to purchase new energy vehicles, which is consistent with the research of foreign scholars Cirillo et al. (2017), with a model coefficient of 0.563, showing that with the increase of monthly income, the respondents in Jinan City will increase their willingness to buy new energy vehicles. According to the binomial logistic regression results, habitation is roughly proportional to the public's willingness to purchase new energy vehicles and the model coefficient is 0.586 (Table 1), indicating that the farther away from the city center, the stronger the purchase willingness.

In addition, we conducted a Moran's I analysis on the purchase willingness of residents in different places in Jinan City. Results show that the Moran's I value is 0.388, the *P* value is in the range of 0.007–0.010, the *z* score is in the range of 2.580–2.696, and the confidence level is 99%. Residents' purchase willingness has a certain clustering feature in spatial distribution, with a spatial positive correlation pattern. Therefore, the willingness has a certain positive diffusion effect in space, and areas with a higher purchase willingness have a positive driving effect on their surrounding regions. Therefore, the promotion of new energy vehicles should strengthen the influence on purchasers and the regional distribution differences of potential purchasers' concern. The significance level of the education is bigger than 0.05, which is not statistically significant, indicating that the education has no effect on the purchase willingness (Table 1).

According to interviews and surveys, women know less about the new energy vehicle market, but they have stronger technical trust and environmental awareness, which makes them more likely to accept new energy vehicles. Men's understanding of new energy vehicles is clearer, so they are more likely to worry about technology and supporting facilities of new energy vehicles. Young people's ability to accept new things is stronger than middle-aged and elderly people (Jiang and Sheng, 2017; Liu et al., 2018b). In addition to the consideration of economy and practicality, middle-aged and elderly people pay more attention to their safety and motivation. They are more conservative and have more concerns, so they are relatively less willing to buy new energy vehicles. People with higher monthly incomes bear smaller economic burden and can pursue better life, so their willingness to buy new energy vehicles is stronger. The survey

shows that the proportion of the respondents owning a car in the central urban area is relatively large, so the willingness to buy a car may be relatively low in the short term, thus making the purchase willingness relatively weak. Imperfect factors like high maintenance costs have led many residents in central city to think twice. Moreover, the high-density land use in the central urban area makes parking space scarce (Kahn and Vaugh, 2009), while in comparison, the suburban residents have more living space, which saves people from the difficulty of charging. Therefore, the suburban residents are relatively willing to purchase new energy vehicles.

3.2.2. *Respondents' subjective perception of new energy vehicles*

More than 53.5% of residents choose new energy vehicles out of low-carbon environmental protection ideas, while only 7.5% are motivated by freshness. Through binomial logistic regression analysis (Table 2), the model coefficient of low-carbon environmental protection motivation and purchase willingness of new energy vehicles is 0.784, which has a strong positive correlation; the model coefficient of future development trend motivation and purchase willingness is 0.355, which has a weak positive correlation; and motivation of curiosity about fresh things has no obvious correlation with the purchase willingness. Therefore, residents motivated by low-carbon environmental protection are more likely to accept new energy vehicles, while residents motivated by curiosity about new things do not necessarily choose new energy vehicles. According to the results of model analysis, environmental protection awareness is directly proportional to the public's willingness to purchase new energy vehicles, and the model coefficient is 0.441 (Table 1), which indicates that people with higher environmental awareness will correspondingly have a higher willingness to purchase new energy vehicles (Mi et al., 2018; Sun and Wang, 2018). The significance level of the degree of understanding is greater than 0.05, which means that the analysis of this sample is not statistically significant to the population. Therefore, the degree of understanding has no significant impact on the purchase intention of new energy vehicles.

Studies have shown that purchasers of new energy vehicles have a stronger perception effect (Li, 2010; Tan, 2014; Sun and Xu, 2018; Wei et al., 2018), their use of new energy vehicles can reduce air pollution and their behavior is environmentally friendly. At the same time, most people have recognized that low-carbon and environmentally friendly consumption patterns and the popularization of the new energy vehicle industry has become an inevitable development trend of contemporary social transportation. Residents with strong awareness of low-carbon environmental protection pay special attentions to the environment. They will choose green and pollution-free travel modes as their transportation means while traveling. New energy vehicles are green vehicles which do not cause air pollution and

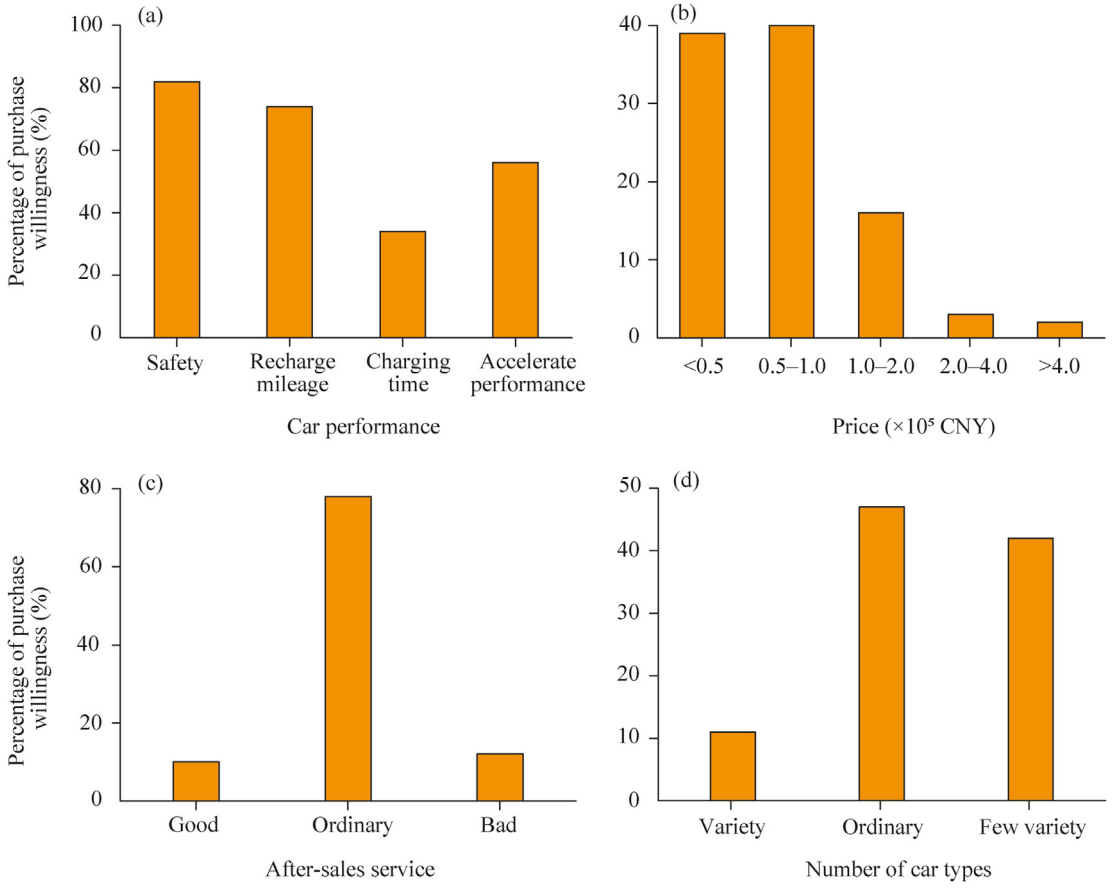

Fig. 2. Percentages of purchase willingness of new energy vehicles in different product factors. (a), car performance; (b), price; (c), after-sales service; (d), number of car types.

are favored by environmentalists.

3.2.3. Products' features

3.2.3.1. Car performance. Residents attach the greatest importance to the safety performance of cars, with 81.59% of attention, followed by 74.23% of recharge mileage, but they pay less attention to acceleration performance and charging time (Fig. 2a). The model coefficients of safety, recharge mileage, and acceleration performance are 0.743, 0.675, and 0.124, respectively (Table 2). It can be seen that the safety and recharge mileage of new energy vehicles are positively correlated with the public's purchase willingness, and the correlation is strong. Acceleration performance is weakly positively correlated with the purchase willingness, and the significance value of charging time greater than 0.05 is statistically insignificant (Table 2). Therefore, safety and recharge mileage have a strong driving power for the public's purchase willingness, and the driving force of acceleration performance is weak, while the charging time has no significant effect on the public's willingness.

Safety is always the basic requirement of a new product, and the endurance mileage varies between new energy vehicles and traditional ones. Meanwhile, endurance is also a technical challenge for new energy vehicles (Kurani et al., 2008; Dang et al., 2014). Therefore, safety and recharge mileage have become the two most concerned performances.

3.2.3.2. Price. According to the sample statistics, 79.00% of the public's acceptable price of new energy vehicles is less than 1.0×10^5 CNY, among which 40.00% is 0.5×10^5 CNY to 1.0×10^5 CNY, and very few users accept the price higher than 2.0×10^5 CNY (Fig. 2b). The regression results show that Exp(B) equals to 0.190, which means that in the case of other influencing factors, the probability of the public accepting new energy vehicles will decrease by 0.190 times for each additional unit of price. It can be seen that economic factors still have great restrictions on the willingness to buy new energy vehicles and most users are more willing to accept cheap ones. Besides, for the US, the purchase price and operating costs are mentioned more often (Till et al., 2018).

From interviews and surveys, some people believe that the cost of new energy vehicles is high. Although there are financial and tax subsidies, fuel-efficient vehicles with the same performance as electric ones are cheaper, and fuel-efficient vehicles with the same price as electric cars have a better performance. With a certain budget, low-income groups are more likely to choose fuel vehicles to meet their travel demand, while middle- and high-income groups will consider the psychological needs of greenness and emission reduction, which will affect residents' willingness to purchase new energy vehicles (Dang et al., 2014; Liu and Mu, 2016; Huang et al., 2018).

3.2.3.3. After-sales service. As high as 78.00% of the respondents believe that the current after-sales service of new energy vehicles is mediocre (Fig. 2c). There is still much room for improvement in terms of after-sales service. The after-sales service of new energy vehicles is positively correlated with the public's willingness to purchase (Table 1). The model coefficient is 0.733 and Exp(B) equals to 1.657, which indicates that the better the after-sales service of cars is, the higher the willingness of the residents to purchase new energy vehicles will be. A perfect after-sales service system can ease people's worries about new energy vehicles and provide guarantee for the public to purchase new energy vehicles. At the same time, it will help establish a good relationship between sellers and customers, which is conducive to the optimization and improvement of product quality, thereby increasing people's purchase willingness.

3.2.3.4. Number of car types. Only 11.00% of the respondents point out that there are many types of new energy vehicles at present (Fig. 2d), and the number of new energy vehicle types has a significance level value greater than 0.05, which is not significant and has no statistical significance on the purchase willingness (Table 1).

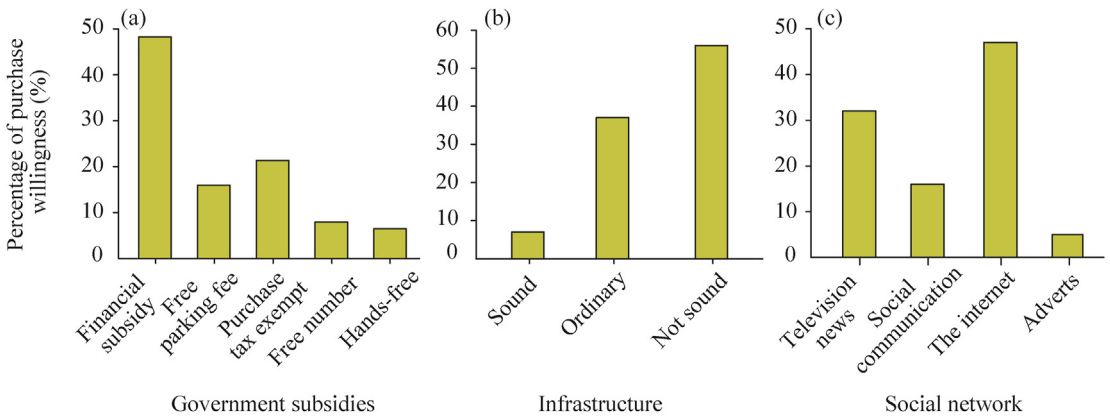

Fig. 3. Percentages of purchase willingness of new energy vehicles for different social environmental factors. (a), government subsidies; (b), infrastructure; (c), social network.

3.2.4. Social environmental factors

3.2.4.1. Government subsidies. Among the expected government subsidies, financial subsidy is the most expected one, accounting for 48.50% of the total (Fig. 3a). The second is exemption from purchase tax and free parking fees. However, the minimum free number and hands-free account for 14.50% in total. By binomial logistic regression analysis, we can see that the model coefficient of financial subsidy is 0.693 (Table 2). Financial subsidy is positively correlated with the public's purchase willingness. Therefore, it has a strong positive impact on the public's purchase willingness. The model coefficients of free parking fees, purchase tax exempt, and hands-free are all small. Although they are positively correlated with the purchase willingness, the correlations are weak. The free number factor is not statistically significant because the significance level is greater than 0.05.

Economic problems are a common issue for most people who consider buying new energy vehicles. However, limited numbers, license plates, parking fees, etc. are problems in some traffic congested cities. From the perspective of the residents, financial subsidy can enhance their willingness to buy new energy vehicles (Wang et al., 2017).

3.2.4.2. Infrastructure. According to the survey, 56.00% of the respondents believe that the current infrastructure of new energy vehicles is inadequate, and only 7.00% show that the current infrastructure is well-developed (Fig. 3b). It can be seen that the current infrastructure construction of new energy vehicles needs to be further strengthened. In the binomial logistic regression analysis, the model coefficient of infrastructure factor is 0.416 (Table 1). Therefore, infrastructure is positively correlated with the public's purchase willingness, and the correlation is moderate. That is to say, infrastructure is the driving factor for new energy vehicle acceptance. The supporting infrastructure of new energy vehicles affects cars' energy supply, charging convenience, battery life, and other important performances, and plays a decisive role in the implementation of new energy vehicles in general. Therefore, sound infrastructure has a significant positive impact on the public's purchase willingness. And in Germany, energy prices and the charging infrastructure are also important factors in the decision to purchase new energy vehicles (Till et al., 2018).

3.2.4.3. Social network. According to the statistics, the number of people who know about new energy vehicles via the Internet is 46.01%, nearly half of the respondents. Secondly, television news account for 32.52%, but only 4.29% learn through adverts (Fig. 3c). Based on the binomial logistic regression analysis, the model correlation coefficients of television news, Internet, and adverts are all above 0.300, positively correlated with the public's purchase willingness. And the Exp(B) value of the Internet is the largest, namely 1.732, indicating that the online channel has the strongest correlation with the public's purchase willingness. However, the significance value of social communication factors is greater than 0.05, which is not statistically significant.

In comparison, the four channels (television news, social communication, internet, and adverts) highlight the characteristics of social network communication: low cost, rapid transmission, large amount of information, detailed information, abundant real-time information, and strong social sensitivity. Considering that new energy vehicles have not yet been officially launched on a large scale, online promotion may be the most effective way. As new energy vehicles have not become a hot issue in society, the effects of news dissemination and social communication are not outstanding. There are only a few independent industries producing new energy vehicles. Due to the incomplete new energy vehicle industry chain, the company's profit margin is small and the advertising funding is insufficient, resulting in the lack of large-scale advertising.

4. Recommendations for the promotion of new energy vehicles

Improving infrastructure construction and promoting cooperation between industry, university, and research institute. The government should recruit high-quality talents in urban space planning so as to establish a network of charging points and car service points across the city, with the goal of providing complete infrastructure services for new energy vehicles. In addition, the establishment of a joint research and development system involving the government, research institutes, and enterprises can improve the efficiency of new energy vehicle technology innovation and industrial development. Therefore, the government should reasonably guide the formation of an industry-university-research cooperation research and development system. Strengthening the cooperation between university research and enterprise production so as to develop new energy vehicle products, is comfortable, environmentally friendly, and energy saving, and meets the consumers' expectations.

Improving people's environmental awareness and enhancing target customers' loyalty. Research shows that women are more supportive and fond of new energy vehicles, and women's opinions play a significant role when a family considers buying a car. Therefore, it is necessary to add elements that appeal to female consumers in advertising and car designing. In terms of education, the respondents with high education backgrounds have a higher purchase willingness, which can be a good breakthrough. Based on the survey results that residents will be more willing to buy new energy vehicles when they are farther from the city center, we recommend companies pay attention to regional differences and increase the number of sales points in suburban areas. Moreover, increasing investment in suburban infrastructure and service points to provide more convenient conditions for suburban new energy vehicle users is also suggested.

Attaching importance to the quality of after-sales service and innovating technologies to reduce car prices. On the basis of the after-sales service system of traditional energy vehicles, we recommend establishing and improving the after-sales service system to provide timely and convenient service for repair, maintenance, and credit of new energy vehicle. We further suggest actively understanding the government's support policies, applying for funds to increase investment (Hu, 2018), and building charging points. In addition, fundamentally reducing the price of car purchases also needs to break through technical bottlenecks.

5. Conclusions

Our results indicate that although most residents point out that they would consider buying new energy vehicles in the future, their understanding of new energy vehicles is generally insufficient, which may lead to a decline in their trust in new energy vehicles, thus affecting their ultimate purchase decision. In addition, there are no prior studies on the spatial distribution of the purchase willingness of new energy vehicles. Our study found that the residents' purchase willingness may have certain aggregation characteristics, i.e., the further away from the city center, the higher the purchase willingness. Therefore, the regularity of the residents' purchase willingness in the spatial distribution can be regarded as one of the focuses of the research on the promotion strategy of new energy vehicles. As one of the earliest new energy vehicle purchase willingness studies in China, our research provides an important information for the promotion of new energy vehicles. However, there are still some limitations in the research due to the large research scope, strong subjective factors, and the narrow way of data collection. Our future study will be improved from the following aspects: combination of environmental background and industrial development direction based on the concept of sustainable development, and in-depth analysis of the economic, social, and ecological values of new energy vehicle promotion. Future research can also strengthen data persuasiveness through big data and official statistics of relevant departments.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix A. Unordered variable description

Category	Factor	Variable	Variable assignment	Assignment meaning
Social environment	Social network	Television news	0, 1	0, Not choose; 1, Choose
		Social communication	0, 1	0, Not choose; 1, Choose
		Internet	0, 1	0, Not choose; 1, Choose
		Adverts	0, 1	0, Not choose; 1, Choose
	Government subsidies	Financial subsidy	0, 1	0, Not choose; 1, Choose
		Free parking fees	0, 1	0, Not choose; 1, Choose
		Purchase tax exempt	0, 1	0, Not choose; 1, Choose
		Free number	0, 1	0, Not choose; 1, Choose
		Hands-free	0, 1	0, Not choose; 1, Choose
Individual subjective cognition	Car purchase motivation	Curiosity about new things	0, 1	0, Not choose; 1, Choose
		Out of low-carbon environmental protection	0, 1	0, Not choose; 1, Choose
		In line with future trends	0, 1	0, Not choose; 1, Choose
Product itself	Car performance	Safety	0, 1	0, Not choose; 1, Choose
		Recharge mileage	0, 1	0, Not choose; 1, Choose
		Charging time	0, 1	0, Not choose; 1, Choose
		Accelerate performance	0, 1	0, Not choose; 1, Choose

Appendix B. Ordinal variable description

Category	Variable	Variable assignment	Assignment meaning
Individual objective attributes	Gender	0, 1	0, Female; 1, Male
	Age	1–5	1, 18–20; 2, 21–28; 3, 29–40; 4, 41–65; 5, ≥66
	Education	1–4	1, Primary school or less; 2, Middle school; 3, Bachelor degree; 4, Master degree and above
	Habitation	1–3	1, Downtown; 2, Peri-urban areas; 3, Outskirts
	Monthly income	1–4	1, Under 2000 CNY; 2, 2000–5000 CNY; 3, 5000–10,000 CNY; 4, More than 10,000 CNY
		1–4	1, Rarely; 2, Occasionally; 3, Often; 4, Always

(*continued on next page*)

(*continued*)

Category	Variable	Variable assignment	Assignment meaning
Individual subjective cognition	Environmental awareness		
	Degree of understanding	1–3	1, Don't understand; 2, Ordinary; 3, Understand
Product itself	New energy vehicle prices	1–5	1, Below 50,000 CNY; 2, 50,000–100,000 CNY; 3, 100,000–200,000 CNY; 4, 200,000–400,000 CNY; 5, Over 400,000 CNY
	After sales service	1–3	1, Good; 2, Ordinary; 3, Bad
	Number of car types	1–3	1, Varieties; 2, Ordinary; 3, Few ordinary
Social environment	Infrastructure	1–3	1, Sound; 2, Ordinary; 3, Not sound

References

Axsen, J., Bailey, J., Castro, M.A., 2015. Preference and lifestyle heterogeneity among potential plug-in electric vehicle buyers. Energy Econ. 50, 190–201.

Caulfield, B., Farrell, S., McMahon, B., 2010. Examining individual preferences for hybrid electric and alternatively fuelled vehicle. Transport Pol. 17 (6), 381–387.

Carley, S., Krause, R.M., Lane, B.W., et al., 2013. Intent to purchase a plug-in electric vehicle: a survey of early impressions in large US cites. Transport. Res. Transport Environ. 18, 39–45.

Cirillo, C., Liu, Y., Maness, M., 2017. A time-dependent stated preference approach to measuring vehicle type preferences and market elasticity of conventional and green vehicles. Transp. Res. Pt. A-Policy Pract. 100, 294–310.

Dang, S.P., Odonde, A., Mirza, T., et al., 2014. Sustainable energy management: an analysis report of the impacts of Electric Vehicles. In: 14th International Conference on Environment and Electrical Engineering. Krakow, Poland, pp. 225–278.

Egbue, O., Long, S., 2012. Barriers to the widespread adoption of electric vehicles: an analysis of consumer attitudes. Energy Pol. 48, 717–729.

Gallagher, K.S., Muehlegger, E., 2011. Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. J. Environ. Econ. Manag. 61 (1), 1–15.

He, X.Q., 2008. Multivariate Statistical Analysis. China Renmin University Press, Beijing.

He, L., Chen, W., Conzelmann, G., 2012. Impact of vehicle usage on consumer choice of hybrid electric vehicles. Transport. Res. Transport Environ. 17 (3), 208–214.

Hinnuber, F., Szarucki, M., Szopik-Depczynska, K., 2019. The effects of a first-time experience on the evaluation of battery electric vehicles by potential consumers. Sustainability 11 (24), 7034.

Hu, S.F., 2018. The dilemma and countermeasures of China's new energy vehicle industry financial subsidy policy. China Collective Economy 16, 35–36 (in Chinese).

Huang, T.B., Li, Y.Y., Xia, X.T., et al., 2018. A survey of public acceptability in the process of science and technology innovation by taking high-voltage transmission technology, new energy vehicles and PX projects as examples. Sci. Res. Manag. 39 (S1), 386–397 (in Chinese).

Jiang, A.H., Sheng, X.L., 2017. Research on factors influencing consumers' willingness to buy and guide policies for new energy vehicles. Fiscal Science 5, 12–26 (in Chinese).

Kahn, M.E., Vaughn, R.K., 2009. Green market geography: the spatial clustering of hybrid vehicle and LEED registered buildings. B E J. Econ. Anal. Policy. 9 (2), 1–22.

Kurani, K.S., Heffner, R.R., Turrentine, T., 2008. Driving Plug-In Hybrid Electric Vehicles: Reports from US Drivers of HEVs Converted to PHEVs, Circa 2006–2007. Institute of Transportation Studies, pp. 1–33.

Lane, B., Potter, S., 2007. The adoption of cleaner vehicles in the UK: exploring the consumer attitude reaction gap. J. Clean. Prod. 15 (11–12), 1085–1092.

Li, J.L., 2010. Research on Energy-Saving and New Energy Vehicle Product Perceived Quality and Customers' Willingness to Buy. MSc Thesis. Dalian Traffic University, Dalian (in Chinese).

Liu, B.W., Li, X.C., 2010. Analysis on the competitiveness of China's new energy vehicle industry. China Economic and Trade Herald 3, 69 (in Chinese).

Liu, T.F., 2016. Research on the Factors Affecting the Willingness of Consumers to Buy New Energy Vehicles in Beijing. MSc Thesis. Beijing Forestry University, Beijing (in Chinese).

Liu, X., Mu, R., 2016. The public environmental concern in China: determinants and variations. Environ. Hazards-UK 37, 116–127.

Liu, X.M., Zhang, D., Cao, J., 2018a. Design of urban new energy vehicle development status and promotion strategy: based on the survey of Hohhot. China Market 33, 137–138 (in Chinese).

Liu, Z.W., Hao, H., Cheng, X., et al., 2018b. Critical issues of energy efficient and new energy vehicles development in China. Energy Pol. 115, 92–97.

Lou, M.Q., Yin, Z.Y., Mo, W.Y., 2012. Research on new energy vehicle product strategy based on consumer choice. Shanghai Management Science 34 (2), 19–25 (in Chinese).

Man, Y.Y., Yin, S.Y., 2015. Analysis of consumer demand for new energy vehicles based on consumer questionnaires. Modern Economic Information 7, 419 (in Chinese).

Mi, L.Y., Yu, X.Y., Yang, J., 2018. Research on the factors influencing the purchase behavior of new energy vehicles for knowledge consumers based on the grounded theory. Corporate Economy 4, 19–26 (in Chinese).

Moons, I., Pelsmacker, P.D., 2012. Emotions as the determinants of the electric car usage intention. J. Market. Manag. 28 (3–4), 195–237.

Peters, A., Mueller, M.G., Haan, P.D., et al., 2008. Feebates promoting the energy-efficient cars: design options to address more consumers and the possible counteracting effects. Energy Pol. 36 (4), 1355–1365.

Shen, J., Saijo, T., 2008. Reexamining the relations between the socio-demographic characteristics and individual environmental concern: evidence from Shanghai data. J. Environ. Psychol. 28 (1), 42–50.

Skippon, S., Garwood, M., 2011. Responses to battery electric vehicles: UK consumer attitudes and attributions of symbolic meaning following direct experience to reduce psychological distance. Transport. Res. Transport Environ. 16 (7), 525–531.

Sun, H., Geng, Y., Hu, L., et al., 2018. Measuring China's new energy vehicle patents: a social network analysis approach. Energy 153, 685–693.

Sun, Q., 2017. Research on Influencing Factors of Electric Vehicle Promotion Based on SEM. MSc Thesis. Tianjin University, Tianjin (in Chinese).

Sun, S.H., Wang, W.C., 2018. Analysis on the market evolution of new energy vehicle based on population competition model. Transport. Res. Transport Environ. 65, 36–50.

Sun, X.H., Xu, S., 2018. Research on the influence of government subsidies on the willingness to buy new energy vehicles. J. Dalian Univ. Technolgy 39 (3), 8–16 (in Chinese).

Tan, H., 2014. Research on Consumers' Preference for New Energy Vehicles and its Influencing Factors. MSc Thesis. Zhenjiang: Jiangsu University of Science and Technology (in Chinese).

Till, G., Thomas, S., Lin, Z.H., et al., 2018. What drives the market for plug in electric vehicles? A review of international PEV market diffusion models. Renew. Sustain. Energy Rev. 93, 159–164.

Wang, Z.H., Zhao, C.Y., Yin, J.H., et al., 2017. Purchasing intentions of Chinese citizens on new energy vehicles: how should one respond to current preferential policy? J. Clean. Prod. 161, 1000–1010.

Wei, Z., Lin, Y., Cai, Y.S., et al., 2018. Dynamic programming for new energy vehicles based on their work modes part I: electric vehicles and hybrid electric vehicles. J. Power Sources 406, 151–166.
Xu, G.H., Xu, F., 2010. Impact factors of purchase decision of new energy automobile. China Population, Resources and Environment 20 (11), 91–95 (in Chinese).
Yang, J., 2012. An empirical study on consumers' willingness to buy electric vehicles based on the government's industrial policy theory. Special Zone Economy 4, 302–304 (in Chinese).
Zhang, X.Y., Zhao, H.B., Zhou, X.K., 2011. The development and problems of China's new-energy auto industry: based on the perspective of sustainable development of auto industry. Theory Mod. 2, 60–66 (in Chinese).
Zhao, H.Q., Yu, H., Wang, J.W., et al., 2018. Research on factors of purchase intention of new energy vehicles – from the perspective of consumer perception. J.Tianjin . Univ. Commer. 38 (3), 20–24 (in Chinese).