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Understanding consumers' adoption of new energy vehicles in the transition to sustainable transportation

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The advent of new energy vehicles (NEVs) presents hopeful pathways to alleviate the strain caused by fossil fuel consumption and environmental deterioration. However, the widespread adoption of NEVs remains a challenge. Current research on the adoption of NEVs tends to concentrate on factors like consumer psychology and vehicle performance while neglecting the role of cultural values and purchase costs in consumers' decision-making process. Therefore, this study innovatively integrates uncertainty avoidance and price awareness into the Technology Acceptance Model (TAM) and explores the moderating effect of environmental awareness. This study employs partial least squares structural equation modelling (PLS-SEM) and fuzzy set qualitative comparative analysis (fsQCA) to validate the hypotheses and the synergistic influence of antecedent combinations on the purchase intention of NEVs. The findings show that price consciousness, perceived ease of use, and attitude are important influencing factors motivating consumers to make purchasing decisions and reveal the mechanisms of uncertainty avoidance, perceived usefulness, and environmental awareness on the purchase intention of NEVs. Furthermore, fsQCA identified four conditions that are sufficient to promote the purchase intention of NEVs.

Keywords Uncertainty avoidance, Price consciousness, Consumer behavior, Perceived risk, Environmental awareness, fsQCA, Sustainability

The transportation industry is one of the China's largest gasoline consumption industry[1], and its emissions have emerged as a significant contributor to air pollution[2]. Existing studies have confirmed that NEVs have significant influence on improving air quality and reducing carbon dioxide emissions[3,4]. Moreover, it was reported that the NEV industry has transformed into a crucial tool for countries to attain sustainable development goals[5]. As a result, governments in various countries have implemented measures to boost the development of the NEV industry including financial subsidies, tax breaks, and the establishment of charging infrastructure[6]. Although China is the world's largest market for new energy vehicles[7], the adoption of NEVs as an alternative to fuel vehicles in China is slow. By the end of September 2023, China had 430 million motor vehicles and 18.21 million NEVs, accounting for 5.5% of the total. Compared to fossil fuel-powered vehicles, there are still some barriers that discourage individuals from purchasing NEVs[8].

Existing research is mainly focused on exploring factors to promote consumer adoption of NEVs[9–12], which offers valuable enlightenment for promoting the popularization of NEVs. However, from a practical standpoint, whether it is the government's monetary stimulus or technological innovation, the promotion role of consumers' choice of NEVs is limited. Despite efforts by some scholars to examine the obstacles that deter consumers from choosing NEVs, such as economy, technology, infrastructure, environment, etc.[13,14], these factors are different in countries and cannot fully demonstrate the obstacles faced by Chinese consumers when buying NEVs. Furthermore, consumers' psychological factors are more important and complex than policies and situations, but research on consumer psychology is scarce in the existing literature[15].

Furthermore, Tarei et al.[16] argued that it was important to construct a survey on overcoming barriers to NEVs adoption in a specific country context. The adoption of NEVs will differ depending on the specific country and

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cultural context. Similarly, Plananska et al.[17] suggested that cross-cultural research on NEV adoption is necessary because cultural value will influence residents' decisions to purchase NEVs. Empirical studies have shown that Chinese traditional cultural values have a profound impact on consumers' pro-environmental behaviour[18,19]. For example, face consciousness inspires consumers' environmentally responsible behaviour during travel[20]. Consistent with this sentiment, it was also reported that group conformity reduces young Chinese consumers' food waste behaviors[21].

In addition to the aforementioned, Chinese Confucianism and the doctrine of the mean have profoundly influenced Chinese consumers' shopping preferences. Therefore, Chinese people like to plan ahead and are suspicious of uncertain outcomes. The driving uncertainty is an important factor hindering the popularity of NEVs[22]. When consumers are confronted with emerging technologies like NEVs, they often face a range of unknowns and uncertainties. These uncertainties may relate to NEVs' performance, reliability, maintenance costs, battery life, and the availability of charging facilities. Extant studies have confirmed that consumers are uncertain about the performance and environmental properties of NEVs[16,23]. However, the existing research has largely overlooked the role of uncertainty avoidance in shaping consumers' adoption of NEVs.

Lastly, NEVs have environmentally friendly attributes[1]. In studies on the consumption of ethical products with environmentally friendly attributes, price is a significant variable often discussed by scholars[24,25]. The elevated price of NEVs, primarily stemming from the costly batteries, surpasses that of traditional fuel-powered vehicles[14]. The price difference makes consumers worry about the economic cost of purchasing NEVs. Consumers need to weigh the environmental and energy-saving advantages brought by the purchase of NEVs against the high price. In order to enhance the attractiveness of NEVs, governments have adopted incentive policies, such as reducing the purchase price of fuel vehicles, tax incentives, etc., but the effect of these policies ultimately depends on the choice of consumers[26]. Numerous research results have revealed that the price factor is the primary reason consumers refrain from selecting NEVs[14,24,26]. However, to date, the influence of price factors on the popularity of NEVs remains incompletely understood.

To address the above gaps, this study aims to extend NEV adoption research by constructing a framework that includes the factors that promote and hinder consumers' choice of NEVs. This study contributes to the extant literature in the following three dimensions: First, this study investigates how uncertainty avoidance of Chinese traditional cultural values affects consumers' purchase intention of NEVs, thereby expanding the scope of the impact of cultural values on consumers' decision-making. Second, this study innovatively explored the influence mechanism of price consciousness and perceived risk on the adoption of NEVs, providing a new theoretical perspective for subsequent research. Third, this study explores the moderating effect of environmental awareness on consumers' adoption of NEVs. By integrating consumer behavior with pro-environmental behavior, it enriches the theoretical dimensions of the research on the adoption of NEVs.

Literature review

Technology acceptance model (TAM)

TAM is a theoretical model that explains and predicts user adoption behavior of new technologies. TAM is grounded in two pivotal factors of perceived usefulness and perceived ease of use, and it explains technology adoption behaviour through attitude[27]. TAM has garnered widespread application in various fields, including service robots in the tourism industry[28], Internet of Things[29], Online and offline delivery[30], and virtual try-on technology[31]. These studies and empirical analyses demonstrate the validity and practical relevance of the TAM model in elucidating and forecasting technology adoption behaviour.

However, some of the scholars have also criticized the applicability of TAM. First, the original TAM primarily focuses on the favourable factors that influence consumers' acceptance of technologies and products, ignoring the factors that hinder consumers' acceptance[32]. Therefore, scholars often incorporate perceived risk into TAM to enhance its explanatory power[33,34]. Second, TAM ignores the influence of cultural and social factors when explaining technology adoption, social values and inter-group differences may have a vital impact on technology acceptance[35]. Third, TAM mainly focuses on individuals' cognition and attitude towards technology, while ignoring the influence of external environmental factors on technology acceptance. Some studies have broadened TAM by incorporating external factors or social influence to better explain technology adoption behaviour[30,36].

New energy vehicles adopt innovative technologies such as intelligent interaction and electric drive systems, it is appropriate to employ TAM to predict the adoption of NEVs[37]. This study fully considers the scholars' criticism of TAM and expands the TAM model. First of all, this study adds perceived risk and price consciousness to TAM, which makes up for the defect that TAM only considers the promoting factors of technology acceptance. In addition, this study expands the scope of TAM's cross-cultural research by adding the cultural value of uncertainty avoidance. Finally, this study tests the moderating role of consumers' environmental awareness in shaping their intention to adopt NEVs.

Research on adoption of NEVs in China

New energy vehicles refers to "those vehicles with new-type power systems, wholly or mainly driven by new energy sources, largely including all-electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell vehicles (FCVs)"[38]. The adoption of NEVs is an important condition for realizing low-carbon and sustainable development in society[39]. As a result, many of the scholars have focused on understanding this issue and improving consumer adoption of NEVs. Given the significant heterogeneity in economic development across different cities and the divergence in consumers' automotive preferences, scholars have directed their attention to investigating the city-level variability in NEV adoption behavior[40,41]. Furthermore, leveraging the inherent environmental attributes of NEVs, another strand of research has centered on the role of consumers'

environmental cognition. In this vein, scholars have explored how various cognitive constructs, such as environmental concerns[42], ecological awareness[39], subjective norms[43], and environmental responsibility[44], exert an influence on consumers' purchase intentions toward NEVs.

However, from the viewpoint of the market penetration or prevalence of NEVs across various nations, consumers' cognition and acceptance of NEVs still have great room for improvement. Although many scholars have studied the barriers in their respective countries in promoting NEVs[22,45,46], there are relatively few studies on the barriers faced by China in promoting NEVs. In the context of ever-changing technology and the environment, scholars' research on barriers to the adoption of NEVs is limited and needs to be further deepened[47,48].

The existing literature disclosed that the barriers to the adoption of NEVs in the Chinese market can be summarized in various ways. A growing body of scholars have identified the inadequacy of supporting infrastructure as a critical barrier to the popularization of NEVs[49,50]. The immaturity of NEV technologies has also garnered widespread scholarly attention[51,52]. Recent empirical studies have indicated that an increasing number of consumers are attaching great importance to the resale value of NEVs[22]. Specifically, the depressed pricing in the second-hand NEV market has exerted a negative impact on consumers' purchase intentions. Moreover, some scholars have identified the scarcity of charging facilities as a significant hindrance to the wider promotion of NEVs[15,49]. Especially when long-distance driving is required, the lack of charging equipment reduces user convenience, thus reducing consumer demand for NEVs. Another barrier to the popularity of NEVs is consumers' range anxiety[53,54].

A systematic review of extant literature examining the factors influencing consumers' adoption of NEVs yields two key findings: First, scholars mainly analyze barriers faced by NEVs adoption from the NEVs' attributes, technology and charging infrastructure, few studies have delved into the factors from the lens of consumer psychology. Second, research on how Chinese cultural values influence consumers' adoption of NEVs remains scarce. Among the existing studies, only Chen et al.[55] explored the promotion effect of frugality and "mianzi" on Beijing consumers' intention to adopt NEVs, but the purchase quota policy in Beijing led to the limited extension of the research conclusions.

Hypothesis development and conceptual framework

Perceived risk (PR)

Perceived risk refers to "consumer evaluations of the likelihood and severity of future negative consequences as a result of a consumption experience, or the chance of loss multiplied by the magnitude of the loss"[56]. Existing studies show that safety is the most important aspect for consumers when purchasing NEVs[57]. Since the technology of NEVs is relatively new, consumers may have concerns about their reliability and safety[58]. For example, the battery's life and the charging system's safety are some of the common concerns raised by the adoption of NEVs. In particular, there are news reports that NEVs explode after a collision, causing a fire, which greatly enhances the perceived risk of consumers[45,59]. The rapid expansion of NEVs leads to disorderly charging behavior, which in turn makes consumers perceive the risk of normal operation of the power grid[57].

In addition, the perceived risk will make consumers doubt the travel efficiency of driving NEVs[39], because the scarcity of charging infrastructure constitutes a significant factor in shaping consumers' perceived risk[36,60]. If consumers think that the charging station is not dense enough or that the charging speed is too slow, they may worry about the charging difficulties of long-distance travel, thus lowering their attitude towards new energy vehicles. Therefore, perceived risk reduces consumers' confidence in NEVs and affects their purchasing decisions. A survey conducted by García de Blanes Sebastián et al.[36] showed that consumers have a negative attitude towards electric vehicles when they perceive physical risks. Furthermore, according to the research of Zhang et al.[37], perceived risk inversely affects consumers' attitudes towards NEVs.

Multiple studies have demonstrated that there is a negative correlation between perceived risk and consumers' intention to adopt NEVs[61,62]. Jia and Lin[22] found that consumers' perceived risk of accidents on NEVs reduced their purchase intention. In a similar vein, Xu et al.[63] investigated 692 consumers' intentions to adopt EVs, and found that the perceived risk was negatively correlated with consumers' intentions. When investigating consumers' intention to adopt NEVs in China, Xiong et al.[62] also reached a similar conclusion that perceived risk reduced consumers' purchase intention for NEVs. Wang et al.[39] studied the factors shaping the decision of consumers' adoption of NEVs in Gansu, China, and found that the perceived risk made consumers feel that the ease of use of NEVs was reduced, thus reducing their purchase intention. Therefore, we proposed the following hypotheses:

H1a: Perceived risk negatively influences attitude.

H1b: Perceived risk negatively influences consumers' intention to purchase NEVs.

Attitude (AT)

Singh et al.[64] believed that accurately forecasting consumers' intentions is not feasible without considering their attitudes towards NEVs. Consumers' positive attitude towards environmental protection may be an important driving force for purchasing NEVs[65]. In addition, new energy vehicles usually cover many innovative technologies, such as electric drive systems and intelligent interconnection functions. If consumers hold a positive attitude towards new technologies and want to experience innovation, they may be more inclined to purchase NEVs. Existing empirical studies have shown that attitude is an important antecedent variable of purchase intention[66,19,67]. Therefore, we hypothesize that:

H2: Attitude positively influences consumers' NEV purchase intention.

Price consciousness (PC)

Price consciousness refers to the mentality of consumers to avoid goods that they think are more expensive[68]. Price is the biggest disadvantage that prevents consumers from purchasing NEVs[34,57,69]. The battery pack is the heart of NEVs, and high cost of battery technology research, development, and production directly leads to a rise in NEV prices[52,70,71]. In addition, the popularity of NEVs necessitates the corresponding charging infrastructure to provide. The construction, maintenance and operation of charging piles all require certain costs[72]. These costs are likely to be reflected in the NEV's selling price. At the same time, Tarei et al.[16] found that the limited availability of raw materials for NEVS would also lead to a high initial cost. Therefore, consumers need to make a trade-off between paying the high initial cost of NEVs and enjoying long-term fuel efficiency[73].

In addition, the study conducted by Shen et al.[74] revealed that Chinese consumers exhibit a high sensitivity towards pricing, and this sensitivity to the purchase and later maintenance costs of NEVs will lead to their perceived risks. When investigating the public's intention to adopt NEVs in developing areas, Wang et al.[39] discovered that perceived cost of the public enhanced the perceived risk of consumers. According to Sun[75] , consumers will suffer greater risk losses as prices rise. Consumers ' perceived risk will be reduced when there is a discount on a product. Therefore, discounts motivate price-sensitive consumers to buy new products[76].

In addition, the empirical findings of Wang et al.[39] revealed that price consciousness reduces consumers' acceptance of NEVs. According to Wang et al.[77], the survey findings indicated that consumers' purchase intention is not primarily influenced by the initial price of NEVs, but the cost of driving NEVs is inversely related to the purchase intention. They believed that the high price of NEVs is a key barrier to their popularity. Irfan et al.[78] contended in their study that the price of renewable energy is negatively correlated with consumers' purchase intention when investigating the factors affecting consumers' adoption of renewable energy in Pakistan. By employing Maslow's hierarchy of demand model, Cui et al.[42] predicted consumers' purchase intention for NEVs and found that price consciousness has a negative impact on consumers' purchase intention. Consistent with the evidences above, Wang et al.[39] found that the increase in the price of NEVs corresponds to a decrease in consumer acceptance. Therefore, the following hypotheses are postulated:

H3a: Price consciousness positively influences perceived risk.

H3b: Price consciousness negatively influences consumers' intention to purchase NEVs.

Uncertainty avoidance (UA)

Hofstede[79] summarized five potential cultural dimensions between countries, among which the second dimension is uncertainty avoidance. He argued that "uncertainty avoidance can be explained as the belief individuals display to reduce any sense of anxiety and avoid ambiguity". Chinese Confucianism advocates following traditions, conservatism and norms. This ideological tendency makes people inclined to avoid risks and uncertainties and maintain stability and security. In addition, the Doctrine of the Mean is an important concept in ancient Chinese philosophy that emphasizes balance and the mean. The idea of the Doctrine of the Mean believes that excessive risk-taking is undesirable and advocates a moderate and balanced attitude. Influenced by Confucianism and the Doctrine of the Mean, Chinese consumers are more inclined to choose stable and reliable products when adopting new products. Consumers tend to prioritize the practicality and quality of products, exhibiting less receptiveness to new products that introduce uncertainty into their lives. A risk-averse culture has a vital influence on consumer adoption of new products[80].

To corroborate the discussion above, Jia and Lin[22] argued that due to the new technology of NEVs, consumers are uncertain about their performance. Berkeley et al.[81] discovered that the high purchase price of electric vehicles and the uncertainty of maintenance and repair infrastructure caused consumers' anxiety. In addition, in the current second-hand automobile market, the resale residual value of NEVs is low, and people's acceptance of second-hand NEVs is uncertain[16]. At the same time, Tarei et al.[16] also found that "electric vehicle technology is relatively unfamiliar, and most consumers are uncertain about its safety and operational reliability". Some consumers find that the use of NEVs lacks obvious environmental benefits, leading to consumers' uncertainty about the impact of their pro-environment behaviors[82]. This view is supported by many scholars, who hold the view that the pollution resulting from the production of batteries and power generation makes consumers uncertain regarding the environmental attributes of NEVs[23]. Therefore, consumers are uncertain about the performance, safety and environmental attributes of NEVs and perceive higher related risks[31]. In their study on consumers' purchase intentions for e-commerce products, Rosillo-Díaz et al.[83] discovered that individuals with a high tendency to avoid uncertainty tend to perceive greater risks associated with e-commerce platforms.

Prospect theory holds that "individuals make decisions based on value functions under uncertain conditions, and people are more sensitive to losses than gains"[84]. This theory shows that consumers will tend to consider future losses and gains when they perceive that there are uncertainties when buying a product. When the losses are greater than the gains, consumers may avoid buying this product. Consumers' perception of potential uncertainty plays a pivotal role in the adoption of innovative products. This view is supported by empirical evidence. A survey of consumers' purchase intentions for NEVs in 32 provinces in China shows that consumers' lack of knowledge about NEVs leads to their uncertainty about charging and range, which reduces their preference for NEVs[73]. Therefore, the following hypotheses are postulated:

H4a: Uncertainty avoidance positively influences perceived risk.

H4b: Uncertainty avoidance negatively influences attitude.

Perceived usefulness (PU)

Perceived usefulness refers to "the perception of the benefits an individual will be getting while adopting a new technology"[85]. The perceived usefulness of NEVs is defined as consumers' awareness of the functions, features,

and advantages provided by NEVs. Under the publicity of the government and the media, many consumers believe that NEVs have contributed to environmental improvement because they reduce exhaust emissions and dependence on fossil fuels. Consumers' perceived usefulness of NEVs in reducing air pollution and climate change[86], which makes consumers hold a more positive attitude towards NEVs. Previous studies show that perceived usefulness is an important predictor of attitude[37,66]. This is because when consumers experience the benefits and advantages of using NEVs, this will enhance their purchasing attitudes, which is significant in leading to the adoption of the innovation[66]. In addition, policies such as subsidies, tax cuts and free parking reduce the cost of using NEVs, which reduces the total expenditure of NEVs during the life cycle, and in the long run, new energy vehicles are economically useful to individuals and society. PU has been described as predicting consumers' purchase intentions[85,87]. Therefore, this study hypothesizes as follows:

H5a: Perceived usefulness positively influences attitude.

H5b: Perceived usefulness positively influences consumers' intention to purchase NEVs.

Perceived ease of use (PEOU)

Perceived ease of use refers to "the degree to which an individual feels that they would not need an additional effort to learn how to use the NEVs"[59]. Some consumers believe that NEVs can provide a smooth and comfortable driving experience with high ease of use[5]. In addition, consumers can feel pleasure or enjoyment from NEV technologies, which affects consumers' attitudes and acceptance of new technologies[88]. Extant studies have revealed that perceived ease of use significantly affects consumers' attitudes towards NEVs[37,66,87]. In addition, the perceived ease of use is intricately linked to the user's experience. Users feel convenient when using the new technology, which will improve users' satisfaction and thus increase their purchase intention. This conclusion indicates that only when consumers perceive that NEVs are easy to drive and beneficial to health will their purchase intention be enhanced[84]. Therefore, we hypothesize that:

H6a: Perceived ease of use positively influences attitude.

H6b: Perceived ease of use positively influences consumers' intention to purchase NEVs.

Environmental awareness (EA)

Environmental awareness is an individual's internal perception of issues and the consequences of their own actions on the environment[89]. Individuals with strong environmental awareness tend to pay more attention to the natural environment crisis, human life's overall environmental quality, and future generations' living conditions. As a result, consumers who possess a high level of environmental awareness tend to choose products that meet environmentally friendly standards because they focus on sustainability, environmental protection, and social responsibility[69]. Consistent with this view, awareness of the environment will reduce consumers' perceived risk of NEVs, which will make them more focused on the environmental-friendly attributes of the innovation that could enhance their purchase intention. Moreover, according to Costa et al.[90], consumers' attitudes towards environmental issues have shifted as they have become more conscious of the detrimental consequences associated with their consumption habits and choices[78]. On the contrary, if consumers' environmental awareness is weak, it may have reverse consequences for them to adopt sustainable consumption.

In addition, increased environmental awareness may lead to a shift in consumers' values[62]. Although the initial price of NEVs may be higher, when consumers realize the benefits of air quality improvement and energy savings through long-term use of NEVs, they are inclined to perceive the usefulness of NEVs and regard them as an environmentally friendly and sustainable choice. Therefore, consumers prefer to purchase NEVs neglecting the initial purchase price. Furthermore, increased environmental awareness is usually accompanied by greater access to environmental knowledge and information. By understanding the characteristics, technology and experience of NEVs, consumers can more accurately evaluate and perceive NEVs' ease of use and thus increase their purchase intentions (Fig. 1).

H7a: The relationship between PC and NEV purchase intention is moderated by environmental awareness.

H7b: The relationship between PR and NEV purchase intention is moderated by environmental awareness.

H7c: The relationship between AT and NEV purchase intention is moderated by environmental awareness.

H7d: The relationship between PU and NEV purchase intention is moderated by environmental awareness.

H7e: The relationship between PEOU and NEV purchase intention is moderated by environmental awareness.

Methodology

Research instruments

The measurement items utilized in this study, as presented in Appendix 1, are adapted from previous research that used well-established scales and were anchored by 1 ("strongly disagree") and 7 ("strongly agree"). Five items from Rosillo-Díaz et al.[83] were employed to measure UA. Furthermore, PR was measured by four items adopted from Jain et al.[91], while EA was measured by a four-item proposed by Wang et al.[67]. Finally, three items for AT, PEOU, PI, PC and PU were adopted from Jaiswal et al.[87], Vafaei-Zadeh et al.[5], Chen et al.[55], Cui et al.[42], Wang et al.[39]), respectively.

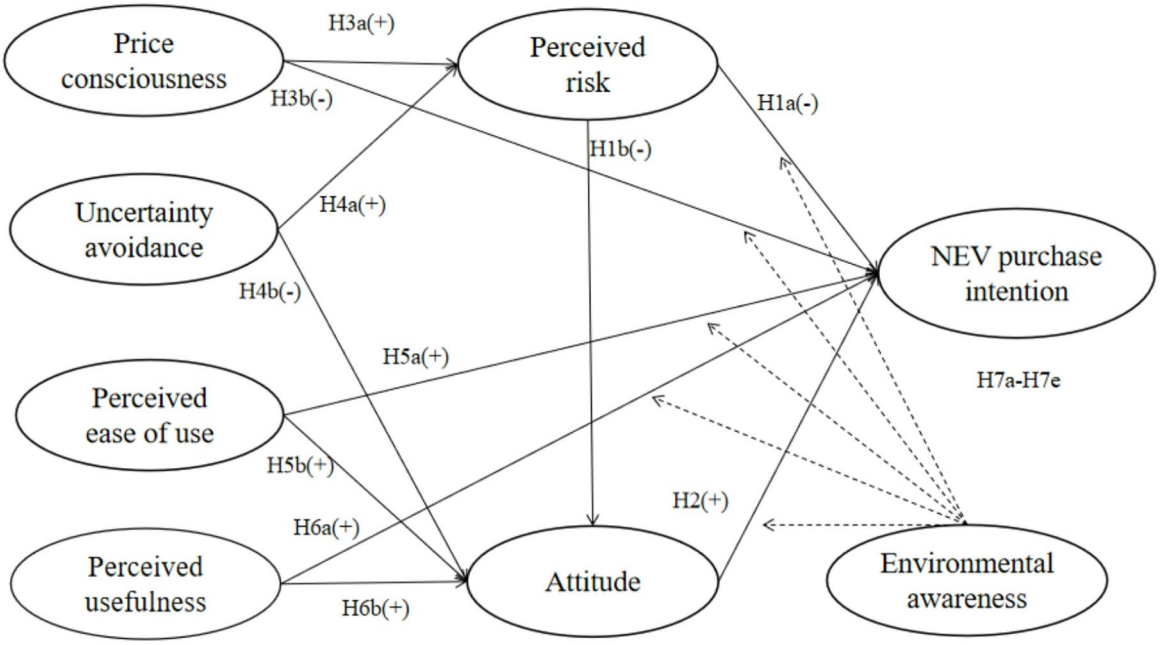

Fig.1. Research model.

Sample and respondent profile

The adoption of NEVs in China is uneven[1]. Some cities are affected by the purchase restriction policy, and the demand for NEVs is higher than in other cities. In order to accurately target respondents and avoid the influence of policy interventions from the provincial authorities, this study used online self-administered questionnaires as a tool to collect research data, filtering out consumers in Beijing, Shanghai, Guangzhou, Shenzhen, Tianjin, Hangzhou and Hainan ageing below 18. Non-probability sampling methods are advantageous when sampling frames are not available[6]. Questionnaires are distributed via the *Wenjuanxing* platform, the largest online questionnaire platform in China, with more than 50 million users and a huge potential respondent database.

This study strictly adheres to the declaration of Helsinki and relevant scientific research ethics guidelines. As a questionnaire-based social science study, it involves no clinical trials on human subjects, sensitive personal data, medical information, or data related to minors. The privacy and data security of all participants are fully protected. The research is conducted anonymously, follows the principle of voluntary participation, poses no potential risks to participants, and implements strict confidentiality measures for all collected information. It complies with the current regulations in China governing social science research.

Two English professionals translated the questionnaire into Chinese by a forward–backward translation method, and then two NEV salespeople and ten actual respondents checked the content, layout and order of the questionnaire to confirm its reliability and validity. The questionnaire is comprised of three distinct sections, with the initial one outlining the questionnaire's intended purpose, providing a definition of NEVs, estimating the approximate time required for completion, assuring confidentiality of responses, and posing filter questions. The second part lists the antecedents affecting consumers' adoption of NEVs. The third part concerns the demographic characteristics of the respondents. Based on *G*Power* (version 3.1.9.7) with a 0.95 power level, 0.05 alpha value, and 0.15 effect size, the 406 valid samples (Table 1) exceed the minimum sample size of 153 required to obtain reliable analytical results.

Data analysis

This study uses a hybrid SEM-fsQCA method to test the proposed model. To assess the statistical significance of hypothesis paths, PLS-SEM was employed, and subsequently, the synergistic influence of antecedent factors on the intention to purchase NEVs was captured through the utilization of fsQCA[92]. As a supplementary analysis to PLS-SEM, fsQCA elucidates how various combinations of conditions work together to produce specific outcomes, providing an aid for the formulation of stronger management policies[93]. The SEM-fsQCA mixed method has been applied in many fields, such as export enterprise competition[94], luxury product purchase intention[95], and informed decision-making[96].

Common method bias (CMB)

CMB is widely present in the questionnaire survey data, and it affects the reliability of the outcomes. Podsakoff et al.[97] suggested two methods to solve the problem of CMB, namely, procedure control and statistical control. Procedural control occurred during the data collection phase, and in the first part of the questionnaire, respondents were told that they were anonymous and that there was no correct or incorrect response. Furthermore, suggestive language is avoided in the questionnaire content setting. As for statistical control, this

Demographic profiles		Frequency	Percentage
Gender	Male	177	43.60
	Female	229	53.40
Age	18–30	112	27.59
	31–40	116	28.57
	41–50	80	19.70
	51–60	69	17.00
	Above 60	29	7.14
Monthly income	Less than CNY 5000	84	20.69
	CNY 5000–7000	141	34.73
	CNY 7001–9000	99	24.38
	CNY 9001–11,000	59	14.53
	More than CNY 11,000	23	5.67

Table 1. Demographic profiles.

Indicators	Original factor loading (Rs)	Rs^2	Method factor loading (Rm)	Rm^2
PI1	0.882	0.778	-0.002	0.000
PI2	0.894	0.799	0.007	0.000
PI3	0.806	0.650	-0.006	0.000
AT1	0.823	0.677	0.021	0.000
AT2	0.873	0.762	-0.027	0.001
AT3	0.845	0.714	0.007	0.000
PR1	0.856	0.733	0.091	0.008
PR2	0.937	0.878	-0.014	0.000
PR3	0.908	0.824	0.029	0.001
PR4	0.982	0.964	-0.108	0.012
UA1	0.826	0.682	0.067	0.004
UA2	0.823	0.677	0.107	0.011
UA3	0.803	0.645	0.131	0.017
UA4	0.975	0.951	-0.156	0.024
UA5	0.968	0.937	-0.155	0.024
PC1	0.869	0.755	0.013	0.000
PC2	0.808	0.653	0.073	0.005
PC3	0.922	0.850	-0.087	0.008
PU1	0.771	0.594	-0.012	0.000
PU2	0.795	0.632	-0.010	0.000
PU3	0.808	0.653	0.021	0.000
PEOU 1	0.793	0.629	0.116	0.013
PEOU 2	0.847	0.717	-0.067	0.004
PEOU 3	0.802	0.643	-0.057	0.003
EA1	0.818	0.669	-0.018	0.000
EA2	0.819	0.671	0.065	0.004
EA3	0.837	0.701	0.007	0.000
EA4	0.781	0.610	-0.059	0.003
Average		0.730		0.005

Table 2. CMV.

study adopted the popular CMB assessment suggested by Liang et al.[98]. As displayed in Table 2, Rs^2 has a much higher ratio than Rm^2 (146), indicating CMB does not exist in this study.

Assessment of the measurement model

Drawing upon the recommendations outlined by Hair Jr et al.[99], this study first checked all measurement items' outer loadings (Table 3); Each of the items possessed outer loadings that surpassed 0.708, significantly exceeding the threshold. Additionally, when evaluating internal consistency reliability through the utilization of composite reliability (CR) and Cronbach's α[100], all metrics indicated a satisfactory level, exceeding 0.7. Following that,

Constructs	items	Outer loadings	Cronbach's α		rho_A	CR	AVE
Price consciousness	PC1	0.879	0.833	0.843		0.899	0.749
	PC2	0.873					
	PC3	0.844					
Uncertainty avoidance	UA1	0.891	0.926	0.946		0.942	0.765
	UA2	0.911					
	UA3	0.910					
	UA4	0.831					
	UA5	0.825					
Perceived ease of use	PEOU1	0.871	0.744	0.775		0.853	0.659
	PEOU2	0.823					
	PEOU3	0.737					
Perceived usefulness	PU1	0.811	0.701	0.711		0.832	0.624
	PU2	0.760					
	PU3	0.797					
Perceived risk	PR1	0.926	0.942	0.949		0.958	0.851
	PR2	0.926					
	PR3	0.931					
	PR4	0.906					
Attitude	AT1	0.860	0.803	0.818		0.883	0.715
	AT2	0.845					
	AT3	0.832					
Environmental awareness	EA1	0.825	0.830	0.857		0.884	0.657
	EA2	0.844					
	EA3	0.853					
	EA4	0.713					
Purchase intention	PI1	0.891	0.826	0.840		0.896	0.742
	PI2	0.899					
	PI3	0.790					

Table 3. Construct validity.

Constructs	EA	PC	PEOU	PI	PR	PU	PPQ
AT	0.079						
EA	0.266	0.071					
PC	0.288	0.104	0.344				
PEOU	0.518	0.259	0.081	0.300			
PI	0.073	0.173	0.481	0.116	0.067		
PR	0.328	0.128	0.251	0.458	0.279	0.168	
PU	0.103	0.087	0.237	0.149	0.089	0.238	0.134

Table 4. Discriminant Validity.

convergence validity measures whether the measurement items centrally reflect the constructs,all constructs' average variance extracted (AVE) was greater than 0.5[101]. Finally, utilizing Heterotrait-Monotrait ratio (HTMT) criteria, the discriminant validity was rigorously examined. As evident in Table 4, the HTMT values for all constructs remain significantly below the conservative threshold of 0.85[102], thereby indicating discriminant validity among the constructs. Collectively, the aforementioned results demonstrate that this study possesses strong internal consistency, as well as robust convergent and discriminant validity.

Assessment of the structural model

Each measurement item' variance inflation factor (VIF) is below the threshold value, indicating the issue of collinearity is not relevant in this study[103]. As exhibited in Table 5 and Fig. 2, PR had no significant effect on PI and AT, suggesting that H1a and H1b are not supported. Furthermore, PU had no relationship with PI, so H6b was rejected. However, the remaining paths were all supported, with AT (H2) having a significant effect on PI. PC (H3a) and UA (H4a) both indicated a positive connection with PR. UA (H4b), PEOU (H5a), and PU (H6a) all have a significant effect on AT. Moreover, the influence of PC (H3b) and PEOU (H5b) on PI is significant. Finally, this study also examined Stone-Geisser's Q^2 value, which serves as an indicator of the model's predictive

Hypothesis	Relationship	β	SE	T Statistics (|O/STDEV|)	p-values	Supported
H1a	PR → PI	0.061	0.052	1.068	0.236	NO
H1b	PR → AT	0.053	0.056	1.185	0.286	NO
H2	AT→ PI	0.397	0.045	8.823	0.000	YES
H3a	PC→ PR	0.396	0.049	8.031	0.000	YES
H3b	PC→ PI	-0.102	0.049	2.089	0.036	YES
H4a	UA→ PR	0.160	0.056	2.862	0.004	YES
H4b	UA→ AT	-0.125	0.061	2.045	0.041	YES
H5a	PEOU→ AT	0.181	0.049	3.295	0.001	YES
H5b	PEOU→ PI	0.133	0.055	0.886	0.004	YES
H6a	PU→ AT	0.200	0.045	4.454	0.000	YES
H6b	PU→ PI	0.068	0.047	1.440	0.150	NO

Table 5. Assessment of the structural model.

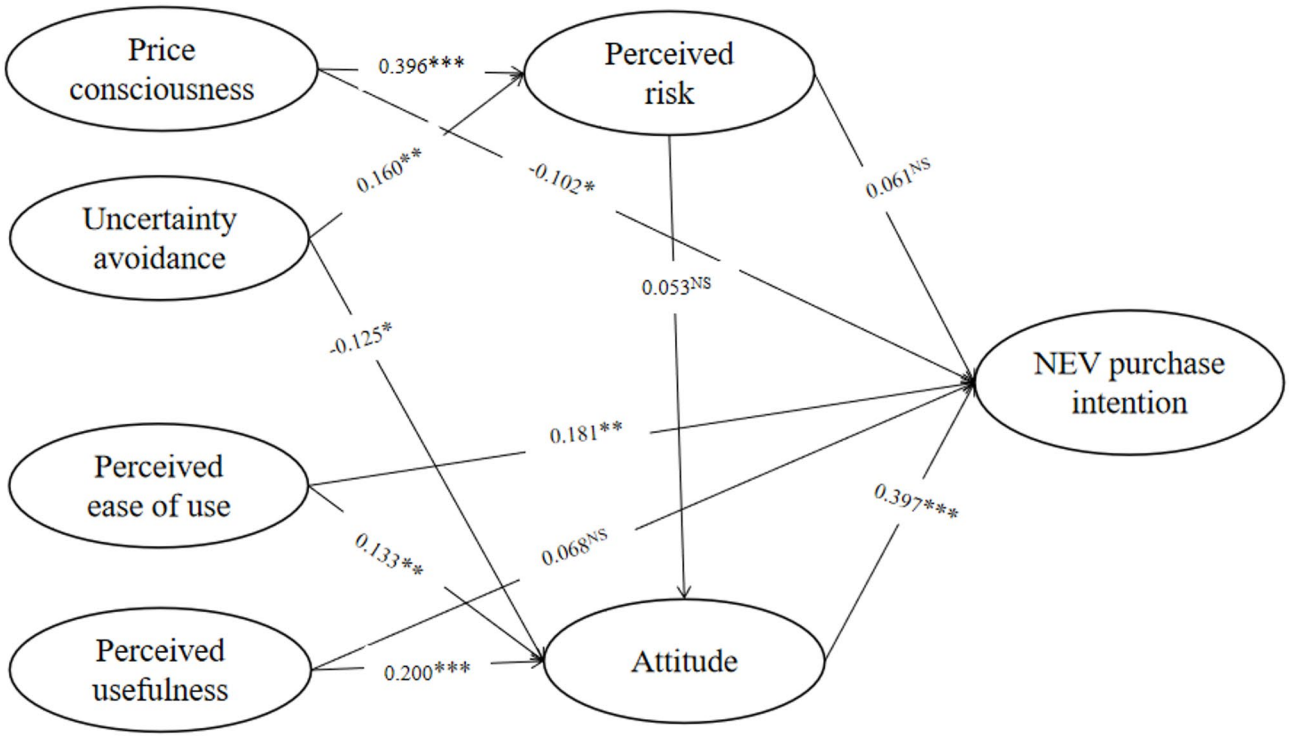

Fig. 2. Results of hypothesis testing.

relevance and measures its external validity[102]. The Q^2 values for AT (0.068), PR (0.174), and PI (0.181) were above zero, indicating this model predictive relevance.

The moderating effect of environmental awareness

As exhibited in Table 6, PLS-SEM results demonstrated that EA does not moderate the relationship between AT, PR, PC, PU and PI, thus H7a-H7d are rejected. However, EA moderates the connection between PEOU and PI, suggesting that H7e is supported.

Fuzzy set qualitative comparative analysis (fsQCA)

Through causal analysis, PLS-SEM verifies the overall impact and importance of independent variables on dependent variables, yet it lacks the capability to ascertain which variables are sufficient or necessary for a specific result. FsQCA is a powerful method based on fuzzy-set and configuration to check how different combinations of factors affect the results[104]. Moreover, fsQCA has advantages in dealing with complex causal relationships, especially causal asymmetry. FsQCA combines qualitative and quantitative assessments by "focusing on the complex and asymmetric relations between the outcome of interest and its antecedents"[105]. The model developed in this study contains both mediator variables (PR and AT) and moderator variable (EA). Therefore, it is necessary to determine which variables can be analyzed by Necessary Condition Analysis (NCA).

Hypothesis	Path	Path coefficients	SE	T statistics	p-values	Remarks
H7a	AT*EA → PI	-0.030	0.054	0.555	0.579	NO
H7b	PR*EA → PI	-0.052	0.054	0.955	0.340	NO
H7c	PC*EA → PI	0.038	0.055	0.682	0.496	NO
H7d	PU*EA→ PI	0.013	0.046	0.286	0.775	NO
H7e	PEOU*EA→ PI	0.127	0.050	2.514	0.012	YES

Table 6. Moderating effect.

	Outcome variable: PI		Outcome variable: ~ PI	
Conditions tested	Consistency	Coverage	Consistency	Coverage
AT	0.8398	0.8405	0.7222	0.7007
~ AT	0.7010	0.7225	0.8356	0.8349
PC	0.8093	0.8051	0.7740	0.7465
~ PC	0.7452	0.7728	0.7979	0.8022
PEOU	0.7979	0.8066	0.7355	0.7208
~ PEOU	0.7238	0.7384	0.8027	0.7938
PR	0.7726	0.7711	0.7651	0.7403
~ PR	0.7398	0.7646	0.7635	0.7650
PU	0.7935	0.7994	0.7387	0.7214
~ PU	0.7235	0.7407	0.7946	0.7886

Table 7. Analysis of necessary conditions.

According to the study of Sharma et al.[106], mediator variables and moderator variable have different ways of influencing the relationship between independent variables and dependent variables. NCA analysis can include mediator variable, but it is not appropriate to include moderator variable.

FsQCA analysis encompasses three stages: data calibration, necessity and sufficient conditions, and the construction of a truth table[105,107]. The first step in fsQCA is data calibration, where the raw data is transformed into a fuzzy set that represents whether a given scenario belongs to the set or not. We extracted latent variable scores from the running results of the PLS algorithm[108] and imported them into fsQCA software for direct calibration. The next step is to analyze the necessity of a single condition, and the consistency and coverage level of each anthem of the result variable can be obtained. There is a commonly held belief that It is generally believed that when the consistency level of the antecedent condition is higher than the threshold value of 0.9, the condition is considered necessary for the emergence of the outcome. As can be seen from Table 7, all variables possess a consistency value beneath 0.9, suggesting that none of the preceding variables serve as an indispensable prerequisite for the resulting outcome[109].

The final step in fsQCA is to obtain a variety of combined solutions for the predictive outcome. According to the suggestion of Ragin[107], if there are large-scale samples (>150), a higher frequency cut-off point should be established based on previous experience[110], we set the frequency cut-off point to 4 and the consistency level to 0.85. Subsequently, the truth table and configuration solutions were built. Configuration solutions include parsimonious, complex, and intermediate ones. The main difference is the treatment of logic residual terms[111]. Ragin[107] believed that both the parsimonious solution and the intermediate solution encompass the fundamental condition analysis, while only the intermediate solution provides the peripheral condition analysis. The intermediate solution can prevent the necessary conditions from being simplified and is extensively employed in qualitative analysis[109]. Therefore, based on the results of the intermediate solution, this study obtains four configuration solutions for predicting the adoption of NEVs. Table 8 reveals that the overall consistency of the solution stands at 0.8895, indicating that the configuration solutions provide a high prediction of the outcome.

The four configurations that can enhance NEV adoption intentions can be categorized into two types, one of which is oriented toward low price consciousness and low perceived risk type (S1 and S3). When consumers exhibit a low level of price sensitivity, their purchase decisions are less constrained by the relatively high premiums associated with battery technologies in NEVs. Instead, these consumers tend to place greater emphasis on the environmental attributes and driving experience of NEVs. A low perception of risk, on the other hand, reduces consumers' subjective assessment of potential risks pertaining to NEVs, such as technological uncertainties, battery lifespan and product safety, thereby mitigating their risk aversion stemming from information asymmetry and the innovative nature of this product category. The other category is characterized by low uncertainty avoidance, low perceived risk and a positive attitude (S2 and S4). Consumers with low uncertainty avoidance demonstrate a higher level of acceptance of the uncertainties associated with new technologies, and thus do not exhibit avoidance tendencies due to the technological and usage uncertainties of NEVs. A favorable attitude reduces the trade-off deliberation in the decision-making process and perceived risk, which ultimately drives purchase intention.

Variables	High NEV purchase intention			
	S1	S2	S3	S4
PC	⊗		⊗	
UA		⊗	×	⊗
PU		·	●	
PEOU	×			·
PR	⊗	⊗	⊗	⊗
AT	·	●		●
Raw coverage	0.5383	0.5368	0.5433	0.5604
Unique coverage	0.0049	0.0160	0.0069	0.0058
Consistency	0.9237	0.9271	0.8775	0.9031
Solution coverage	0.8895			
Solution consistency	0.7931			

Table 8. Configurations that lead to high NEV purchase intention. ●indicates the existence of the core condition; · indicates the existence of the auxiliary condition; ⊗indicates the absence of the core condition; × indicates the absence of the auxiliary condition.

Discussion

This study uses PLS-SEM-fsQCA to explain how perceived risk, attitude, price consciousness, uncertainty avoidance, perceived usefulness, and perceived ease of use affect consumers' NEVs purchase intention. Moreover, this study also delved into the moderating impact of environmental awareness. The PLS-SEM results reveal that price consciousness exerts a negative influence on the NEVs purchase intention, whereas perceived ease of use and attitude towards NEVs foster a positive correlation with purchase intention. Furthermore, uncertainty avoidance indirectly influences NEVs purchase intention through its direct relationship with attitude. fsQCA results enrich the multiple configurations of variables that lead to high NEVs purchase intention, which complements the single-variable impact analysis of PLS-SEM.

Similar to previous studies, attitude exhibits a positive and highly significant correlation with the intention to purchase NEVs, which has been proven by PLS-SEM and fsQCA. This indicates that a positive attitude is the main driving force for consumers to purchase NEVs[5]. Some consumers reject technological innovation or hold a skeptical attitude towards the safety of NEVs,they are reluctant to focus on NEVs. PLS-SEM result shows that perceived risk has no meaningful relationship with NEVs purchase intention and attitude, but consistent with the studies of Vafaei-Zadeh et al.[61] and Choo et al.[112]. Interestingly, fsQCA reveal that perceived risk is not neglective for high purchase intention. This indicates that perceived risk is not a universal factor in predicting intentions, but rather a contingent factor. Its influence on purchase intentions depends on low uncertainty avoidance and attitude. In addition, consumers' perceived risk is frequently linked to their knowledge of the product and trust[32]. China's NEVs have made significant achievements in technological innovation, greatly enhancing consumers' trust and quality perception of NEVs. Recent years, the government has augmented its investment in the construction of NEV charging facilities and carried out publicity activities for NEVs through various channels, filling the gap in consumer knowledge of NEVs. These activities have weakened consumers' risk perception.

Furthermore, the findings of PLS-SEM and fsQCA both suggest that price consciousness negatively influences NEVs purchase intention, which aligns with the findings reported by Cui et al.[42]. Price is the biggest obstacle for consumers to choose NEVs, making it difficult for consumers to afford. In addition, price consciousness was found to be positively correlated with perceived risk. This is due to the fact that price consciousness increases consumers' financial risk[113], and consumers are concerned about the returns on their investments. The results also show that uncertainty avoidance positively influences perceived risk and is negatively related to attitude. Confucianism makes people tend to avoid uncertainty and avoid the risk of loss caused by uncertainty[114].

The PLS-SEM result is consistent with the findings of fsQCA, demonstrating that attitude and intention to purchase NEVs are positively impacted by perceived ease of use . In other words, consumers are more inclined to trust NEVs, develop a positive attitude, and exhibit purchase intention when they perceive the usage process of NEVs as simple and convenient. However, it was discovered that there was no direct but indirect correlation between perceived usefulness and intention to purchase NEVs. which is consistent with the research of Nuralam et al.[115]. One factor that consumers take into account when purchasing NEVs is their environmental attributes[86]. However, many scholars doubt the environmental attributes of NEVs[52] and believe that the production and use of NEVs require huge resources. In addition, the primary function of a car is to meet the need for travel. At this level, the usefulness of fuel vehicles and NEVs does not differ significantly. Therefore, the perceived usefulness of NEVs is limited.

Implications

Theoretical implications

This study broadens the application of TAM theory in relation to NEVs purchase intention by integrating PLS-SEM and fsQCA. Contrary to the traditional theoretical conclusion, the PLS-SEM results indicate that neither perceived usefulness nor perceived risk exerts a statistically significant influence on consumers' intention to

purchase NEVs. However, fsQCA revealed perceived risk is necessary determining high purchase intention. The fsQCA results complement the PLS-SEM findings by overcoming its limitation of examining variables in isolation. The result of this study resonate with the call for adopting multiple analytical methods advocated by Sheng et al.[116].

This study innovatively explores the indirect impact of uncertainty avoidance of Chinese traditional cultural values on NEVs purchase intention. By incorporating uncertainty avoidance, the research framework can more comprehensively consider the effect of cultural factors on users' technology acceptance behavior, so that the research conclusions have stronger cross-cultural applicability. In addition, the moderating influence of environmental awareness in the purchase of NEVs has also been deeply studied, which helps to more accurately grasp consumers' psychological mechanisms and decision-making processes when making purchase decisions and enriches the application of consumer behavior theory.

Practical implications

Our findings reveal that price consciousness detrimentally affects consumers' intention to purchase NEVs and correlates positively with their perceived risk. This underscores that price is a significant consideration for consumers when deciding on NEVs purchasing[42]. Consequently, the government can aid in reducing the cost of NEVs by offering subsidies or tax exemptions. Meanwhile, NEV manufacturers must carefully devise pricing strategies, focusing on utilizing technological advancements to lower costs and make their products more affordable. Given the significant correlation between perceived ease of use and purchase intention, we recommend that NEV manufacturers enhance consumers' opportunities to gain hands-on experience with NEVs. Manufacturers have refined the driving operation of NEVs, and consumers' purchase intention will be influenced if they find the operating system easy to navigate.

In addition, consumers frequently adopt a cautious attitude towards innovative products, refraining from purchasing them until uncertain conditions are resolved[117]. To address this, manufacturers should employ engaging strategies to dispel consumer doubts. This could involve offering comprehensive product information to enhance consumer understanding or introducing measures like extended warranty periods and warranty services to alleviate consumer concerns when considering the purchase of NEVs. Environmental awareness can, to some extent, moderate the intention to purchase NEVs. Public policy makers can promote the environmental contributions of NEVs through education and social media advertising, enhancing consumer environmental awareness and preference for NEVs.

Limitations and future directions

Although this study offers several noteworthy contributions, it nonetheless entails certain limitations that can offer valuable guidance for future studies. First, the influence of culture on consumer attitudes and behaviors is interesting. This study investigates the cultural value elements that affect Chinese consumers to adopt NEVs. Due to the differences in cultural values between the East and the West, the results of this study are not universally applicable. Moreover, as for the different development conditions of NEVs in different countries, there may be some technological and environmental factors in other countries that were not considered in this study. Subsequent studies may investigate how cultural variations affect consumers' intentions to purchase NEVs through a cross-country survey.

Second, new energy vehicles have environmental attributes, and consumers will weigh the price of NEVs against their own environmental values. This study examined the influence of price consciousness on purchase intention of NEVs, but it did not fully demonstrate the psychological balance between environmental consciousness and price consciousness among consumers. In future research, further analysis will be conducted on the influence of consumers' environmental awareness and values on the adoption of NEVs.

Data availability

The data are available upon reasonable request; further inquiries may be directed to the corresponding authors.

Appendix I: Measurement items

Constructs	Code	Items	Source
Purchase intention	PI	1. In contrast to conventional cars, I would rather drive new energy vehicles (NEVs)	Chen et al.[55]
		2. When I buy my next car, I will prioritize purchasing a NEV	
		3. I like to suggest to friends that they purchase NEVs	
Perceived risk	PR	1. I'm worried that using NEVs may result in financial losses	Jain et al.[91]
		2. I wouldn't feel completely secure driving a NEV on the road	
		3. Given the drawbacks of NEVs (such as their short driving range and lengthy recharge times), I believe utilising NEVs may result in significant time losses	
		4. I worry about whether NEVs will really perform as well as traditional gasoline vehicles	
Attitude	AT	1. New energy vehicles are appealing to me	Jaiswal et al.[87]
		2. I think it's a good idea to drive NEVs	
		3. Choosing to drive a new energy vehicle is something I feel good about	
Price consciousness	PC	1. When making a purchase, I always take the cost of NEVs into account	Cui et al.[42]
		2. I believe the cost of NEVs is too expensive for me to purchase	
		3. Until NEVs become more affordable, I will stick to purchasing regular goods	

Constructs	Code	Items	Source
Uncertainty avoidance	UA	1. I believe it is critical to have clear instructions so that I always understand what is expected of me	Rosillo-Díaz et al.[83]
		2. I believe it's critical to pay great attention to directions and protocols	
		3. I believe that laws and norms are crucial because they let me know what is expected of me	
		4. Standardised work processes, in my opinion, are beneficial	
		5. I consider operating instructions to be crucial	
Perceived usefulness	PU	1. NEVs can help with the energy crisis by reducing carbon emissions	Wang et al.[39]
		2. NEVs can help cut down on transportation costs	
		3. The quality of life and traffic efficiency are enhanced by NEVs	
Perceived ease of use	PEOU	1. NEV is useful to reduce carbon emissions and alleviate the energy shortage problems	Vafaei-Zadeh et al.[5]
		2. Having a NEV helps my family spend less on commuting	
		3. I can live better and travel more efficiently with a NEV	
Environmental awareness	EA	1. I think taking a traditional fuel vehicles will damage the environment	Wang et al.[67]
		2. I think taking a traditional petrol car will damage the environment	
		3. If my driving style contributes to environmental pollution, I'm willing to make a change	
		4. I believe that taking positive action for the environment is my obligation	

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Author contributions

Yan-yan Zhang contributed to conceptualization, data collection, software development, theoretical model development, and writing the original draft. Wen-jie Li contributed to conceptualization and proofreading. Tat-Huei Cham contributed to proofreading and editing.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

This study was approved by the Research Ethics Committee of the School of Economics at Shandong Women's University (Study No. 2025-06-05) and was conducted in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

All individuals who participated in the study were provided with a statement of informed consent. The informed consent clearly explained their rights as research participants.

Additional information

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