

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Journal of Business Research

journal homepage: www.elsevier.com/locate/jbusres

Can sustainable technology features of products stimulate market performance? The perspective of consumer engagement in climate change[☆]

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ARTICLE INFO

Keywords:

Electric vehicles (EVs)
Consumer engagement
Climate change, market performance
Signaling theory, automobile features

ABSTRACT

Climate change has accelerated the adoption of electric vehicles (EVs). However, it remains unclear how EVs shape consumers' climate engagement and market performance. This study uses signaling theory to examine how driving range, a key sustainability signal, influences climate engagement under varying price levels and manufacturer types, and how this, in turn, affects market performance. Drawing on 67,757 EV model-year observations from the Chinese market (2018–2022), it combines emotional analysis of consumer reviews with hierarchical regression models. The findings show that driving range enhances climate engagement, especially for higher-price models and non-domestic manufacturers, which strengthens signal credibility. In turn, climate engagement boosts sales performance and partially mediates the range-sales relationship. Theoretically, the study extends signaling theory to sustainability and clarifies the boundary conditions of effective signals. Methodologically, it introduces a novel measure of climate engagement and practical insights for manufacturers to enhance consumer engagement and market performance in emerging markets.

1. Introduction

Climate change is reshaping the global industrial landscape on an unprecedented scale and has been a main discussion in global forums, businesses, and governments (Schill & Fosse-Gomez, 2025). The green transformation of the transportation sector is particularly urgent as it accounts for 27% of global greenhouse gas emissions (IEA, 2023). As the world's largest emitter of greenhouse gases, China faces particularly significant environmental risks (Liu et al., 2018; Luo et al., 2025). To address the increasing environmental challenges and achieve carbon neutrality, governments worldwide are actively promoting the use of electric vehicles (EVs) (Ren, 2018; Singh et al., 2024). Paiho et al. (2018) define EVs as “any vehicle in which some or all of the driving energy is supplied through electricity from a battery” (p.515). The widespread adoption of EVs is an effective way to reduce air pollutant emissions (Wang et al., 2020) and drive environmental change (Cuma & Koroglu, 2015). Many scholars also argue that EVs are a positive and effective way to save energy and reduce emissions (Poullikkas, 2015;

Raslavičius et al., 2015; Speidel & Bräunl, 2014). Therefore, EVs have gradually become a strategically sustainable industry, especially in emerging countries such as China (Zhu et al., 2026; Guo & Zou, 2025; Yang et al., 2021). It is worth noting that China's EV industry is at the heart of this transformation as Chinese EV sales surged between 2020 and 2023 and it is now the world's largest automotive market (Statista, 2024). This rapidly developing market presents both opportunities and challenges for understanding the environmental commitments associated with EVs and the mechanisms driving consumer adoption and market success.

However, this environmentally driven industrial revolution faces fundamental management and marketing challenges: how can EVs effectively communicate their environmental commitments to consumers and ultimately drive market success? While the promotion of EVs has significant environmental and social implications and is developing rapidly, most research in this field still focuses on the impact of policy regulation and frameworks (Dong & Liu, 2020; Wang et al., 2024), charging stations (Globisch et al., 2019), and the general characteristics

[☆] This article is part of a special issue entitled: ‘Climate Change Engagement’ published in Journal of Business Research.

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<https://doi.org/10.1016/j.jbusres.2026.116079>

Received 1 May 2024; Received in revised form 10 February 2026; Accepted 10 February 2026

Available online 19 February 2026

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of EVs and their technological advancements (LaMonaca & Ryan, 2022; Yuan et al., 2015) on their market performance. This singular research perspective creates a crucial research gap: how can the product characteristics of EVs serve as a market signal to effectively stimulate consumer climate engagement and thus influence their purchasing decisions (Aronson et al., 2025; Gupta, 2021)? Consumers consider environmental impact (Nagel et al., 2024; Wang et al., 2020) and acceptance of EVs (Zhao et al., 2024; Chhikara et al., 2021) in their purchasing decisions. Existing literature has failed to provide insights into how consumers influence their engagement with climate change mitigation by augmenting their awareness of EVs and, consequently, affecting EVs' sales performance (Secinaro et al., 2022; Wang et al., 2017).

Signaling theory provides a powerful explanation for examining this challenge. Signaling theory was originally conceptualized by Spence (1978) and further developed by Connelly et al. (2011). It explains how organizations communicate unobservable qualities to stakeholders through observable attributes (Liu et al., 2023). In the EV context, range serves as a costly and difficult-to-replicate signal of both technological capability and environmental commitment. The range is defined as the maximum distance that the vehicle can continue to travel after a single charge. Range can effectively show the quality and the greenness of the vehicle model (Su et al., 2020; Zhang & Qin, 2018) and is the primary environmental signal due to its unique saliency and direct interpretability (Malik et al., 2025; Wang & Mohamed, 2025). Range is an easily quantifiable metric that directly addresses a core consumer concern in EV adoption and unequivocally communicates a manufacturer's investment in battery technology and energy efficiency (Robbenolt et al., 2025). Unlike other features whose environmental implications might be indirect or require deeper consumer interpretation, an extended range immediately and clearly signals a vehicle's reduced reliance on fossil fuels and its enhanced capability for sustainable mobility which thereby serves as a potent and unambiguous indicator of environmental commitment (Singh et al., 2020). This direct link makes the range a particularly effective and measurable signal for this empirical investigation.

In addition, the boundary conditions affecting signal effectiveness and their subsequent impact on market performance have not been adequately explored, especially in emerging markets where competition among domestic and foreign manufacturers is fierce. Therefore, this study aims to explore two additional research questions. The first research question is: what boundary conditions (price and manufacturer type) affect the relationship between EVs' technical features, specifically range, and consumers' climate engagement? This question extends signaling theory into sustainable consumption contexts by not only examining how to foster consumer awareness but also to encourage them to actively seek environmentally protective options, thus increasing consumer confidence in the socio-environmental legitimacy of EVs. The question responds to recent calls for understanding contextual factors in consumer engagement (Chuah et al., 2020; Pucci et al., 2020; Smith et al., 2022) and addresses the complex interplay between technical features, brand characteristics, environmental consciousness, and ultimately enhances sales performance.

The second research question asks: how does consumers' climate engagement subsequently impact EVs' market performance? This question addresses the definitive link between environmental engagement and purchase behavior, helping resolve the persistent attitude-behavior gap in sustainable consumption (ElHaffar et al., 2020). Despite rising environmental consciousness, the translation of engagement into purchase behavior remains poorly understood (Saari et al., 2021).

Based on signaling theory, this study uses a unique dataset of EVs model-year observations from the Chinese market (2018–2022) to answer and test the three research questions mentioned above. This research contributes to both theoretical knowledge and practical insights into EVs' sustainable market development. On a theoretical level, this study constructs technological attributes (range) as a key

environmental commitment signal thereby expanding the application of signaling theory in the field of sustainable consumption and revealing the important moderating role of price and brand country of origin in the effectiveness of this signal. This study contributes to the literature on marketing and sustainability by further investigating consumer climate engagement and its impact on corporate market performance. On a practical level, the findings of this study provide empirically based decision-making references for EV manufacturers in formulating product and marketing strategies and for policymakers in designing differentiated incentive programs. Finally, this study provides an integrated analytical framework for understanding how technological characteristics drive the market performance of sustainable products by influencing consumer environmental engagement in highly competitive and emerging markets.

2. Theoretical background and hypotheses development

2.1. Signaling theory and consumer engagement

Signaling theory occupies an important position in the field of organizational strategic management (Connelly et al., 2011). Generally, the sender of a signal can choose whether and how to deliver (or signal) information while, at the same time, the receiver needs to choose how to interpret the signal. Spence (1978) proposed signaling theory mainly using the labor market. Job seekers send information about their qualifications to employers, by sending their educational level, because candidates with low qualifications may not be able to withstand the rigors of higher education. Similarly, manufacturers that need initial public offerings (IPOs) will recruit reputable directors to convey a legitimacy signal to potential investors that they are worthy of trust and investment (Certo, 2003; Filatotchev & Bishop, 2002). Therefore, in this study the range of EVs was used as a legitimacy signal. The authors believe that the level of the EVs' range can reflect environmental friendliness and the transmission of this signal can reduce information asymmetry between firms and consumers (Spence, 2002). Thus increasing consumers' cognition of the environmental sustainability of EVs and increasing consumers' searches for environmental protection. This will also increase consumers' climate engagement.

Meanwhile, consumer engagement has gradually received a lot of attention from scholars in different fields (Hollebeek et al., 2019). Many studies have shown that consumer engagement is one of the most important factors influencing firm development (Kumar & Pansari, 2016; Kumar et al., 2019; Verhoef et al., 2010). Some scholars have broadly defined consumer engagement as consumers' cognition, emotions, and behaviors towards a certain brand (Bazi et al., 2023; Calder et al., 2009; Rubin et al., 2022) which includes different interactions or involvement with a product or service (Brodie et al., 2011) such as searching, commenting, and sharing (Chevalier & Mayzlin, 2006; Feng et al., 2020). Therefore, consumers' contribution value to a firm does not only exist in buying behaviors but in consumers' non-purchasing behaviors as well (Kumar & Reinartz, 2016). Furthermore, consumer engagement can be categorized into social and non-social indicators (Ding et al., 2017). Therefore, the emotional attitudes of consumers' comments and the Baidu index of information searches were used in this study (public searches on environmental protection) and represent consumers' climate change.

2.2. Electric vehicles' range and consumer engagement

EVs aim to reduce reliance on traditional fossil fuels and mitigate environmental impact (Su et al., 2021). Consumers' perceptions of their efficacy in addressing environmental concerns are pivotal in shaping their environmentally conscious behavior (Ellen et al., 1991). White et al. (2019) suggests that when the message or context makes use of psychological factors (social influence, habit formation, individual self, feelings, cognition, and tangibility) consumers are more likely to engage

in pro-environmental behaviors. Modern technology and energy-saving measures, two aspects that are consistent with sustainable development objectives, have expanded the driving range of EVs (Anfinson et al., 2019; He et al., 2022). Consumers are becoming more aware of the environmental advantages of electric vehicles as manufacturers and other stakeholders highlight the extended driving range of these vehicles in their advertising campaigns and specifications (Asif et al., 2021; Ziegler & Abdelkafi, 2022). This greater comprehension not only educates consumers about the sustainable characteristics of EVs but also fosters their enthusiasm for environmental preservation initiatives (Liu et al., 2022; Salari, 2022).

Thus, as the driving range of EVs increases, customers increasingly consider them as practical solutions to environmental problems which, in turn, encourages greater customer engagement in addressing climate issues. Increased awareness of the sustainability features of EVs may lead to customers becoming more knowledgeable and motivated to engage in environmental conservation initiatives. As a result, this creates a positive feedback loop that contributes to addressing climate change. Therefore, the expansion of EV ranges may resonate with consumers who prioritize environmental stewardship, prompting them to engage more actively in discussions and actions aimed at addressing climate change. Thus:

Hypothesis 1. The increase in the range of electric vehicles positively affects consumers' climate engagement.

2.3. The role of the price of electric vehicles

Price is often perceived by consumers as an indicator of product quality and performance (Wong et al., 2020). Higher-priced EVs are often associated with superior quality, advanced technology, and enhanced performance including extended driving range (Benzidia et al., 2021; Nykvist et al., 2019). As customers evaluate the trade-offs between price and features, they may attribute greater significance to the range of higher-priced EVs and perceive it as a reflection of superior environmental performance and sustainability. For instance, Tesla vehicles have been accepted in the market more quickly than other brands' vehicles due to Tesla's superior innovation, eco-friendliness, prestigious price, and strong brand associations (Long et al., 2019). A prestigious price can reflect high quality and environmental awareness (Berger, 2019); it increases the perceived signal of vehicle range in addressing climate-related issues (Lee et al., 2022). Qiao and Dowell (2022) found that the consumers' environmental responsibilities are reflected by the prestigious status and price of electric vehicles (EVs). Price plays a significant role in influencing consumer preferences not only in terms of product characteristics but also in relation to wider social and cultural aspects (Ishaq et al., 2021).

There is a relationship between consumption and environmental consciousness (Culiberg et al., 2022). Consumers are more inclined to be interested in climate-related issues when they are considering purchasing more expensive EVs as they believe that these vehicles are more effective in addressing environmental concerns. Consumers perceive the extended range of EVs as a valuable feature that aligns with their environmental values, leading to increased climate engagement and commitment to eco-friendly transportation solutions. Thus:

Hypothesis 2. The price of electric vehicles positively moderates the relationship between the range of electric vehicles and consumers' climate engagement.

2.4. The role of the electric vehicle manufacturer type

Customers' perceptions of countries of origin are influenced by factors such as perceptions of industrial capabilities (Fischer & Zeugner-Roth, 2017). Based on this, customers often relate foreign brands with superior quality, advanced technology, and exceptional performance (Kumar et al., 2009; Laforet & Chen, 2012; Samiee et al., 2020) whereas

domestic brands may be perceived as falling behind in terms of innovation and reliability (Jean et al., 2014; Zhou & Wu, 2010). According to Tarei et al. (2021) there are several shortcomings in locally produced EVs that may impact their environmental and technological performance and reduce the number of customers tempted by locally produced EVs. Foreign manufacturers are often seen as more proactive and dedicated to sustainability (Lartey et al., 2021) as they invest more in research and development to improve the environmental performance of their products (Awan et al., 2021). Domestic manufacturers' attempts to cut costs and sell at a lower price than foreign manufacturers have raised concerns about their environmental reputation. Kabongo (2019) found that larger domestic manufacturers report higher environmental concerns and lower environmental ratings.

Corporate responsibility and environmental stewardship shape consumers' behavior (Iglesias et al., 2019). Therefore, customers may be less likely to consider the extended range of domestically produced EVs as a significant factor compared to that of foreign-manufactured EVs, something which might lower customers' climate engagement as a result. Therefore, even when locally built EVs have equivalent or superior driving ranges they may face criticism for their technological and environmental shortcomings. Customers' confidence in the environmental benefits of locally manufactured EVs may decline because of this critique which, in turn, might lower their engagement with climate concerns. Hence:

Hypothesis 3. The domestic manufacturer of EVs negatively moderates the relationship between the range of EVs and customers' climate engagement.

2.5. Consumer engagement and electric vehicles' sales

Climate change is clearly changing consumers' spending (Sharma, 2021). Purchasing EVs is a behavioral step toward lowering greenhouse gas emissions and encouraging greener transportation alternatives (Kumar & Alok, 2020). Customers are seeking ways to reduce their emissions output and support sustainable practices as they become more aware of environmental issues (Longo et al., 2019). EV manufacturers have found a niche in consumers' changing values (Hamzah et al., 2022) as these vehicles are promoting ethical and sustainable consumption (Ali et al., 2019). Customers' changing value toward transportation is influenced by peer pressure and society which results in increases of EV sales (Vrain et al., 2022). This study proposes that consumers will keep buying EVs as these vehicles care about climate change and are powered by consumers' engagement with climate issues. Marketing initiatives emphasizing the ecological benefits of EVs, such as lower emissions and less reliance on fossil fuels, can enhance customers' engagement with climate change. As a result, these customers are more inclined to choose EVs over traditional fuel-consuming vehicles which therefore boosts EV sales. Thus:

Hypothesis 4. Consumers' engagement in environmental protection positively affects the sales of electric vehicles.

Overall, the conceptual framework was summarized in Fig. 1.

3. Methodology

3.1. Research Design: A Two-Step approach

This study employs a two-step analytical approach to examine the relationships between EV features, consumer engagement, and market performance. The first step investigates how EVs' driving range influences consumers' climate engagement under different boundary conditions (price and manufacturer type), testing Hypotheses 1–3. The second step establishes the empirical link between consumer engagement and market performance, testing Hypothesis 4. This sequential approach follows the logic of the Heckman Two-Step procedure

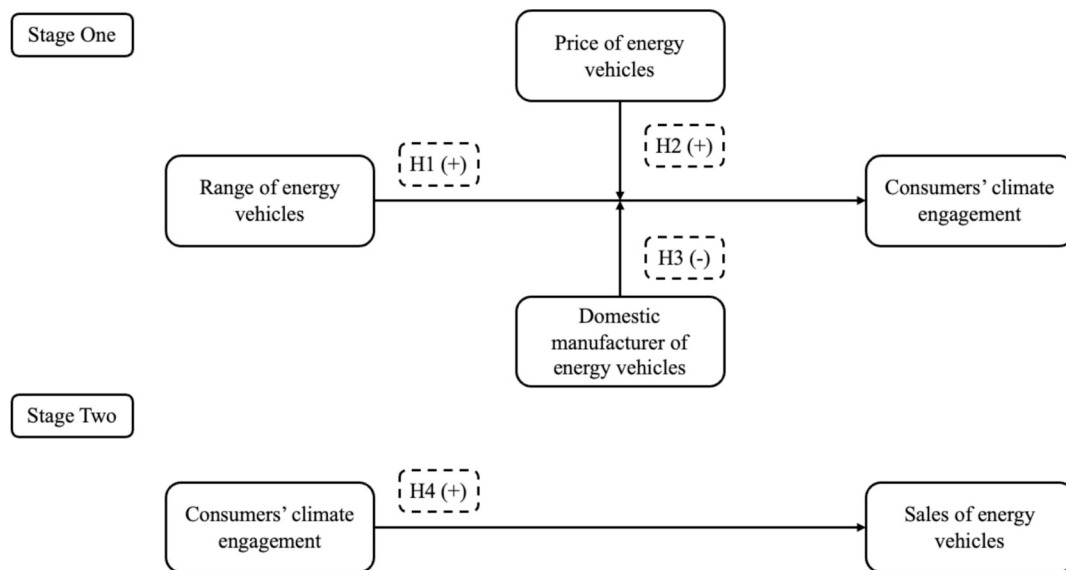


Fig. 1. Conceptual framework.

(Hamilton & Nickerson, 2003; Heckman, 1979) which is particularly valuable for addressing sample selection bias and endogeneity concerns in complex marketing phenomena. The Heckman approach is especially appropriate for our research context because consumer engagement data may not be randomly distributed across EV models and therefore may potentially lead to biased estimates of the relationship between engagement and sales performance. By implementing this procedure, the selection process (what drives consumer engagement) is first modeled before examining outcome effects (how engagement influences market performance) thereby obtaining more accurate and reliable parameter estimates (Germann et al., 2015). This methodological rigor allows a more precise identification of the mechanisms through which technical features translate into market outcomes through the mediating role of consumer engagement while also controlling potential self-selection issues that could otherwise threaten the validity of these findings. Next, the sample, data sources, and specific measurements used in each analytical stage were described.

3.2. Sample and data sources

To examine this study's hypotheses in observational data, the Chinese EV industry was selected to comprise the sample. China has become a global leader in the manufacture and sales of EVs (Dong & Liu, 2020). EVs are now a strategy initiative for the Chinese government to address the high level of air pollution (Liu et al., 2018; Zhang et al., 2020). A unique longitudinal dataset of Chinese EVs at product level from 2018 to 2022 was constructed. In 2018, China's Ministry of Industry and Information Technology officially released the measures for the parallel administration of the average fuel consumption and new energy vehicle points of passenger vehicle enterprises, penalizing manufacturers that fail to meet the standards while raising the purchase tax levied on non-EVs to 10 percent. As a result, 2018 began to witness a rapid growth in the sales of EVs in China, which was systematically different from sales in previous years. Thus, the year 2018 was chosen as the starting point for this study.

Multiple sources of data were collected to construct this dataset. Yearly city-level sales data for each EV model was obtained from the DaaS-Auto (<https://www.daas-auto.com>), a leading database that provides data services for the automotive industry (He & Zheng, 2024). All data regarding the technological characteristics and consumer engagement for each EV model were manually collected from Dongchedi (<https://www.dongchedi.com>), one of the most popular online automobile

websites in China (Zhao et al., 2024). Additionally, missing values were checked and verified through the EVs' official websites. After eliminating cases with missing values, a final sample of 67,757 observations was obtained.

3.3. Measurements

3.3.1. Consumers' climate engagement

Consumer climate engagement was treated as the dependent variable to evaluate Hypotheses 1–3 (Stage One) and the independent variable to test Hypothesis 4 (Stage Two). The emotional analysis of consumer reviews of products was used to measure this variable (Hollebeek, 2018; Wu, Duan, et al., 2023; Wu, He, et al., 2023). Specifically, the Python technique was first used to capture all review data from Dongchedi for all of the models used in the original sample. Only verified consumers are allowed to post reviews under the corresponding models on the Dongchedi website. Ultimately, 61,901 independent reviews that matched the sample period were captured. Second, previous studies (e.g., Li et al., 2024; Mu & He, 2024) were followed and a popular Chinese text sentiment analysis model named *Cemotion* was used to analyze the textual content of these reviews (<https://github.com/Cyberbolt/Cemotion>). The model employs the latest natural language processing (NLP) technique combining the BERT and the convolutional neural networks (CNN) method, enabling the system to understand the deeper meaning of the text and be able to judge the emotional preferences of each consumer review. It was determined to be positive or negative respectively (Wang et al., 2020; Zeng et al., 2015). Although the *Cemotion* model is pre-trained and publicly recognized, the authors further validated whether it had sufficient performance to process consumer reviews of these EV models. 1,000 reviews were randomly selected as the validation dataset and five graduate students with driver's licenses were recruited to form a coding team. They manually judged the positive or negative sentiment of each review based on its specific content and compared the results with those obtained from the *Cemotion* model training. The accuracy rate reached 92.3%, which is at a high acceptable level. Finally, the difference between the numbers of positive and negative comments of each model in each year was calculated and then transformed as the natural logarithm value because this variable is highly skewed. In addition, the natural logarithm of the number of only positive reviews was used as the alternative measure in the robustness check.

Moreover, the Baidu index and TikTok index were used to reflect the

cognitive dimension of engagement as it denotes consumers' active information-seeking and learning efforts about environmental protection and EVs' sustainable attributes. In line with [Hollebeek et al. \(2019\)](#), such knowledge sharing and learning processes are central to the cognitive component of customer engagement as the alternative measures to the key variable in the robustness tests. In recent years Baidu and TikTok have been China's most important internet web and video search engines respectively. According to Baidu's official website (index.baidu.com), the volume and frequency of consumer searches for specific keywords are weighted to produce the related Baidu Index ([Huang et al., 2017](#)) which is provided daily up to the prefecture-city level ranging from 1 to 100. The TikTok index takes a similar measure approach while covering a shorter period of time in comparison. Specifically, the Baidu index was developed earlier so it can effectively cover the sample time period of this study. However, since the TikTok Index has only been available since 2022, when using TikTok index as the alternative measure the robust regression analysis was actually only conducted based on the 2022 sample. Overall, the search volume for different keywords can be a good indicator of public attitudes and perceptions of an issue ([Li et al., 2021](#)) and, in general, the higher the value the higher the public's engagement with the keyword. More importantly, the public search for information is a manifestation of customer engagement ([Feng et al., 2020](#)). In practice, following previous studies ([Yu & Jin, 2022](#)), the term environmental protection ([Li et al., 2020](#)) was carefully selected as a keyword to capture the consumer engagement towards climate change and their concerns about the development of EVs ([Rivera, 2016; Shi & Guo, 2019](#)).

3.3.2. Market performance

Market performance was used as the dependent variable in Stage Two. Following previous studies ([Wang et al., 2021](#)) the variable was measured as the natural logarithm value of the number of vehicle sales. Specifically, sales of each EV model in each prefecture-city region in one year were captured.

3.3.3. Range

Range was used as the independent variable of Stage One. The range of an EV can not only effectively indicate the product quality and greenness of the model ([Su et al., 2020; Zhang & Qin, 2018](#)) but also determine whether it can satisfy the consumer's travel needs in daily life ([Su et al., 2020; Wang et al., 2017](#)). Since the ranges of EVs generally have large values (greater than 100), the natural logarithm transformation of the range officially disclosed by each EV model was used.

3.3.4. Price and manufacturer

The price and manufacturer of EVs were used as moderating variables in Stage One. Following the setting of [Bu et al. \(2022\)](#) this study used the manufacturer's suggested retail price (in tens of thousands of Chinese Yuan) in a given year to measure a EV's price. For the variable manufacturer it was found that the manufacturers of EVs can be divided into four types: (1) fully domestically produced; (2) joint ventures; (3) wholly foreign owned; and (4) imports. The latter three all have foreign elements in their manufacturers. Thus, in this study a dummy variable was set; it measured as 1 if the manufacturer of an EV model was domestic and 0 otherwise.

3.4. Control variables

Following the existing literature, a set of control variables were used to control for the potential influence of products on consumer engagement and their market performance. At vehicle level, scores were measured as the real consumer rating of each EV model which reflects consumer satisfaction with the products ([Zhao et al., 2023](#)). These data were manually collected from Dongchedi with each rating scored from 1 to 5, with 5 being the highest. The torque of EVs can affect the efficiency of the drivetrain which helps improve the performance and safety of the

vehicle ([Yuan & Wang, 2012](#)). The Torque of each EV model was measured as the real number of Newton-Meter (N.m) and transformed as the natural logarithm value. The length and height were also controlled to measure a model's size ([Bu et al., 2022](#)). In addition, the power and power consumption (horsepower-to-weight ratio) of EVs were controlled because these key technical indicators can affect the driving range of EVs and this is the focus of consumer attention for this category of products ([Bu et al., 2022](#)). Power was calculated as the ratio of a model's horsepower to weight and power consumption was measured as the kilowatt-hours (kWh) of electricity consumption per 100 km.

At regional level, the policy and charging station were added as control variables ([Hardman et al., 2018; Li et al., 2016; Sun, 2021; Zhang et al., 2018](#)). The policy was measured as a dummy variable; it equaled 1 if the vehicle model has received government subsidies and otherwise 0. The charging station was measured as the natural logarithm value of the number of charging stations in each province, sourced from the reports of the China Electric Vehicle Charging Infrastructure Promotion Alliance.

Year dummies, city-level regional dummies, fuel type dummies, and vehicle type dummies were also included to control for potential influence of various years, regions, and vehicle characteristics ([Cao et al., 2022; Zhao et al., 2024](#)). Specifically, fuel type dummies capture the types including extended range electric vehicles, fuel cell electric vehicles, and battery electric vehicles. Vehicle type dummies capture the types including mini/small/medium/large/executive/luxury sedans, small/medium/large/executive/luxury sport utility vehicles, medium/executive multi-purpose vehicles, and sports cars. [Table 1](#) provides the measurement, data sources, and literature support for all variables.

3.5. Estimation method

The sample used in this study has a panel-data structure and the dependent variables in both stages are continuous and normally distributed. The Hausman test was conducted to determine whether to use the fixed-effect or random-effect models and the results suggested the empirical superiority of random-effect models ($p > 0.05$). Thus, an ordinary least squares (OLS) regression with random effect is appropriate to test the hypotheses. Specifically, the final data for this study is an unbalanced panel dataset because not all manufacturers were observed in all years (due to the closure or delisting of some manufacturers) which may cause sample selection bias ([Tilcsik & Marquis, 2013](#)). The two-stage Heckman selection model was also conducted and no evidence of selection bias (reported in the Endogeneity check section) was found. In addition, to obtain the actual impact of the unstandardized coefficients on the dependent variable, which enhances the interpretability of the results, the variables were not standardized. The results were also reported using all standardized variables in the Appendix to further supplement the interaction effects and cross-variable comparisons and demonstrate the robustness of the results.

4. Results

4.1. Descriptive statistics and correlation

[Tables 2 and 3](#) provide the descriptive statistics and correlation matrix for all the explanatory variables for Stage One and Stage Two respectively. The results show that almost all correlations between the variables are less than 0.5. In addition, the variance inflation factors (VIFs) in [Appendix Table A](#) were calculated for all models and the maximum value of VIFs is 6.29 with a mean value of 2.76, both less than 10. Thus, multicollinearity is not a serious concern for this analysis in both stages.

4.2. Hypotheses results

[Table 4](#) reports the main regression results for Stage One, estimated

Table 1
Collection of measurements.

	Variable name	Hypothesis	Measurement	Sources	Reference
DV for Stage 1	Consumers' climate engagement	Hypotheses 1,2,3	1. The natural logarithm value of the difference between the numbers of positive and negative comments of each model in each year; 2 & 3. The volume and frequency of consumer searches for specific keywords on Baidu or TikTok	1. The DaaS-Auto (https://www.daas-auto.com); 2. Baidu website; 3. TikTok	Huang et al., 2017; Wang et al., 2020
IV for Stage 1	Range	Hypotheses 1,2,3	The natural logarithm value of the range officially disclosed by each EV model (KM)	Dongchedi App	Su et al., 2020; Wang et al., 2017
DV for Stage 2	Market performance	Hypothesis 4	The natural logarithm value of the number of EV sales of each model	The DaaS-Auto (https://www.daas-auto.com)	Wang et al., 2021
IV for Stage 2	Climate engagement	Hypothesis 4	The same as above		
MV for Stage 1	Price	All hypotheses	The price-to-range	Dongchedi App	Bu et al., 2022
	Manufacturer type		Measured as 1 if the manufacturer of an EV model was domestic and 0 otherwise	The DaaS-Auto (https://www.daas-auto.com)	
CV for Stages 1 & 2	Scores		The real consumer rating of each EV model scored from 1 to 5 with 5 being the highest	Dongchedi App	Yuan & Wang, 2012; Zhao et al., 2023
	Torque		The real number of Newton-Meter (N.m) and transformed as the natural logarithm value		
	Power		The ratio of a model's horsepower to weight		Bu et al., 2022
	Length		The real number of each EV model		
	Height		The real number of each EV model		
	Power consumption		The kilowatt-hours (kWh) of electricity consumption per 100 km		
	Policy		A dummy variable, equaled 1 if the vehicle model has received government subsidies and otherwise 0	The DaaS-Auto (https://www.daas-auto.com)	Hardman et al., 2018; Li et al., 2016; Sun, 2021; Zhang et al., 2018
	Charging station		The natural logarithm value of the number of charging stations in each province	The reports of the China Electric Vehicle Charging Infrastructure Promotion Alliance	

Table 2
Descriptive statistics and correlation matrix for Stage One.

Variables	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Consumer's climate engagement ^a	3.457	2.551	1.000											
(2) Range ^a	5.710	0.809	-0.194	1.000										
(3) Scores	3.718	0.278	0.314	0.017	1.000									
(4) Torque ^a	5.824	0.553	0.211	-0.024	0.850	1.000								
(5) Power	0.119	0.056	0.005	0.362	0.614	0.695	1.000							
(6) Length ^a	8.142	0.128	0.270	0.011	0.787	0.748	0.459	1.000						
(7) Height ^a	7.373	0.058	0.030	-0.092	0.269	0.241	0.047	0.072	1.000					
(8) Power consumption	14.516	3.182	0.158	-0.139	0.700	0.723	0.431	0.533	-0.488	1.000				
(9) Policy	0.713	0.452	-0.040	-0.004	-0.394	-0.421	-0.441	-0.175	-0.182	-0.433	1.000			
(10) Charging station ^a	10.515	1.126	0.010	0.007	0.077	0.045	0.027	0.037	0.062	0.059	-0.050	1.000		
(11) Price	26.260	20.668	0.147	0.034	0.617	0.584	0.581	0.436	0.088	0.503	-0.496	0.043	1.000	
(12) Manufacturer type	0.604	0.489	-0.388	0.189	-0.057	-0.012	0.133	0.079	0.084	0.026	0.098	0.045	-0.143	1.000

Note: N = 67,757; ^a denotes variables using natural logarithm value; correlations greater than |0.01| are significant at 0.05.

Table 3
Descriptive statistics and correlation matrix for Stage Two.

Variables	Mean	S.D.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Market performance ^a	2.405	1.696	1.000											
(2) Consumers' climate engagement ^a	3.457	2.551	-0.085	1.000										
(3) Range ^a	5.710	0.809	0.080	-0.194	1.000									
(4) Price	26.260	20.668	-0.094	0.147	0.034	1.000								
(5) Manufacturer type	0.604	0.489	0.099	-0.388	0.189	-0.143	1.000							
(6) Scores	3.718	0.278	-0.170	0.314	0.017	0.617	-0.057	1.000						
(7) Torque ^a	5.824	0.553	-0.165	0.211	-0.024	0.584	-0.012	0.850	1.000					
(8) Power	0.119	0.056	-0.040	0.005	0.362	0.581	0.133	0.614	0.695	1.000				
(9) Length ^a	8.412	0.128	-0.160	0.270	0.011	0.436	0.079	0.787	0.748	0.459	1.000			
(10) Height ^a	7.373	0.058	-0.048	0.030	-0.092	0.088	0.084	0.269	0.241	0.047	0.072	1.000		
(11) Power consumption	14.516	3.182	-0.147	0.158	-0.139	0.503	0.026	0.700	0.723	0.431	0.533	0.488	1.000	
(12) Policy	0.713	0.452	-0.047	-0.040	-0.004	-0.496	0.098	-0.394	-0.421	-0.441	-0.175	-0.182	-0.433	1.000
(13) Charging station ^a	10.515	1.126	0.247	0.010	0.007	0.043	0.045	0.077	0.045	0.027	0.037	0.062	0.059	-0.050

Note: N = 67,757; ^a denotes variables using natural logarithm value; correlations greater than |0.01| are significant at 0.05.

Table 4
Main results for Stage One.

Variables	DV – Consumer’s climate engagement				
	Model 1	Model 2	Model 3	Model 4	Model 5
Scores	4.887*** (0.095)	4.848*** (0.095)	4.865*** (0.096)	2.604*** (0.094)	2.750*** (0.095)
Torque	-0.632*** (0.032)	-0.625*** (0.032)	-0.662*** (0.032)	-0.804*** (0.031)	-0.779*** (0.031)
Power	-0.486** (0.182)	-0.567** (0.183)	-0.552** (0.184)	0.980*** (0.178)	1.303*** (0.179)
Length	2.747*** (0.229)	2.646*** (0.229)	2.647*** (0.229)	6.062*** (0.222)	6.114*** (0.222)
Height	-4.355*** (0.405)	-4.422*** (0.405)	-4.294*** (0.410)	-1.059** (0.385)	-1.537*** (0.389)
Power consumption	0.000 (0.003)	-0.003 (0.003)	-0.006† (0.003)	0.009** (0.003)	0.010** (0.003)
Policy	-0.162*** (0.016)	-0.194*** (0.016)	-0.194*** (0.016)	-0.166*** (0.016)	-0.173*** (0.016)
Charging station	-0.028 (0.021)	-0.023 (0.021)	-0.024 (0.021)	-0.023 (0.020)	-0.022 (0.020)
Range (Test for H1)		0.095*** (0.013)	0.045** (0.015)	0.234*** (0.013)	0.200*** (0.015)
Price			0.015*** (0.002)		0.019*** (0.002)
Range × Price (Test for H2)			0.003*** (0.000)		0.002*** (0.000)
Manufacture type				2.463*** (0.137)	2.246*** (0.137)
Range × Manufacture type (Test for H3)				-0.749*** (0.024)	-0.721*** (0.024)
Constant	-4.868 (3.546)	-3.853 (3.547)	-4.324 (3.567)	-47.817*** (3.401)	-45.006*** (3.412)
R ²	0.246	0.252	0.252	0.275	0.275
Number of Obs.	67,757	67,757	67,757	67,757	67,757

Note: †p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001; year, city, fuel type, and vehicle type dummies are included in each model; standard errors are in parentheses.

by consumers’ climate engagement. Table 5 reports the main regression

Table 5
Main results for Stage Two.

Variables	DV – Market performance	
	Model 1	Model 2
Scores	-1.578*** (0.061)	-1.766*** (0.062)
Torque	-0.049† (0.026)	0.004 (0.026)
Power	0.930*** (0.187)	0.849*** (0.187)
Length	-0.527*** (0.153)	-0.806*** (0.153)
Height	1.404*** (0.239)	1.532*** (0.238)
Power consumption	-0.054*** (0.003)	-0.055*** (0.003)
Policy	-0.200*** (0.017)	-0.207*** (0.017)
Charging station	0.186*** (0.029)	0.186*** (0.029)
Price	-0.001* (0.000)	-0.001 (0.000)
Manufacture type	0.141*** (0.014)	0.228*** (0.015)
Range	-0.110*** (0.015)	-0.100*** (0.015)
Consumers’ climate engagement (Test for H4)		0.048*** (0.003)
Constant	1.137 (2.182)	2.837 (2.176)
R ²	0.374	0.376
Number of Obs.	67,757	67,757

Note: †p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001; year, city, fuel type, and vehicle type dummies are included in each model; standard errors are in parentheses.

results for Stage Two, estimated by sales. Specifically, model 1 in both tables includes only control variables. Model 2 in both tables adds the independent variable to test Hypotheses 1 and 4. Models 3–4 in Table 4 add the interaction terms between the independent variable and moderating variables to test Hypotheses 2 and 3 while Model 5 in Table 4 includes all the variables used in each stage.

Hypothesis 1 suggests that the range of EVs positively influences consumers’ climate engagement. As shown in Model 2 of Table 4, the coefficient of range is positive and significant at the 0.1% level ($\beta = 0.095; p < 0.001$), thus supporting Hypothesis 1.

Hypotheses 2 and 3 propose the moderating roles of the price and manufacturer type of EVs on the relationship between the range of EVs and consumers’ climate engagement. As shown in Model 3 of Table 4, the coefficient of the interaction term between range and price is positive and significant at the 0.1% level ($\beta = 0.003; p < 0.001$). This suggests that the EVs model with a higher price will promote consumers’ climate engagement which supports the positive moderating effect. As shown in Model 4 of Table 4, the coefficient of the interaction term between range and manufacturer type is negative and significant at the 0.1% level ($\beta = -0.749; p < 0.001$) which suggests that the domestic manufacturer of EVs, rather than foreign manufacturers, decreases consumers’ climate engagement. This supports the negative moderating effect.

Hypothesis 4 suggests that consumers’ climate engagement is positively associated with EV sales in the local market. As shown in Model 2 of Table 5, the coefficient of consumers’ climate engagement is positive and significant at the 0.1% level ($\beta = 0.048; p < 0.001$), supporting Hypothesis 4.

In addition, regression was performed again after standardizing all variables used across all models and the results, reported in Appendix B (Tables B1 and B2), remain the same and support all hypotheses.

4.3. Robustness results

To check whether the findings of this study were robust to different situations alternative measures were used for the key variable of consumers' climate engagement. Three types of measurements were used to check the robustness. First, the number of positive consumers' reviews of each model was used. The results are shown in Models 1–2 of Table 6. In addition, rather than using the number of consumers' reviews the Baidu index was used to reflect the public's concern and engagement. The robust results are shown in Models 3–4 of Table 6. Last, to avoid the Baidu index capturing consumers' climate engagement that is biased, the TikTok index was also used to replace the core variables to expand the scope of data collection for consumers' climate engagement. Multiple data sources better help to demonstrate the robustness of this study's results. The results are shown in Models 5–6 of Table 6. All of the robustness results remain consistent with those in Tables 4 and 5 thus indicating that the estimation results of this paper are robust using the alternative measures of key variables.

4.4. Endogeneity check

Although it was confirmed that EV range can influence consumer engagement (Stage 1) and that consumer engagement can boost EV sales (Stage 2), the sample for the study's final regression is based on the presence of models that are able to capture consumer engagement data. The observations that are not captured were not considered and therefore may potentially result in sample selection bias. To mitigate this potential endogeneity issue, the two-stage Heckman selection model (Quan et al., 2021) was employed. Specifically, in the first-stage panel the Probit model, estimated by the dummy variable to select EV models for which consumers' climate engagement exists, was used. Following previous studies (Zhang et al., 2016) an additional variable, average consumers' climate engagement, was added in the first stage and was measured as the average number of consumers' climate engagements in each EV manufacturer per year. This served as an instrumental variable.

Table 6
Robustness results using alternative measures on consumers' climate engagement.

Alternative measure	Positive comments		Baidu index		TikTok index	
	Stage One Model 1	Stage Two Model 2	Stage One Model 3	Stage Two Model 4	Stage One Model 5	Stage Two Model 6
Scores	4.500*** (0.106)	-1.752*** (0.061)	2.519 (3.267)	-2.230*** (0.071)	0.111 (0.077)	-3.116*** (0.101)
Torque	-0.554*** (0.034)	-0.009 (0.026)	0.745 (0.588)	0.164*** (0.030)	-0.091** (0.035)	0.442*** (0.045)
Power	-1.735*** (0.196)	1.041*** (0.185)	-1.193 (3.086)	-0.124 (0.215)	0.348 (0.273)	1.931*** (0.362)
Length	4.085*** (0.252)	-0.989*** (0.149)	18.127** (6.059)	1.191*** (0.212)	0.154 (0.217)	2.168*** (0.279)
Height	-3.785*** (0.458)	1.760*** (0.236)	-50.225*** (13.533)	5.578*** (0.330)	-2.185*** (0.351)	6.415*** (0.452)
Power consumption	-0.010** (0.004)	-0.055*** (0.003)	0.129* (0.061)	-0.066*** (0.003)	0.013*** (0.004)	-0.073*** (0.005)
Policy	-0.326*** (0.017)	-0.209*** (0.017)	-0.093 (0.268)	-0.141*** (0.019)	0.006 (0.025)	-0.302*** (0.036)
Charging station	-0.000 (0.022)	0.176*** (0.028)	10.761*** (0.218)	0.172*** (0.005)	0.362*** (0.005)	0.109*** (0.007)
Range	0.040** (0.013)	-0.089*** (0.015)	0.367† (0.202)	-0.242*** (0.016)	0.041* (0.017)	-0.308*** (0.022)
Price		-0.001 (0.000)		0.000 (0.001)		-0.009*** (0.001)
Manufacture type		0.213*** (0.015)		0.090 (0.074)		-0.162† (0.087)
Consumers' climate engagement		0.050*** (0.002)		0.011*** (0.000)		0.819*** (0.007)
Constant	-18.819*** (3.997)	2.711 (2.151)	207.440† (109.595)	-42.058*** (2.969)	20.662*** (3.080)	-59.876*** (3.953)
R ²	0.309	0.377	0.132	0.448	0.167	0.498
Number of Obs.	68,938	68,938	68,175	68,175	31,866	31,866

Note: †p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001; year, city, fuel type, and vehicle type dummies are included in each model; standard errors are in parentheses.

The Inverse Mills ratio was then calculated based on the first-stage model and then added as the control variable in the second-stage model to correct for the sample selection bias. Similar to the main estimation, the OLS regression with random effect was used in the second stage. The results of the two-stage models are reported in Models 1–3 of Table 7. According to the results, all the coefficients of the key independent variables are positive and significant which is similar to the main estimations of the study reported in Tables 4 and 5.

In addition, although a set of control variables were included some omitted variables fail to be controlled which results in potential endogeneity issues. To address this type of issue a propensity score matching (PSM) estimator, that matched observations receiving treatment (models with consumers' climate engagement) or not, was conducted. After matching, the value of Mean Bias ranged from 27.7 to 5.7 and the value of Med Bias ranged from 26.8 to 2.1 reflecting a good match effect. The results of the matched sample after using the PSM estimator are reported in Models 5–6 of Table 7. It suggests that all the coefficients of the key variables to test the hypotheses are robust to the main estimation results. Therefore, potential endogeneity issues are not a serious risk of interference in this study.

5. Discussion

Customer engagement is a strategic marketing tool to retain customer relationships. In recent years, climate and environmental problems have driven the huge development of EVs (Chen et al., 2019) and consumers' climate engagement is seen as an important bridge. The use of multiple studies helps to reveal the relationship among the range of EVs, consumers' climate engagement, and EV sales. This research offers a new generalization on the impact of vehicles range, price, and manufacturer's origin on customer engagement and, consequently, on the EVs sales based on longitudinal data.

The global transportation market has witnessed a major change to combat climate change and one of the most important driving factors in this change is the rise of EVs (Du et al., 2024). In order to develop and

Table 7
Endogeneity results using a two-stage Heckman selection model and PSM estimator.

Variables	Two-stage Heckman selection model			PSM estimator	
	First-stage Heckman Model 1	Stage One Model 2	Stage Two Model 3	Stage One Model 4	Stage Two Model 5
Scores	8.340*** (0.479)	4.133*** (0.078)	-0.219* (0.091)	4.493*** (0.133)	-0.013 (0.083)
Torque	-6.090*** (0.221)	-0.447*** (0.026)	-0.091** (0.030)	-0.603*** (0.046)	-0.174*** (0.035)
Power	21.823*** (1.430)	-3.623*** (0.155)	2.465*** (0.211)	-1.365*** (0.275)	-0.315 (0.252)
Length	11.029*** (0.889)	-9.277*** (0.260)	-0.708** (0.265)	1.123*** (0.325)	-2.391*** (0.189)
Height	17.308*** (1.845)	-12.888*** (0.274)	0.741* (0.302)	-4.391*** (0.528)	-0.499 [†] (0.289)
Power consumption	0.301*** (0.038)	-0.031*** (0.003)	-0.057*** (0.003)	-0.023*** (0.006)	-0.062*** (0.004)
Policy	2.434*** (0.148)	-0.215*** (0.015)	0.003 (0.020)	-0.218*** (0.024)	-0.122*** (0.023)
Charging station	-0.308*** (0.047)	-0.007 (0.022)	0.243*** (0.033)	-0.046 (0.030)	0.150*** (0.037)
Average consumers' climate engagement	27.828*** (0.482)				
Inverse Mills ratio		-0.147*** (0.007)	-0.219*** (0.009)		
Range		0.248*** (0.011)	-0.174*** (0.016)	0.045* (0.019)	-0.071*** (0.019)
Price			-0.006*** (0.001)		-0.002* (0.001)
Manufacture type			0.376*** (0.019)		0.424*** (0.019)
Consumers' climate engagement			0.086*** (0.006)		0.049*** (0.003)
Constant	-235.996*** (15.434)	164.077*** (2.928)	1.385 (3.167)	12.028* (4.711)	25.942*** (2.617)
R ²		0.379	0.405	0.109	0.360
Number of Obs.	68,938	47,672	47,672	42,368	42,368

Note: [†]p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001; year, city, fuel type, and vehicle type dummies are included in each model; standard errors are in parentheses.

maintain effective customer relationship strategies, it is essential to understand the factors that influence consumer engagement with EVs. Consumers are the driving force for market demand and growth in the automotive sector. In this study, the consumers' engagement with EVs is explained by signal theory and the impact on the firms' sales performance.

The study proved that consumers' engagement with EVs is largely influenced by EVs' range. This study expands Spence's (1978) framework to include sustainable transportation and suggests that the signals EVs send about manufacturers' commitment to environmental stewardship, in addition to the vehicles' intrinsic qualities, influence consumers' engagement with these vehicles. This confirms the importance of range as an important attribute affecting consumers' climate engagement which aligns with prior research that has shown how signals shape consumer perceptions and behaviors (Han et al., 2024; White et al., 2019). EVs' firms can reduce information asymmetry and increase consumers' engagement with climate-related issues by investing in extending the range of their vehicles. This signals their commitment to sustainability and technological innovation.

Price and the country of origin of the manufacturer are also two factors that significantly impact how consumers engage with EVs. Existing studies on conspicuous consumption and brand origin effects were utilized (Heine et al., 2019, Sahin & Nasir, 2021). When consumers pay more for an EV they usually get better quality, more features, and more performance, including a longer range. As consumers consider various EV models they may pay more attention to a longer range because they believe it indicates better environmental performance and sustainability. The results of this study corroborate the findings of Boukis et al. (2024) and Munten and Vanhamme (2023) who discovered that price is a proxy for a product's quality and environmental concern. This research also demonstrates that additional elements that

significantly impact customer participation include the kind of manufacturer and the cost of EVs. According to Sichtmann et al. (2019), buyers may choose domestically produced items, such as EVs, in markets where manufacturing is seen as a source of pride in the country and economic prosperity. In a similar vein, the place of manufacturing has a significant impact on how customers interact with EVs.

As consumers become more conscious of the impact of their activities on the environment they are seeking methods to reduce the negative consequences they have on the environment and change to more sustainable practitioners (Liu et al., 2022, Salari, 2022). EVs, which are viewed as greener choices than conventional automobiles, are becoming increasingly popular as a result of this shift in consumer preferences because buying an EV shows sustainability and responsible consumption (Ali et al., 2019). Consequently, there will be a surge in demand for EVs from environmentally conscious consumers who see them as meeting their environmental responsibilities.

5.1. Theoretical contributions

This study offers multiple theoretical contributions. First, signaling theory provides powerful insights for examining how strategic signaling can address information asymmetry between parties (Spence, 1978). This study's findings extend the signaling theory into the sustainable transportation context by illustrating how technical features serve as environmental signals. This research shows that the range of EVs is a specific message that EV manufacturers send to the public about their commitment to climate and environmental protection. EV manufacturers use this message to enhance consumers' interest and involvement in climate ultimately leading to improved market performance for EV manufacturers. Previous studies focused on how manufacturers signal through corporate governance (Connelly et al., 2025) or brand attitude

(Rahman et al., 2018). Second, this research looks beyond existing literature regarding the factors that influence the market performance of EVs, for example the availability of charging stations (Huang & Qian, 2018) or energy factors (Fetene et al., 2017). This research explains that price levels and manufacturer origin significantly moderate how driving brand influences customer climate engagement which illustrates that higher prices strengthen this relationship while domestic manufacturing weakens it. This new insight shows how technical factors share signal interpretation in the Chinese market which, in turn, advances the knowledge of when and how technical features effectively signal environmental legitimacy.

Third, there is a dearth of research on the impact of EVs on consumers' climate engagement. Limited research has empirically demonstrated its impact on sales performance. Previous studies explored consumer engagement through brand relationship lenses (Hollebeek et al., 2023), luxury brands (Bazi et al., 2023; Liu et al., 2021), and low involvement products (Żymkowska et al., 2023). Consumer engagement encompasses a range of behaviors spanning from seeking information and sharing knowledge to advocating and engaging in activism (Hollebeek et al., 2019). This research conducted the analysis of the significant stakeholder group of customers and enhanced the existing body of knowledge in the field of EVs and consumer engagement while previous literature has examined the influence of consumers' experience and perception using cross-sectional studies (surveys/interviews) (Bazi et al., 2020; Wang et al., 2020a).

Fourth, this study demonstrates the significance of taking into account various types of consumer engagement that go beyond conventional measurements such as brand equity (Zollo et al., 2020), purchase behavior, value creation (An and Han, 2020), brand loyalty and love (Bazi et al., 2023), brand trust (Kwon et al., 2021), community satisfaction, and relationship (Haverila et al., 2021) in assessing and evaluating the effect of sustainable transportation initiatives.

Fifth, by elucidating the nuanced ways in which consumers interact with and respond to environmental issues this study contributes to a more comprehensive understanding of the drivers of sustainable transportation adoption by leveraging the Baidu index of information searches as a proxy for non-socialized engagement with environmental topics. Rather than treating customer engagement as a multifaceted construct with cognitive, emotional, and behavioral dimensions, this study captures the depth and breadth of consumers' engagement with climate change issues. This study enriches this important mechanism. Finally, these results enrich research in the field of EVs in developing countries. The results and robustness tests of this research fully demonstrate that, in the field of EVs, high prices and imported vehicles may further enhance manufacturers' market performance.

5.2. Practical implications

This study offers valuable insights, guidelines, and practical implications for policymakers, EV manufacturers, marketers, and environmental organizations to promote the adoption and widespread use of electric vehicles. First, policymakers play a crucial role in creating an environment for the adoption of EVs. They can develop more targeted and proactive subsidy policies to encourage manufacturers to increase the range of EVs. It is worth emphasizing that policymakers should consider implementing differentiated policy support that accounts for the varying effectiveness of range signaling between domestic and international brands, potentially with additional support for domestic manufacturers to strengthen their environmental signaling. For consumers, policymakers can also develop incentive policies to promote consumer support for EVs, for example providing consumers with more behavioral incentives (such as parking discounts for EVs). In addition, policymakers should consider incentivizing the adoption of low-cost charging solutions to enhance consumer confidence in environmental engagement. Meanwhile, governments can conduct widespread public awareness campaigns about EVs to raise awareness of their

environmental advantages and emphasizing that a longer range promotes ecological sustainability.

Second, EV manufacturers can leverage these research findings to enhance their product development and marketing strategies. The findings suggest a strategic repositioning of long-range features. Manufacturers need to shift from a functional feature addressing range anxiety to a core signal of brand environmental excellence and technological leadership. Manufacturers should build a consistent marketing narrative around long-range features and explicitly link it to premium pricing strategies thereby allowing consumers to perceive the environmental value behind the green premium. Domestic brands, in particular, need to invest more resources in building credible green brand stories to compensate for their relative disadvantage in the effectiveness of their environmental messaging.

Third, the key advice for marketers lies in implementing differentiated signaling strategies. International brands should leverage their inherent perceived advantages by linking their range with environmental performance. Local brands, on the other hand, need to build green credibility through more transparent, technology-driven, and continuous educational communication. Furthermore, marketing professionals can associate high prices with superior environmental responsiveness (represented by long range) to reinforce consumers' perceived value and sense of environmental engagement.

Finally, this study recommends that environmental organizations mobilize public support for EVs by emphasizing the link between range and environmental impact and using this technological characteristic as a starting point for advocacy. They should also collaborate with EV manufacturers and policymakers to conduct educational campaigns to help consumers understand the environmental advantages of EVs. Environmental organizations can more effectively promote sustainable transportation by highlighting how these vehicles represent an important step towards a sustainable future.

6. Broader context of the research

The demonstration that range serves as both a functional attribute and an environmental signal challenges the conventional product development framework. This duality suggests technical specifications in sustainable products, from energy-efficient appliances to biodegradable packaging, could similarly communicate environmental commitment when designed intentionally. The study's application of signaling theory reveals how inherent product attributes reduce information asymmetry between producers and consumers, a mechanism applicable to any market where sustainability claims require verification. By establishing a causal pathway from technical features (signal transmission) to climate engagement (signal interpretation) to market performance (behavioral outcome), the research provides a replicable model for analyzing sustainable consumption patterns in sectors like renewable energy technologies or circular economy products.

Furthermore, a higher price amplifies the environmental signaling effect of technical features. This suggests luxury sustainable products, from organic textiles to carbon-neutral electronics, may benefit from positioning technical innovations as markers of both quality and ecological responsibility. In addition, the moderating role of manufacturer origin, where domestic brands face skepticism despite technical parity, highlights a global challenge for emerging economies.

7. Limitations and future research directions

This study has some limitations that can pave the way for future research. First, only China was chosen as the basic research context. While a single-country context can control the bias of results due to potential differences between countries in the empirical analysis it also tends to cause limited generalizability. This paper calls on future scholars to test the robustness of these results in other emerging economies and to conduct comparative studies on innovation strategies or

market performance in non-single regions for the electric vehicle industry (Qi et al., 2025; Xu et al., 2025). Second, this study used internet searches for environmental protection to measure consumers' climate engagement. While it has been demonstrated in the literature that such information searches can be identified as consumer engagement (Feng et al., 2020), this model might have been better explained if data could have been utilized directly from consumer interviews. Therefore, researchers are encouraged to use questionnaires or interviews to better illustrate the mechanism between consumers' climate engagement and EVs. In addition, the TikTok index used in this study as an alternative measure of this variable in the robustness check may introduce potential sample selection bias as it can only test the sample starting from 2022. This highlights the need for future research to enrich the data sources (e. g., Google Trends, YouTube, or X analytics) and measurement methods of this variable. Finally, with the development of artificial intelligence and digitalization, scholars could focus on the integration of ethical factors with EVs and the relationship between consumer behavior under the development of artificial intelligence (Shahzad et al., 2025).

CRedit authorship contribution statement

Yumeng Luo: Writing – review & editing, Writing – original draft,

Appendix A. – Variance inflation factors results

Table A1
Variance inflation factors results for two stages.

Stage One Variables	VIF value	Stage Two Variables	VIF value
Torque	6.14	Torque	6.29
Scores	5.12	Scores	5.93
Length	3.37	Length	3.65
Power	3.09	Power	3.54
Power consumption	2.99	Power consumption	3.09
Height	1.48	Range	2.12
Policy	1.46	Height	1.56
Range	1.45	Policy	1.55
Charging station	1.01	Consumer engagement	1.48
Mean VIF	2.90	Manufacture type	1.43
		Price	1.41
		Charging station	1.01
		Mean VIF	2.76

Appendix B. – Results using all standardized variables

Table B1
Additional results using all standardized variables for Stage One.

Variables	DV – Consumer's climate engagement				
	Model 1	Model 2	Model 3	Model 4	Model 5
Scores	0.571 ^{***} (0.011)	0.566 ^{**} (0.011)	0.568 ^{***} (0.011)	0.304 ^{***} (0.011)	0.321 ^{***} (0.011)
Torque	-0.156 ^{***} (0.008)	-0.155 ^{***} (0.008)	-0.163 ^{***} (0.008)	-0.199 ^{***} (0.008)	-0.192 ^{***} (0.008)
Power	-0.011 ^{**} (0.004)	-0.013 ^{**} (0.004)	-0.012 ^{**} (0.004)	0.022 ^{***} (0.004)	0.029 ^{***} (0.004)
Length	0.160 ^{***} (0.013)	0.154 ^{***} (0.013)	0.154 ^{***} (0.013)	0.354 ^{***} (0.013)	0.357 ^{***} (0.013)
Height	-0.112 ^{***} (0.010)	-0.114 ^{***} (0.010)	-0.111 ^{***} (0.011)	-0.027 ^{**} (0.010)	-0.040 ^{***} (0.010)
Power consumption	0.001	-0.005	-0.008 [†]	0.012 ^{**}	0.014 ^{**}

(continued on next page)

Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Saleh Bazi:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Shajara Ul-Durar:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Marco De Sisto:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Nadja Damij:** Writing – review & editing, Supervision, Project administration.

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.

Acknowledgment

The authors acknowledge the handling editor and reviewers for their valuable feedback.

Table B1 (continued)

Variables	DV – Consumer’s climate engagement				
	Model 1	Model 2	Model 3	Model 4	Model 5
Policy	(0.004) -0.028***	(0.005) -0.033***	(0.005) -0.033***	(0.004) -0.029***	(0.004) -0.030***
Charging station	(0.003) -0.014	(0.003) -0.011	(0.003) -0.012	(0.003) -0.011	(0.003) -0.011
Range (Test for H1)	(0.010)	0.033*** (0.004)	0.016** (0.005)	0.081*** (0.004)	0.070*** (0.005)
Price			0.006*** (0.001)		0.008*** (0.001)
Range × Price (Test for H2)			0.001*** (0.000)		0.001*** (0.000)
Manufacture type				1.003*** (0.056)	0.915*** (0.056)
Range × Manufacture type (Test for H3)				-0.833*** (0.026)	-0.802*** (0.027)
Constant	-1.197*** (0.176)	-1.171*** (0.176)	-1.169*** (0.176)	-1.793*** (0.171)	-1.632*** (0.171)
R ²	0.246	0.252	0.252	0.275	0.275
Number of Obs.	67,757	67,757	67,757	67,757	67,757

Note: †p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001; year, city, fuel type and, vehicle type dummies are included in each model; standard errors are in parentheses.

Table B2

Additional results using all standardized variables for Stage Two.

Variables	DV – Market performance	
	Model 1	Model 2
Scores	-0.282*** (0.011)	-0.316*** (0.011)
Torque	-0.019† (0.010)	0.001 (0.010)
Power	0.032*** (0.006)	0.029*** (0.006)
Length	-0.047*** (0.014)	-0.072*** (0.014)
Height	0.055*** (0.009)	0.060*** (0.009)
Power consumption	-0.112*** (0.006)	-0.115*** (0.006)
Policy	-0.053*** (0.004)	-0.054*** (0.004)
Charging station	0.139*** (0.021)	0.139*** (0.021)
Price	-0.001* (0.000)	-0.000 (0.000)
Manufacture type	0.088*** (0.009)	0.142*** (0.009)
Range	-0.059*** (0.008)	-0.053*** (0.008)
Consumers’ climate engagement (Test for H4)		0.074*** (0.004)
Constant	-0.536** (0.166)	-0.486* (0.166)
R ²	0.374	0.376
Number of Obs.	67,757	67,757

Note: †p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001; year, city, fuel type, and vehicle type dummies are included in each model; standard errors are in parentheses.

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