



Perceived value and adoption intention for electric vehicles in Korea: Moderating effects of environmental traits and government supports

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ABSTRACT

In response to concerns about rapid climate change and air pollution, electric vehicles (EVs) have been diffusing rapidly in some countries since the early 2010s. Many researchers have investigated the value attributes affecting consumers' attitudes to and behaviors around EVs. Little effort has been made, however, to identify the interacting factors in the relationship between perceived value and adoption. To fill this research gap, we examine the moderating effects of environmental traits and government supports on adoption intention. Using survey data collected from 285 drivers in Korea, we identify the significant impacts of perceived value as a predictor of consumers' intention to adopt EVs. Operational economic benefit and charging risk are revealed as the main motivators of and barriers to EV diffusion, respectively. We also find that environmental concern and financial incentives significantly enhance the effects of perceived value on adoption intention. The implications of these findings for the success of EV market diffusion are discussed.

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1. Introduction

Electric vehicles (EVs) have many advantages over internal combustion engine vehicles (ICEVs). For example, EVs are more economical in terms of fuel cost due to their excellent energy efficiency [1,2]. Since EVs have fewer parts, their maintenance and repair costs are also lower [1,3]. Further, EVs are environmentally friendly because they emit almost no greenhouse gases such as carbon dioxide [4–7]. They also tend to provide greater comfort, as they produce little vibration or noise [8,9].

However, EVs face many barriers to market expansion. New EVs are relatively expensive due to the lack of economies of scale [10]. The charging infrastructure is underdeveloped, and the one-charge driving range is not far enough to meet consumer expectations [10–12]. The charging time is long, and battery replacement cost is a heavy burden on consumers [13,14].

Many studies have investigated the multi-dimensional factors of

EVs and their relative importance, particularly their benefits and risks as value attributes affecting adoption intention (e.g., [8–10,12,14,15]). Consumers consider EVs' main value to be their economic benefits in terms of fuel economy and running costs (e.g., [1,13,16,17]), their emotional benefits related to driving pleasure (e.g., [8,9]), and the environmental benefits associated with carbon emissions reduction (e.g., [8,15,18]). The major barriers inhibiting adoption are perceived to be financial risks such as car price and battery exchange costs (e.g., [10,15,19,20]), performance risk concerning technological issues such as engine power, safety, and reliability (e.g., [14,21]), and risks concerning charging time and infrastructure availability (e.g., [10,14,15,17,19,21]).

Several studies have explored the moderating effects of personal traits such as personal innovativeness (e.g., [22,23]) and policy instruments such as government supports (e.g., [24]) on the relationship between value attributes and the adoption of some innovation artifacts. To the best of our knowledge, the literature has paid little attention to the interacting factors that amplify or mitigate the relationship between perceived value and adoption intention for EVs. The very few studies on this issue have produced inconsistent statistical results (e.g., [16,25]). The empirical analysis

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of the moderating effects of personal traits and policy instruments in EV adoption has significant theoretical and practical implications. It enables better understanding of the roles of endogenous psychological traits and external environmental factors in EV adoption, which can adopt eco-innovation in the energy and transportation sectors. In addition to strategic focus on these factors, it can also combine the motivators, and these factors as moderators to leverage EV adoption more efficiently.

To fill these research gaps, we first reviewed the literature on consumer attitudes to EVs and proposed a research model in order to examine the interaction relationships with four novel factors: environmental innovativeness and environmental concern as personal attitudes to the environment, and financial incentives and non-financial policies as government support characteristics. We then empirically assessed these factors' roles and relative importance as moderators by analyzing survey data collected from drivers in Korea. Finally, we presented a theoretical discussion to deepen our understanding of the relationships among consumer adoption factors and their practical implications for promoting the market proliferation of EVs.

2. Theoretical background and research hypotheses

2.1. EV market and policy status in Korea

Global climate change caused by greenhouse gases and technological evolution have become powerful drivers for the emergence and development of EVs. Global emissions of greenhouse gases are increasing every year, with transport accounting for 14% of the increase. The gas generated from automobiles accounts for 72% of transportation sector emissions [26]. In an attempt to cope with these global challenges, government policies on the environment have been strengthened through global cooperation. The EV market has also been growing rapidly in some countries since the early 2010s due to these challenges. The International Energy Agency [27] reports that the cumulative sales volume of global EVs had exceeded 2 million units by the end of 2016, after having exceeded 1 million units by 2015. However, EV market diffusion in Korea is lower than in Canada, China, some European countries, Japan, and the United States. Table 1 shows that the cumulative stocks of EVs in Korea totaled 11.21 thousand units, which was only 0.56% of the global market in 2016; EVs accounted for only 0.34% of newly registered vehicles, which was significantly lower than 1.10% of the global market [27].

To remedy the low market diffusion of EVs, Korea's central government and municipalities have expanded their financial incentives and non-financial policies to promote EV diffusion. As of 2017, 14 million KRW (about 12,900 USD) of the central government's subsidy and 3 to 12 million KRW (about 2,764 to 11,058 USD) of the local governments' subsidy are being provided for each battery EV within a certain amount (13,559 units; [28]). The Korean government has also made EVs exempt from sales taxes (up to 4.6 million KRW, about 4,240 USD) and consumption taxes. As of February 2017, 1,139 fast chargers and 1,387 normal chargers had been installed nationwide through the Korean government's direct

installation program and support policies designed to expand Korea's charging infrastructure [29]. In addition to the central government's fuel economy and emissions control regulations, policy measures such as exemptions from toll road charges and parking fee discounts are being implemented by some local governments [28].

2.2. Literature review on consumer adoption of EVs

Since EVs began being introduced and diffused in the early 2010s, many studies have been attempting to identify the values, benefits, and risks influencing EV market diffusion based on analyses of data collected from individuals, drivers, and experts [6,30]. Several researchers have decomposed the relevant values into sub-constructs in terms of consumer perceptions and have examined their relative influence on consumers' adoption attitudes and intentions. Han et al. [8] divided EV values into functional and non-functional attributes and identified the direct effects of monetary, performance, and convenience values (in the "functional value" category) on adoption intention for EVs in China.

Other researchers have examined value components involving specific or multi-dimensional benefits, such as consumers' beliefs or expectations about the positive outcomes of EVs. Schuitema et al. [9] found that instrumental attributes such as performance, practicality, and range; hedonic attributes such as pleasure of driving; and symbolic attributes such as driving pride affected the intention to adopt EVs in the United Kingdom. Economic benefits have been empirically analyzed as core determinants of adoption intention for EVs (e.g., [1,13,16,17]). Environmental and emotional benefits have also been found to be the preferred values for consumer acceptance of EVs (e.g., [16,18]).

Many other empirical approaches have shown that consumers perceive various risks as being barriers to predicting negative outcomes from adopting EVs. Egbue and Long [15] identified multiple risks affecting consumer acceptance of EVs in the United States from a socio-technical perspective. She et al. [14] also identified the negative effects of consumer-perceived risks in financial, vehicle performance, and infrastructure terms on public acceptances in China. Consumer-perceived financial risks such as vehicle price and battery exchange costs have been found to impede EV diffusion (e.g., [13,17,19,20]). Many studies on EVs have revealed that performance and infrastructure risks related to battery and charging are the main obstacles for consumers (e.g., [2,10–13,19,21]).

Information system and marketing studies have shown that personal traits and contextual factors moderate the relationship between value attributes and adoption. Personal innovativeness has been found to act as a moderator in the adoption process and in behavior concerning information technology artifacts (e.g., [22,23]). Government support has been found to positively moderate innovative technology adoption (e.g., [24]).

The approach to interaction effects is rarely seen in studies on EV acceptance. Many studies on EV adoption have revealed the direct effects of personal traits such as innovativeness, environmental beliefs, and attitudes (e.g., [15,31–33]) as well as

Table 1
Korean and global EV market trends.

Division		2011	2012	2013	2014	2015	2016
Cumulative sales volume (unit: thousands)	Korea	0.34	0.85	1.45	2.76	5.95	11.21
	Global	64.58	182.64	388.07	715.39	1262.61	2014.22
Market share among newly registered cars	Korea	0.02%	0.04%	0.05%	0.09%	0.21%	0.34%
	Global	0.10%	0.23%	0.38%	0.54%	0.85%	1.10%

Source: IEA [27].

government incentives and regulations on the diffusion of EVs (e.g., [2,12,34–37]. To the best of our knowledge, the moderating effects of extrinsic characteristics such as policy instruments have hardly been examined in the context of EVs, except for a few previous studies (e.g., [16,25]. In particular, there is little or no research on the moderating effects of personal traits on the environment on EV adoption.

2.3. Research model and hypotheses

Our review of studies on EV adoption indicates that the research has paid little attention to the factors moderating the relationship between value and adoption. This study addresses this gap by examining the moderating roles of environmental traits and government supports on EV adoption, as shown in Fig. 1. We divided environmental traits into environmental innovativeness and environmental concern sub-factors, and divided government supports into financial incentives and non-financial policies sub-factors. In selecting these variables, we reflected the opinions of five experts with at least five years of experience in research and development (R&D) and marketing divisions for EVs at Korean research institutes, universities, and automobile companies.

Kim et al. [38] proposed the value-based adoption model (VAM) to explain an individual's acceptance of technological innovations based on the theory of consumption value. A value in consumer purchase decisions is the consumer's overall assessment of the item's utility [39], arrived at after comprehensively considering the relative weights of the benefits and risks of the item [38,40]. A higher value perception is likely to lead to a more positive adoption decision, as has been found for information technology innovation (e.g., [41–43]. This relationship may also be applicable to EV adoption. Hence, we hypothesize the following:

H1. Perceived value positively affects EV adoption intention.

Perceived benefits refer to the advantages derived from the adoption of a product or service [44,45]. The more benefits a person perceives in a product or service, the more value the person will derive from it. Perceived benefits play a positive role in the value perception for technological innovations [38,46,47]. The perceived benefits of innovations such as EVs may be divided into economic and non-economic aspects [40,44]. Regarding the former, EVs can save on operational costs such as fuel and maintenance costs due to

their efficient usage of energy and smaller number of parts compared to ICEVs [1,8,13,16,17,48]. Regarding the latter, EVs are environmentally friendly because they produce few greenhouse gas emissions [4,15,16,18]. Moreover, EVs offer driving pleasure and convenience because they emit less noise and vibrations than ICEVs [8,9,16]. Hence, we hypothesize the following:

H2a. Operational economic benefit positively affects the perceived value of EVs.

H2b. Eco-friendly benefit positively affects the perceived value of EVs.

H2c. Driving enjoyment benefit positively affects the perceived value of EVs.

Perceived risks are the perceptions of the unexpected and uncertain results of purchasing a product or service [49]. The higher the perception of the risks of a product or service, the lower the value perceived in that product or service. Perceived risks negatively affect the value perception of technological innovations (e.g., [38,40,43]. The perceived risks of innovations such as EVs may be divided into financial and non-financial types [50]. Regarding the former, as EVs lack economies of scale, they are relatively expensive. The cost of replacing batteries in EVs is also a burden that ICEVs do not impose [10,14,51]. Regarding the latter, some consumers are concerned that EVs have lower engine power, top speeds, safety, and reliability than ICEVs [12,14,21]. Furthermore, EVs suffer from a short travel distance on a battery charge, a lack of charging infrastructure, and long charging times, which are major reasons why consumers are reluctant to adopt them [10–14,17,19]. Hence, we hypothesize the following:

H2d. Price and battery cost negatively affect the perceived value of EVs.

H2e. Technological performance risk negatively affects the perceived value of EVs.

H2f. Charging risk negatively affects the perceived value of EVs.

Personal traits related to adoption such as personal innovativeness have often been found to have a moderating effect on consumers' adoption attitudes or behaviors in information system research (e.g., [22,23]. However, the moderating effects of these factors have not been thoroughly investigated in studies on EV

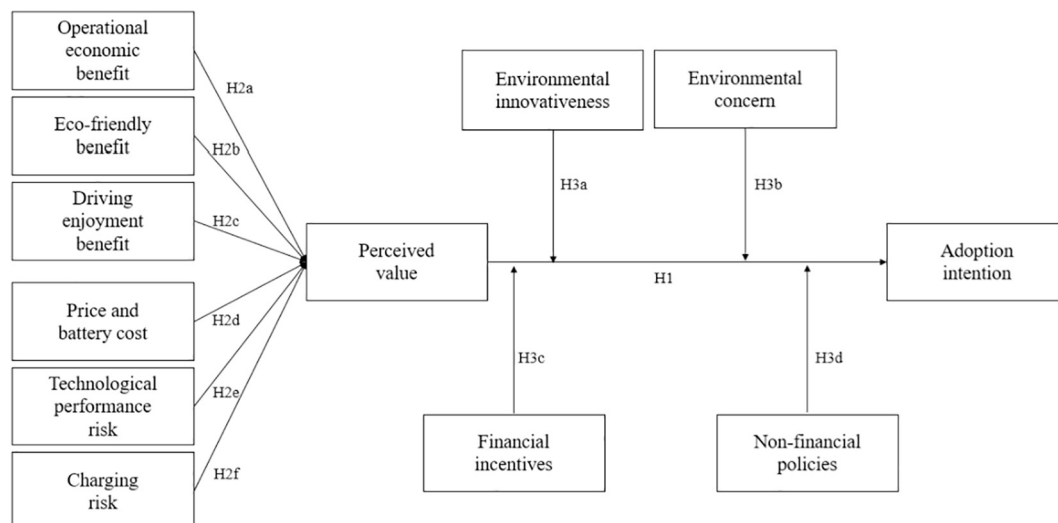


Fig. 1. Proposed research model.

adoption. To fill this gap, we incorporate personal traits regarding environmental innovativeness and environmental concern in our interaction analysis. Environment innovativeness, a domain-specific kind of innovativeness, refers to the willingness of an individual to try an environmental innovation [52–54]. Environmental concern refers to an individual's awareness of environmental problems and willingness to solve them [55,56]. Some studies have found that personal pro-environmental traits have a positive influence on consumer attitudes to EVs, leading indirectly to adoption intention [32,33]. Therefore, among people with similarly high perceptions of EV value, those with high environmental traits are more likely to adopt the vehicles than are those without. Hence, we hypothesize as follows:

H3a. Environmental innovativeness positively moderates the relationship between perceived value and EV adoption intention.

H3b. Environmental concern positively moderates the relationship between perceived value and EV adoption intention.

Government supports play important roles in the market diffusion of some innovative products and services. Such supports are efficient instruments for promoting market demand and building infrastructure to prevent the market failure of innovations that offer public good and high social value [57,58]. Government supports, including subsidies, tax exemptions, and charging

infrastructure proliferation, have been found to foster EV adoption [2,34–37,59]. Only a few studies have identified the moderating effect of government supports (including financial and non-financial policies) on innovation adoption in the context of information systems (e.g., [24], and the moderation of government supports has also received scant attention in the EV adoption literature, with some exceptions (e.g., [16,25]. This study fills this research gap and explores the interaction of government supports by incorporating financial incentives and non-financial policies in its analysis of EV adoption. Among people with similarly high perceptions of EV value, those with a high awareness of government supports are more likely to adopt the vehicles than are those without. Hence, we hypothesize as follows:

H3c. Financial incentives positively moderate the relationship between perceived value and EV adoption intention.

H3d. Non-financial policies positively moderate the relationship between perceived value and EV adoption intention.

3. Research methodology

3.1. Constructs and measures

To verify the research hypothesis, we conducted an empirical

Table 2
Measurement items.

Construct	Measurement items	Related studies
Operational economic benefit (ECO)	- EVs save fuel energy costs during driving. - EVs save maintenance costs due to their fewer parts. - EVs save repair costs due to their fewer mechanical issues.	[1,16]
Eco-friendly benefit (EFB)	- EVs indicate care for the environment. - EVs help in responding to global warming via emissions reduction. - Driving EVs is a contribution to social responsibility for the environment.	[11]
Driving enjoyment benefit (ENJ)	- EVs give drivers pleasure. - EVs are comfortable with less noise during driving. - EVs are comfortable with low vibration during driving.	[9,16]
Price and battery cost (COST)	- EVs are expensive to purchase. - EVs have high costs to replace a battery. - The costs of purchase and batteries reduce the attractiveness of EVs compared to conventional vehicles.	[1,9]
Technological performance risk (TECH)	- EVs do not satisfy the driver's expectation of top speed. - EVs do not satisfy the driver's expectation of vehicle power. - EVs do not satisfy the driver's expectation of safety and reliability.	[12,16]
Charging risk (CHAR)	- EVs do not satisfy the driver's expectation of driving range. - EVs do not satisfy the driver's expectation of charging time. - EVs do not satisfy the driver's expectation of charging infrastructure. - Charging stations for EVs are difficult to find and make drivers anxious.	[10,11]
Environmental innovativeness (INNO)	- In general, I am among the first in my circle of friends to know about new pro-environmental products when they appear. - In general, I am among the first in my circle of friends to buy new pro-environmental products when they appear. - Compared with my friends, I own many pro-environmental products.	[53,54]
Environmental concern (ENC)	- I think people should change their behavior to reduce climate change and protect the environment - I am concerned about human behavior and its influence on climate change and the environment - I think climate change is a threat to me and my family	[60]
Financial incentives (FIN)	- Overall, financial incentives help me adopt EVs. - Purchase subsidies help me adopt EVs. - Reducing purchase-related taxes helps me adopt EVs.	[16,36]
Non-financial policies (NFIN)	- Overall, non-financial policies help me adopt EVs. - Preferential measures such as access bus lanes help me adopt EVs. - The government's charging infrastructure expansion policy helps me to adopt EVs.	[16,34]
Perceived value (VALUE)	- Compared to the fee that I need to pay, EVs offer value for money. - EVs are considered to be a good buy. - Overall, EVs deliver me good value.	[38,41]
Adoption intention (AI)	- I intend to buy an EV in the near future. - If I replace my car, I will consider an EV first. - I recommend that others buy an EV.	[32,38,40]

analysis through questionnaires. The measurement items were established after considering related studies, as listed in Table 2. All items were measured with a seven-point Likert scale, ranging from “absolutely disagree” (1) to “absolutely agree” (7).

Regarding perceived benefit, three items of operational economic benefit (ECO) reflected the cost savings from EVs, following Hagman et al. [1] and Zhang et al. [16]. Three items of eco-friendly benefit (EFB) reflected the environmental contributions of EVs, based on Carley et al. [11]. Three items of driving enjoyment benefit (ENJ) reflected the emotional attributes of driving EVs, with reference to Schuitema et al. [9] and Zhang et al. [16]. Among the perceived risks, three items of price and battery cost (COST) were measured to reflect the cost burdens of purchase and battery replacement, based on Hagman et al. [1] and [9]. Three items of technological performance risk (TECH) reflected unsatisfied expectations in terms of vehicle performance, following Steinhilber et al. [12] and Zhang et al. [16]. Four items of charging risk (CHAR) reflected issues related to battery charging, following Carley et al. [11] and Junquera et al. [10].

As potential moderators between personal traits and environmental factors, three items of environmental innovativeness (INNO) reflected innovative attitudes to the environment, following Ahn et al. [53] and Gurtner and Soyeze [54]. Three items of environmental concern (ENC), reflecting awareness of environmental issues, were taken from Mohamed et al. [60]. Regarding government supports, three items of financial incentives (FIN) were adapted and modified to reflect how awareness of financial support impacts EV adoption, following Mersky et al. [36] and Zhang et al. [16]. Three items of non-financial policies (NFIN) reflected how awareness of regulatory or infrastructure support impacts EV adoption, following Bjerkan et al. [34] and Zhang et al. [16].

Regarding mediating constructs, three items of perceived value (VALUE) were adapted and modified based on Chu and Lu [41] and Kim et al. [38]; and three items of adoption intention (AI), as a dependent construct, were measured based on Kim et al. [38]; Wang et al. [32]; and Yang et al. [40].

3.2. Data collection

We collected data for empirical analysis using surveys on drivers in South Korea. Respondents were limited to license-holding drivers with at least one year of driving experience. The survey was conducted online by a professional company, using the structured questionnaires. Prior to the survey, preliminary tests were conducted on five automotive experts and 30 general drivers. Some of the questions were slightly modified based on their feedback.

The survey was conducted during first half of 2017, and 300 pieces of individual data were collected. Of these, missing and clearly inauthentic (i.e., repetitive) responses were removed, leaving 285 valid responses for statistical processing. We used the R software package and Smart PLS 3.0 package for statistical analysis, including descriptive statistics, factor analysis, structural equation modeling, and moderating effects analysis.

Table 3 shows the profiles and characteristics of the 285 respondents. The shares of male (56.8%) and female (43.2%) respondents are similar. Respondents in their 30s accounted for the majority (31.9%), followed by those in their 40s (31.6%), 50s (23.2%), and 20s (13.3%). Most respondents were housewives (22.8%), followed by office workers (22.5%), factory workers (20.4%), self-employers (20.4%), professional persons (11.6%), and others (2.5%). The shares of university and high school graduates are the highest, at 38.6% and 29.8% respectively. Most respondents (28.8%) had a monthly household income of 4–5 million KRW (around 3,670 to 4,580 USD). Most respondents (36.1%) had driving experience of 10 years or more, followed by five to less than 10 years (28.1%), two to less than five (25.3%), and one to less than two (10.5%). Most respondents were in one-car households (82.5%) and reported an annual driving distance of 15,000 km to less than 20,000 km (30.9%).

4. Results

4.1. Reliability and validity

Statistical analysis was conducted to examine the reliability and validity of the instrument and latent variables. Exploratory factor analysis (EFA) was done via principal component analysis to test whether the items were loading on the instrument dimensions appropriately. As shown in Table 4, each item posited on the corresponding constructs with factor loadings greater than 0.70 and higher than that on other constructs, which indicated construct validity [61]. The Kaiser–Meyer–Olkin (KMO) score of sampling adequacy was 0.652, exceeding the minimum threshold of 0.50, and the Bartlett's test of sphericity (BTS) index for evaluating the correlation matrix was satisfying the significant level of 0.05 or less [62]. Common method bias (CMB) were assessed through Harman's single-factor test. All variables were included in a factor, with 16.13% of variance, well below the cutoff threshold of 50.0% [63].

Convergent validity was evaluated by examining the factor loadings via confirmatory factor analysis (CFA), as shown in Table 5. All factor loadings of the model items were greater than 0.70, which satisfied the threshold recommendation of Hair et al. [64].

Table 3
Respondent profiles (n = 285).

Category	Percentage	Category	Percentage
Gender		Education level	
Male	56.8%	High school	29.8%
Female	43.2%	University	38.6%
Age group		Graduate or more than	11.2%
20–29	13.3%	Other	20.4%
30–39	31.9%	Driving experience	
40–49	31.6%	1 year to less than 2 years	10.5%
50 or more than	23.2%	2 years to less than 5 years	25.3%
Occupation		5 years to less than 10 years	28.1%
Office worker	22.5%	10 years or more than	36.1%
Factory worker	20.4%	Car ownership	
Professional person	11.6%	1	82.5%
Self-employed	20.4%	2	15.1%
Housewife	22.8%	3 or more than	2.5%
Other	2.5%	Annual driving distance	
Monthly household		Less than 5000 km	16.5%
income (million KRW)		5000 km to less than 10,000 km	11.6%
Less than 2	14.0%	10,000 km to less than 15,000 km	22.1%
2 to less than 3	16.8%	15,000 km to less than 20,000 km	30.9%
3 to less than 4	21.1%	20,000 km to less than 25,000 km	11.2%
4 to less than 5	28.8%	25,000 km or more than	7.7%
5 or more than	19.3%		

Table 4
Results of exploratory factor analysis.

	CHAR	EFB	COST	AI	ECN	ENJ	TECH	FIN	INNO	ECO	VALUE	NFIN
CHAR1	0.914	0.049	0.077	0.005	−0.068	0.048	−0.007	−0.071	0.073	−0.080	−0.078	−0.036
CHAR2	0.956	0.076	0.038	0.009	−0.059	−0.002	−0.001	0.004	0.037	−0.081	−0.075	−0.033
CHAR3	0.897	0.067	−0.009	−0.001	−0.091	0.013	−0.030	−0.020	0.053	−0.125	−0.148	0.013
CHAR4	0.975	0.068	0.043	0.003	−0.085	0.010	−0.001	−0.033	0.067	−0.100	−0.103	0.009
EFB1	0.079	0.904	0.017	0.060	−0.039	0.001	−0.085	0.076	0.060	0.019	0.053	−0.032
EFB2	0.067	0.913	0.083	0.081	0.029	0.076	0.004	−0.060	0.065	−0.017	0.051	−0.023
EFB3	0.092	0.975	0.074	0.083	0.005	0.049	−0.053	0.003	0.074	0.009	0.064	−0.026
COST1	0.039	0.009	0.905	−0.080	0.031	−0.003	0.060	−0.056	0.017	−0.038	−0.124	−0.154
COST2	0.042	0.115	0.847	−0.083	−0.068	0.074	0.056	0.009	−0.020	−0.168	−0.055	−0.227
COST3	0.066	0.071	0.950	−0.065	−0.018	0.044	0.063	−0.012	0.002	−0.088	−0.086	−0.213
AI1	0.060	0.122	−0.067	0.885	0.093	0.032	−0.085	0.143	0.050	−0.039	0.076	0.093
AI2	−0.044	0.059	−0.079	0.898	0.083	0.024	−0.071	0.080	0.082	0.013	0.135	0.080
AI3	0.004	0.059	−0.080	0.962	0.087	0.018	−0.067	0.126	0.077	0.001	0.117	0.076
ECN1	−0.081	0.042	0.019	0.067	0.816	0.132	−0.074	0.061	−0.108	0.083	0.086	0.198
ECN2	−0.095	0.021	−0.018	0.135	0.842	0.066	−0.118	0.021	−0.172	0.100	0.032	0.094
ECN3	−0.119	−0.065	−0.053	0.062	0.888	0.043	−0.074	0.032	−0.120	0.063	0.035	0.112
ENJ1	−0.002	0.027	0.010	0.015	0.051	0.919	−0.024	0.011	−0.114	0.045	0.090	0.001
ENJ2	−0.020	0.110	0.030	0.008	0.119	0.910	0.002	0.046	0.026	0.071	0.109	−0.016
ENJ3	0.111	−0.014	0.066	0.054	0.067	0.705	−0.022	−0.063	−0.121	0.317	0.046	0.124
TECH1	0.033	−0.100	0.090	−0.050	−0.103	0.051	0.853	−0.075	−0.080	0.016	−0.060	0.060
TECH2	0.003	−0.012	0.044	−0.068	−0.095	−0.026	0.911	0.029	−0.007	−0.048	−0.011	0.025
TECH3	−0.076	−0.020	0.027	−0.088	−0.044	−0.068	0.769	−0.044	−0.104	−0.049	−0.033	−0.242
FIN1	0.007	0.092	0.070	0.053	−0.043	0.000	−0.074	0.877	0.022	−0.074	−0.029	0.099
FIN2	−0.012	0.011	0.002	0.095	0.041	−0.001	−0.061	0.890	−0.011	−0.057	0.018	0.007
FIN3	−0.113	−0.093	−0.139	0.182	0.113	0.007	0.058	0.773	0.062	0.072	0.044	−0.056
INNO1	0.048	0.082	−0.001	0.096	−0.066	−0.082	0.003	0.065	0.792	−0.108	−0.017	−0.040
INNO2	0.080	0.038	0.012	0.024	−0.143	−0.012	−0.059	−0.049	0.879	−0.035	0.010	−0.080
INNO3	0.072	0.067	−0.006	0.066	−0.150	−0.083	−0.132	0.048	0.791	−0.077	0.036	0.010
ECO1	−0.134	0.013	−0.153	−0.005	0.116	0.107	−0.067	−0.053	−0.060	0.704	0.135	0.012
ECO2	−0.056	0.007	−0.032	0.019	0.066	0.116	−0.076	−0.060	−0.047	0.870	0.105	0.032
ECO3	−0.186	−0.008	−0.085	−0.044	0.046	0.110	0.067	0.051	−0.127	0.784	0.140	−0.009
VALUE1	−0.127	−0.013	−0.075	0.107	0.006	0.176	0.032	−0.019	0.042	0.238	0.794	0.025
VALUE2	−0.070	0.074	−0.152	0.123	0.000	0.080	−0.020	−0.021	−0.054	0.138	0.885	−0.022
VALUE3	−0.227	0.125	−0.035	0.109	0.157	0.012	−0.131	0.076	0.047	0.048	0.725	−0.009
NFIN1	−0.022	−0.031	−0.275	0.103	0.163	0.121	−0.045	−0.033	−0.073	−0.022	−0.052	0.758
NFIN2	−0.040	−0.033	−0.109	0.030	0.051	−0.125	−0.045	0.096	−0.051	0.018	0.010	0.792
NFIN3	0.025	−0.022	−0.246	0.132	0.228	0.147	−0.040	−0.025	0.000	0.047	0.028	0.787

Construct reliability was measured via Cronbach's alpha and composite reliability (CR). All values exceeded 0.70, and all of the average variance extracted (AVE) values were higher than the threshold of 0.50. These scores also satisfied the recommendations of Hair et al. [64]. The square roots of AVE were all greater than the off-diagonal elements, demonstrating the discriminant validity of all constructs, as shown in Table 6.

4.2. Model test results

We analyzed the main and moderating effects of the variables using the structural equation model through the Smart PLS statistical package program. The analysis results are shown in Table 7.

First, perceived value positively and significantly determined EV adoption intention ($\beta = 0.201$; H1 is accepted). The consumer's overall value perception is thus a prerequisite for EV acceptance, as suggested in the value adoption model.

Second, in terms of benefit aspects, perceived operational economic benefit was the strongest positive factor influencing the perceived value of EVs ($\beta = 0.210$; H2a is accepted). Perceived eco-friendly benefit and driving enjoyment benefit also positively and significantly affected perceived value ($\beta = 0.159$ and $\beta = 0.153$ respectively; H2b and H2c are accepted). Individuals showed positive interest in all benefit constructs as a value offered by EVs. The public strongly perceived the economic advantages in fuel and maintenance cost savings, followed by environmental benefits such as greenhouse gas reduction and the emotional factor of driving pleasure as the main EV values.

Third, in terms of risk aspects, perceived charging risk was the

strongest negative factor influencing the perceived value of EVs ($\beta = -0.231$; H2f is accepted). Perceived price and battery cost also negatively affected perceived value ($\beta = -0.166$; H2d is accepted), whereas technological performance risk was not a predictor (H2e is not accepted). Charging risk was perceived as the greatest obstacle to EV value. The cost burden, including the initial purchase cost and the cost of battery replacement, was also recognized as a barrier. As technological advances have greatly improved the functionality of EVs, respondents were not concerned about their technological performance.

Finally, hierarchical multiple regression analyses of models 2 to 6 revealed that the sub-constructs of environmental traits and government supports all positively affected EV adoption intention. However, environmental concern and financial incentives positively moderated only the relationship between perceived value and EV adoption intention ($\beta = 0.122$ and $\beta = 0.148$ respectively; H3b and H3c are accepted). Environmental innovativeness and non-financial policies showed a direct effect only on EV adoption (H3a and H3d are not accepted). Overall, as shown in Fig. 2 for the full model (model 6), environmental concern and financial incentives were found to enhance the effect of value perception on EV adoption.

5. Discussion and conclusion

5.1. Discussion

The objective of this paper was to investigate the factors influencing the intention to adopt EVs in Korea. In the absence of

Table 5
Results of testing construct reliability.

Construct	Item	Factor loading	AVE	C.R.	Cronbach's alpha
Operational economic benefit	ECO1	0.802	0.694	0.872	0.779
	ECO2	0.862			
	ECO3	0.834			
Eco-friendly benefit	EFB1	0.919	0.897	0.963	0.942
	EFB2	0.927			
	EFB3	0.993			
Driving enjoyment benefit	ENJ1	0.916	0.769	0.909	0.848
	ENJ2	0.924			
	ENJ3	0.784			
Price and battery cost	COST1	0.936	0.894	0.962	0.940
	COST2	0.903			
	COST3	0.995			
Technological performance risk	TECH1	0.895	0.743	0.896	0.828
	TECH2	0.900			
	TECH3	0.787			
Charging risk	CHAR1	0.926	0.913	0.977	0.968
	CHAR2	0.963			
	CHAR3	0.935			
	CHAR4	0.996			
Environmental Innovativeness	INNO1	0.851	0.710	0.880	0.803
	INNO2	0.839			
	INNO3	0.838			
Environmental concern	ENC1	0.875	0.803	0.925	0.879
	ENC2	0.914			
	ENC3	0.899			
Financial incentives	FIN1	0.833	0.734	0.892	0.823
	FIN2	0.881			
	FIN3	0.855			
Non-financial policies	NFIN1	0.870	0.698	0.872	0.784
	NFIN2	0.702			
	NFIN3	0.918			
Perceived value	VALUE1	0.849	0.724	0.887	0.807
	VALUE2	0.908			
	VALUE3	0.791			
Adoption intention	AI1	0.920	0.903	0.965	0.946
	AI2	0.934			
	AI3	0.996			

Table 6
Correlation of latent variables.

	ECO	EFB	ENJ	COST	TECH	CHAR	INNO	ECN	FIN	1NFIN	VALUE	AI
ECO	0.481											
EFB	−0.006	0.805										
ENJ	0.290	0.103	0.592									
COST	−0.213	0.118	0.038	0.799								
TECH	−0.068	−0.115	−0.037	0.142	0.552							
CHAR	−0.273	0.150	0.010	0.115	−0.010	0.833						
INNO	−0.211	0.159	−0.163	0.015	−0.141	0.156	0.504					
ECN	0.227	−0.002	0.213	−0.098	−0.198	−0.208	−0.285	0.645				
FIN	−0.018	0.007	0.006	−0.079	−0.082	−0.091	0.069	0.110	0.538			
NFIN	0.102	−0.063	0.123	−0.443	−0.136	−0.044	−0.095	0.348	0.055	0.698		
VALUE	0.356	0.125	0.224	−0.220	−0.116	−0.281	−0.002	0.173	0.066	0.064	0.524	
AI	0.013	0.168	0.071	−0.185	−0.188	−0.006	0.151	0.211	0.263	0.226	0.263	0.816

Note: The diagonal elements in bold are the square root of the AVE.

literature on the moderating roles of personal traits and external factors in EV adoption, this study focused on the interaction among perceived value, environmental traits, and government supports. The results are summarized below.

First, the overall value perceived by individuals determined EV adoption intention. The basic premise of the value adoption model applies as well to EVs as it does to new innovations including information systems [38,46]. This result should influence studies on the hierarchical value structure and the value of innovations as perceived by consumers in the energy and automotive industries [8,65].

Second, the economic benefit of operational cost savings had a

strong effect on value perception in EV adoption, in line with the literature [1,13,17]. Eco-friendly benefits and driving enjoyment benefits were also predictive factors in perceived EV value [4,9,15,16,18]. The emotional and hedonic benefits of EVs have been less studied than other benefits have, and findings on their effects on adoption intention have not been consistent [8,9]. Empirically identifying EVs' benefits in emotional terms, in addition to utilitarian and social terms, should deepen our understanding of the motivators of EV adoption.

Third, as pointed out in many studies, charging risk was a strongly negative factor in EV value perception [11,14,15]. The effect of charging risk as an obstacle to EV adoption is not likely to be

Table 7
Results of main and interaction models.

Path	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Estimate (p-value)	Estimate (p-value)	Estimate (p-value)	Estimate (p-value)	Estimate (p-value)	Estimate (p-value)
ECO→VALUE	0.210*** (3.295)	0.210*** (3.300)	0.210*** (3.346)	0.210** (3.261)	0.210*** (3.330)	0.210*** (3.350)
EFB→VALUE	0.159** (2.813)	0.159** (2.882)	0.159** (2.786)	0.159** (2.801)	0.159** (2.782)	0.159** (2.745)
ENJ→VALUE	0.153** (2.606)	0.153** (2.586)	0.153** (2.643)	0.153* (2.536)	0.153** (2.585)	0.153** (2.601)
COST→VALUE	−0.166** (2.985)	−0.166** (2.984)	−0.166** (2.989)	−0.166** (3.022)	−0.166** (3.000)	−0.166** (2.937)
TECH→VALUE	−0.057 (1.052)	−0.057 (1.034)	−0.057 (1.045)	−0.057 (1.033)	−0.057 (1.021)	−0.057 (1.016)
CHAR→VALUE	−0.231*** (3.943)	−0.231*** (4.005)	−0.231*** (3.963)	−0.231*** (3.936)	−0.231*** (3.989)	−0.231*** (4.033)
VALUE→AI	0.212*** (4.093)	0.229*** (4.550)	0.203*** (3.965)	0.193*** (3.972)	0.208*** (4.106)	0.201*** (4.213)
INNO→AI	0.195** (2.968)	0.202** (3.182)	0.188** (2.905)	0.178** (2.763)	0.201** (3.141)	0.184** (2.954)
ENC→AI	0.148** (2.648)	0.143** (2.674)	0.124* (2.216)	0.179** (3.274)	0.147** (2.655)	0.143** (2.659)
FIN→AI	0.211*** (4.072)	0.192*** (3.822)	0.228*** (4.448)	0.198*** (4.041)	0.205*** (3.936)	0.198*** (3.921)
NFIN→AI	0.168*** (3.494)	0.182*** (3.686)	0.170*** (3.585)	0.147** (3.033)	0.172*** (3.556)	0.168*** (3.580)
VALUE*INNO→AI		0.139 (1.271)				0.135 (1.414)
VALUE*ENC→AI			0.118* (2.081)			0.122* (2.197)
VALUE*FIN→AI				0.187*** (4.029)		0.148** (2.817)
VALUE*NFIN→AI					0.074 (0.863)	0.037 (0.523)
R ² of VALUE	0.210	0.229	0.223	0.243	0.215	0.270

Note: *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$.

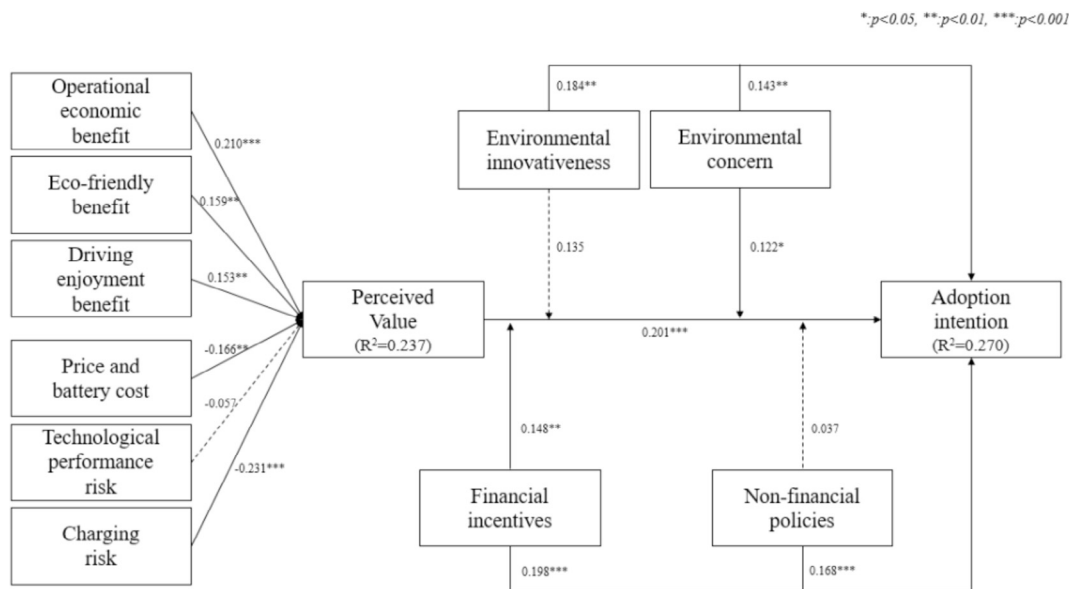


Fig. 2. Results of the structural equation model.

controversial. The cost burdens of car purchase and battery replacement, which negatively affected EV value perception in this study, were also considered important in previous studies [10,11,20,65,66]. Findings on the relative impacts of charging and cost-related risks as barriers to EV adoption have been mixed in the literature. Although the effect of charging risk was relatively high in this study, identifying the differences between these risks while considering the different market environments and competitive conditions is required to understand which mechanism could provide efficient market diffusion. Concerns about technological performance have not been a major obstacle for Korean consumers; studies have shown both negative [14,21,66] and non-significant effects [25]. The influence of technological performance as an adoption barrier should decrease as the functionality of the vehicle continues to improve.

Fourth, environmental innovativeness had only a main effect, but environmental concern had both main and moderating effects on EV adoption intention. These environmental traits in the context of EV diffusion have been shown to have different effects. Some

studies have revealed that environmental concern directly affects EV preference or adoption [9,21,60], while other studies have been shown to have indirect effects of environmental concern via other mediating constructs [32]. Few studies examine the interaction of environmental innovativeness and concern on EV adoption. The findings of this study suggest that environmental traits have a positive and direct influence on EV adoption, while the moderating effect varied according to the environmental constructs.

Finally, government supports were found to be an important facilitator in previous studies [19,34,67]; [2,36,37,56]. This study also found that financial incentives and non-financial policies via government supports all directly and positively affected EV adoption intention. This study also revealed that only financial incentives enhanced the relationship between value perception and adoption intention. Little attention has been paid in the literature to the moderation of government supports in EV diffusion. Clearly identifying the main and moderating roles of government supports (both monetarily and non-monetarily) should help lead to an understanding of how to foster the efficient and widespread diffusion

of EVs.

5.2. Practical implications

Our findings suggest the following implications for the ecosystem participants and policymakers concerning the efficient market expansion of EVs. The value attributes perceived by consumers for EVs were the most critical factors in operational economic benefit, charging risk, and price and battery cost, from perspective of market diffusion strategy. Therefore, the ecosystem participants should focus their resources and capabilities on securing competitive advantage over existing vehicles in terms of life-cycle costs, and total ownership costs, including operational cost. Despite expansion in charging infrastructure for EVs, consumers remain concerned about charging facilities. It is important to consider efficient deployment and utilization of charging facilities while investing in charging technology and infrastructure. Next, environmental traits and government supports had direct and positive effects on the take-up of the EV market. Environmental concern and financial incentives, in particular, enhanced the purchasing psychology of consumers. The ecosystem participants and the government must reinforce publicity through various online and offline media to strengthen public perception of the environmental value provided by EVs. It is also necessary for the central and municipal governments to continue expanding subsidies for diffusion of the EV market and pursue effective financial support policies, such as discrimination of subsidies by strategic targeting on potential adopters. The following are some detailed practical implications.

First, to accelerate EV diffusion, it is necessary to increase consumers' perceptions of EV value. Consumers go through various steps when considering the overall value of innovative products or services prior to purchase. Value is ultimately an assessment of benefits and risks. Therefore, it is necessary to develop a strategic approach and the required technology to improve the benefits and reduce the risks of EVs as perceived by consumers. In addition, emotional and social values as well as functional value influences how consumers perceive value [30]. Therefore, it is necessary to strengthen not only the functional advantages of EVs, but also various emotional and social values, including participation value in eco-friendliness, and emotional experiences.

Second, it is important that consumers appreciate the benefits of EVs in terms of their economic efficiency, eco-friendliness, and emotional advantages. Because EVs are likely to form substitute relationships with existing vehicles (including ICEVs), consumers need to raise their awareness of EVs' benefits, such as reduced running costs, pro-environmental features, and more comfortable driving. It should be emphasized that consumers can enjoy significant costs savings, contribute to society through environmental responsibility, and derive emotional satisfaction by driving EVs. In addition, providing differentiated consumer benefits from conventional vehicles helps strengthen the marketability of EVs. Leading the next-generation vehicle market with self-driving or connected functionalities is also a good way to secure competitiveness. An advantage of EVs is that they integrate or converge relatively easily with intelligent systems that combine networks, sensors, and artificial intelligence technology, as most of their parts comprise of electrical components [68]. Self-driving vehicles will also reduce driver discomfort in driving, charging, and improve energy efficiency, which will enhance the competitiveness of EVs [69].

Third, concerns about charging are the greatest obstacles to the proliferation of EVs; this may be difficult to change in the near future. The shortage of battery charging stations, the long time required for charging, and the driving distance limitations are

serious burdens for consumers. Solving this problem will require expanding the charging infrastructure through continuous government investment and the voluntary participation of the private sector, as well as generating technological innovations in the battery sector. It is also necessary to arrange charging infrastructure efficiently by analyzing the driving patterns of vehicles and usage patterns of charging facilities. Consumers also feel burdened by the initial purchase costs and battery replacement costs of EVs; this requires a substantial decline in vehicle prices through economies of scale. In particular, to reduce cost concerns about battery replacements, it is necessary to increase financial supports for replacement for a specific period after purchase, while enhancing battery capacity and quality.

Fourth, expanding the EV market requires targeting consumer groups with accepting attitudes to environmental innovations and who are inclined to respond to environmental problems. To encourage consumers with pro-environmental traits to purchase EVs, it would be appropriate to establish conditions favorable to EV purchase and strengthen public relations through cooperation with environmental non-profit organizations. For example, as people with high environmental concerns tend to display a positive relationship between value perception and EV purchase, it would be effective to convince these groups of the environmental advantages of EVs over existing vehicles through various online and offline channels. It is also necessary to consider the importance of strengthening social pressure or influence on the environment. Strong social norms for the environment affect an individual's pro-environmental behavior [70,71]. Social influence and pressure also have a positive effect on individuals that purchase eco-friendly innovations [72]. Therefore, it is required to develop strong and effective means of strengthening social influence, such as positive word of mouth, empathy for the social value of environment, opinion leadership of early adopters, and positive peer effects.

Finally, government supports such as financial incentives and non-financial policies play critical roles in the diffusion of EVs at the market formation stage. Government financial support such as tax exemptions and subsidies has greatly reduced the burden of purchasing EVs, which has fostered EV market growth in many countries, including Korea. Non-monetary measures such as providing free parking spaces and allowing bus lane driving have provided convenience and regulatory benefits for EV driving [59]. Since the budget available to the central government and municipalities is limited, it is necessary to find ways to provide financial support efficiently via subsidies and tax exemptions. It might help to expand non-financial measures governing conventional vehicles, such as regulations on fuel consumption, exhaust, and access to urban areas. What should not be overlooked is that a more strategic approach is needed to improve the effectiveness of government supports. With government supports for the public, it is also necessary to consider positioning strategies that select key target groups and customize financial or non-financial supports for them.

5.3. Limitations and possibilities for further study

This study has several limitations, which offer directions for future research. First, the study examined general drivers in Korea. It will be necessary to conduct comparative studies on drivers in other countries with EV diffusion market environments similar to Korea's. For example, a comparative study of nation-specific factors such as driving culture would provide important implications. Second, the moderating effects of environmental traits and government supports were empirically examined in this study. However, individual characteristics such as demographics and vehicle driving traits are also likely to moderate the relationship between value perception and EV adoption intention. Future studies could

analyze the differences between groups by gender, age, and occupation, or examine the interaction of driving-related characteristics such as vehicle driving purpose, annual vehicle distance, and car involvement. Finally, along with previous studies, this study focused on predicting enablers, barriers, and moderators of EV diffusion at the market introduction stage, using consumer survey data. It would be useful for research and practice of innovation adoption in the energy and transportation sectors to examine how the results are efficient for real applications, policy, or market strategy, based on the actual data at the post-growth stage.

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