Economic Change and Restructuring (2023) 56:3335–3352
https://doi.org/10.1007/s10644-022-09477-2

Predicting consumer intention toward eco-friendly smart home services: extending the theory of planned behavior

Wenqing Zhang[1] · **Biao Luo**[2]

Received: 8 December 2021 / Accepted: 19 December 2022 / Published online: 30 December 2022

Abstract

Although smart home services have been acknowledged to promote environmental protection, few studies have explored the willingness of consumers to adopt eco-friendly smart home services. This study aims to investigate the influencing factors that affect Chinese consumers' intention to adopt eco-friendly smart home services. The theory of planned behavior is used as the basic theoretical background and is further extended by adding the constructs of environmental knowledge, ambiguity tolerance, compatibility, and living habits. Data were collected from 629 respondents in China through a self-administered questionnaire survey and analyzed by structural equation modeling. Results indicate that attitude and perceived behavioral control have positive and significant effects on consumers' intention toward adopting eco-friendly smart home services, whereas subjective norm does not have any effect. Moreover, environmental knowledge, ambiguity tolerance, compatibility significantly and positively affect consumer intention toward eco-friendly smart home services. Living habits have a negative effect on consumers' intention under eco-friendly smart home services context. The implications for promoting the popularization of smart home services are discussed to motivate consumers to adopt eco-friendly smart home services on the basis of empirical results.

Keywords Theory of planned behavior · Environmental knowledge · Ambiguity tolerance · Compatibility · Living habits · Eco-friendly smart home services

✉ Biao Luo
luobiao8833@163.com

Wenqing Zhang
2766237994@qq.com

[1] School of Accountancy, Nanjing University of Finance & Economics, Nanjing, China

[2] School of Management, Hefei University of Technology, Hefei, China

1 Introduction

Smart home refers to a residence integrated with network communication, security, and automatic control technology that intend to provide families with a safe, comfortable, and convenient living environment (Kim et al. 2017). Generally, smart home services are multifunctional services which include lighting control, household appliance control, intelligent security, scene management, and time management, aiming to provide residents with flexible and efficient remote control services (Alam et al. 2012).

Data indicate that global smart home market revenue has reached 48.71 billion dollars in 2018, and the revenue is predicted to grow to 121.96 billion dollars by 2022 with an annual growth rate of 25.8% (Zhang and Liu 2021). With the expansion of the smart home market, scholars have also gradually attached significance to the research on smart homes. However, most of the previous literature about smart home services have focused on the perspective of engineering or technology; few studies have discussed the acceptance of consumers toward smart home services (Yang et al. 2017; Mashal and Shuhaiber 2019). In addition, most of the published research has emphasized the functional or egocentric benefits that smart home services can provide (Park and Lee 2014). Only a limited amount of research has conceptualized smart homes as eco-friendly, while published literature has largely ignored the environmental protection function of smart homes (Schill et al. 2019).

Actually, smart home services promote environmental protection (Marikyan et al. 2019). The core parts of smart homes include smart electricity meters, smart energy appliances, and energy management functions. In addition, smart homes are also the terminal use node of the smart energy system, which can reduce carbon emissions and save energy by promptly shutting down household appliances when they are not in use (Alexandra et al. 2012; Wilson et al. 2015). The reduced energy consumption contributes to the formation of a low-carbon society. Such smart home services that facilitate the effective use of resources and reduce environmental degradation are called eco-friendly smart home services (ESHS) (Schill et al. 2019).

Despite the ability of ESHS to facilitate the lives of people and its huge market value, the rapid and widespread adoption of ESHS have fallen short of expectations (Mashal and Shuhaiber 2019). Public understanding toward ESHS is still in its conceptual stage. Smart home services have not been widely accepted (Yang et al. 2018). Moreover, global environmental problems have become increasingly prominent. As a typical representative of innovative technology, ESHS can substantially contribute to environmental protection (Schill et al. 2019). The exploration of consumer acceptance toward smart home services is a relatively new research filed (Mashal and Shuhaiber 2019), and few scholars highlight the environmental protection function of smart homes. On the basis of the above points, the influencing factors that may influence consumer intention to adopt ESHS must be explored to accelerate the adequate adoption of these services.

Scholars have mostly employed the theory of planned behavior (TPB) and the theory of technology acceptance model (TAM) as the research frameworks in the analysis of the adoption intention toward technologically innovative products or

services (Cheng 2018). ESHS are typical representatives of the application of IoT. In the existing literature about the adoption of smart home services, scholars tend to use TAM rather than TPB (Pal et al. 2018; Shin 2018; Hubert et al. 2019; Shuhaiber and Mashal 2019). However, the present study highlights the environmental protection function of smart home services. TPB is also applied widely in the research of consumer acceptance of green purchasing behaviors (Montano and Kasprzyk 2015). ESHS combine the characteristics of technology and environmental protection. And few scholars use TPB theory to study consumers' behaviors of smart home services. Thus, adopting TPB instead of TAM is appropriate in the research on adoption intention toward ESHS.

Despite the widespread application of the TPB model in the research of consumer acceptance toward environmental technological products or services, previous studies have pointed out that the model still has some limitations. The TPB model assumes that consumers are rational and reasoned (Wang et al. 2014). However, each consumer has a different amount of knowledge, which may have significant effects on the decisions of consumers to some extent. Published literature that has employed the TPB model for the research of pro-environmental behaviors has also neglected the role of environmental knowledge. Considering that ESHS are beneficial to environmental protection, previous studies have proven that lacking knowledge on environmental issues is likely to create apathy among residents (Mohiuddin et al. 2018). Thus, the variable of environmental knowledge must be used as the influencing factor to analyze consumer intention toward ESHS. Published works have also confirmed that the personality of consumers influences their decisions when they have other choices (Wang et al. 2018b). Although adopting ESHS provides an efficient, intelligent, and safe living experience and plays a role in protecting the environment, most consumers are not aware of these benefits and remain ambiguous or unwilling to accept such services (Geissdoerfer et al. 2017). Few scholars have explored the role of ambiguous tolerance on consumer intention to adopt certain services. Thus, ambiguous tolerance to TPB must be applied to explore consumer intention toward ESHS. Moreover, external factors should also be integrated to the TPB model to provide a comprehensive view of the research problem (Wang et al. 2014). ESHS must be connected to other products seamlessly. Existing studies have proven that compatibility is an important reminder for technology acceptance (Lee et al. 2011). Thus, compatibility is a key consideration. In addition, the living habits of consumers vary. Previous literature has proven that living habits are considered a decisive factor that affects the energy-saving behavior of residents (Wang et al. 2014). Few studies have considered the effect of living habits in the research on the adoption intention of consumers and the TPB model. Thus, living habits should be integrated into TPB to explore the adoption intention of consumers.

The contributions of this study are mainly reflected in the following three aspects. First, this study takes into account the environment-friendly functions of smart home, which have been ignored by most previous studies. Second, previous studies on smart home mainly focus on technology optimization. This study innovatively explores consumers' intention to adopt ESHS, expanding the scope of research in the field of smart home. Third, this study innovatively uses the TPB theory to

explore consumers' intention to adopt ESHS, and includes the two variables of environmental knowledge and ambiguity tolerance to expand the TPB theory.

The remaining sections of this article are shown below. Section 2 describes the relevant theoretical background and hypothesis development. Section 3 presents the data and research methodology. In Sect. 4, the data analysis and results are introduced by using structural equation modeling. Section 5 provides and discusses the conclusions, implications of the findings, limitations, and future research.

2 Theoretical background and hypothesis development

2.1 Theory of planned behavior

The TPB model proposed by Ajzen (1991) is widely applied in the field of pro-environmental and technology acceptance. It consists of the variables of attitude, subjective norm, and perceived behavioral control, which have significant effects on consumer intention. Attitude is expressed as the negative or positive evaluation of an individual to practice a particular behavior. Published literature has proven that attitude is related to consumer intention (Ajzen 1991). For instance, Yadav and Pathak (2016) confirmed that if an individual holds a positive attitude to purchasing green products, then they are likely to accept green products. Wang et al. (2018a) also proved that positive attitude is associated with the strong intention of consumers to choose green hotels. Subjective norm is regarded as an individual's perceptions of subjective pressures from important people or groups to conduct or not conduct a certain behavior (Ajzen 1991). Wang et al. (2014) confirmed that if residents perceive high subjective norm in Beijing, then they are likely to conduct energy-saving behavior. Ru et al. (2019) verified that if residents perceive high subjective norm, then they are likely to reduce $PM_{2.5}$. Perceived behavioral control is defined as the individual's perception of the extent of ease or difficulty in performing a certain behavior, which includes influencing factors, such as time, money, and knowledge (Ajzen 1991). Yazdanpanah and Forouzani (2015) verified that if Iranians perceive high behavioral control, then they are inclined to buy organic food. Chen and Hung (2016) confirmed that when the perceived behavioral control of consumers is high, then they are willing to accept green products. Dou et al. (2022) proved that subjective norm and perceived behavioral control significantly and positively influence consumers' intention toward inoculating COVID-19 vaccine.

Within the context of ESHS, we can infer that if the attitude of consumers toward ESHS is positive, they are more enthusiastic about ESHS and more willing to adopt ESHS. When consumers perceive high pressure from loved ones (e.g., relatives or friends), they may feel reluctant to refuse or have a herd mentality and prefer to adopt ESHS. In addition, when consumers perceive the ease in conducting eco-friendly behavior, they have more time, opportunities and funds to adopt ESHS, and they are more likely to accept ESHS. Thus, the following assumptions can be assumed:

H1: Attitude exerts a significant and positive effect on consumers' intention to adopt ESHS.

H2: Subjective norm exerts a significant and positive effect on consumers' intention to adopt ESHS.

H3: Perceived behavioral control exerts a significant and positive effect on consumers' intention to adopt ESHS.

2.2 Extended theory of planned behavior model

2.2.1 Environmental knowledge

Environmental knowledge is an understanding of the factors that affect the health and sustainability of the ecosystems we live in Diekmann and Preisendörfer (2003). The impact of environmental knowledge on consumer intention has two distinct views. Chen and Peng (2012) further proved that consumer attitude is inspired by their environmental knowledge. If the environmental knowledge of consumers is higher, consumers care more about the environment. Fu et al. (2020) suggested that an individual's high level of environmental knowledge reflects the awareness of environmental issues. Liu et al. (2020) proved that residents with high environmental knowledge are likely to take a positive attitude toward household energy-saving behavior and adopt such behavior. Previous studies have also verified that environmental knowledge plays a role in the environmental behavior of consumers (Sun et al. 2018). Mohiuddin et al. (2018) pointed that environmental knowledge exert a positive influence on the attitude and intention of consumers toward purchasing green vehicles in emerging countries. Moslehpour et al. (2022) also proved that environment knowledge is positively correlated with green purchase intention. However, some scholars doubt the influence of environmental knowledge in pro-environmental behavior intention (Flamm 2009). For instance, Maichum et al (2016) confirmed that environmental knowledge fails to influence consumer intention to purchase green products. Li and Wu (2020) confirmed that the pro-environmental behavior intention of consumers is not affected by environmental knowledge. Under the ESHS background, we prefer to assume that environmental knowledge is a stimulation to encourage consumers to employ ESHS. If consumers increase their knowledge of environmental protection, then their attitude and intention to adopt ESHS are strengthened. The hypotheses can be presented as follows:

H4: Environmental knowledge exerts a significant and positive effect on consumers' attitude to adopt ESHS.

H5: Environmental knowledge exerts a significant and positive effect on consumers' intention to adopt ESHS.

2.2.2 Ambiguity tolerance

Ambiguity situation occurs when a person is unable to construct or organize an environment because of the lack of adequate criterion (Hammond et al. 2017). As a personality trait, ambiguity tolerance generally refers to the extent of the threat or discomfort people perceive that an ambiguous situation brings (Budner 1962). Generally, consumers with high ambiguity tolerance experience little pressure from

ambiguous information or situations because they can have a strong understanding of the information, whereas consumers with low ambiguity tolerance are less likely to accept ambiguous information or situations (Xu and Tracey 2015). Previous studies have investigated the association of ambiguous tolerance with the attitude and behavioral intention of consumers (Matsumoto et al. 2017; Wang et al. 2018b). For instance, Jena and Sarmah (2015) proved that ambiguous tolerance immediately affects the attitude and intention of consumers to pay an additional charge for returning used products. Wang et al. (2018b) also verified the positive relationship between ambiguous tolerance and the attitude and intention of consumers toward remanufactured products.

In the context of ESHS, consumers may perceive that unknown risks due to ESHS are new and high-tech for consumers. Previous literature has identified three main risks in the context of ESHS, namely, time risk, security risk, and performance risk (Yang et al. 2017). The three risks of adopting ESHS usually leave consumers in an ambiguous situation. Consumers with high ambiguity tolerance are more comfortable and confident to face distrust and poor understanding than those with low tolerance (Hazen et al. 2012). Thus, consumers are likely to shape a positive attitude and intention toward ESHS. If the tolerance of consumers for ambiguity is low, they are unwilling to be in a nondeterministic situation, and consumers are unlikely to shape a positive attitude and are reluctant to adopt ESHS. Thus, the hypotheses are shown as follows:

H6: Ambiguity tolerance exerts a significant and positive effect on consumers' attitude to adopt ESHS.

H7: Ambiguity tolerance exerts a significant and positive effect on consumers' intention to adopt ESHS.

2.2.3 Compatibility

Compatibility refers to the extent to which the innovative products or services are regarded as consistent with the existing systems (Chong et al. 2009). In the area of technology acceptance, compatibility is an important driver of adoption intention because consumers usually tend to avoid changes. ESHS demand the high connectivity and fluent communication between different appliances (Shin et al. 2018). Thus, the compatibility of smart home applications with the lifestyles of potential users must be reconciled. Previous studies have proven that compatibility positively affects consumers' adoption intention of innovation (Wang et al. 2020). Susanto and Goodwin (2013) verified that compatibility is the predictor of the intention of users in innovation. Hubret et al. (2019) proved that if the technology of smart home applications is compatible with current systems, users are likely to adopt it. Hidayat-ur-Rehman et al. (2022) also indicated that compatibility is the key factor affecting the use of mobile wallet. Based on the above analysis, under the ESHS context, if the compatibility of ESHS is high, then customers are more likely to adopt ESHS. Thus, the following assumption can be proposed:

H8: Compatibility exerts a significant and positive effect on consumers' intention to adopt ESHS.

2.2.4 Living habits

Living habits are usually associated with comfortable behaviors that individuals are unwilling to change (Wang et al. 2014). Living habits may be regarded as a momentous role of consumer intention toward energy-saving behavior. Wang et al. (2014) confirmed that living habits significantly and negatively affect consumer intention to save energy. Liu et al. (2015) also conducted that if additional consideration is given to the living habits of residents in residential energy-saving renovation, the effectiveness for measures of energy-saving can be improved. Under the ESHS context, the introduction of new technologies is a lifestyle disruption, which may bring about a major lifestyle change among consumers. Consumers who do not like or are not willing to change living habits may be reluctant to embrace it. Thus, the following hypotheses are proposed:

H9: Living habits exert a significant and negative effect on consumers' intention to adopt ESHS.

Hence, we develop the conceptual framework as shown in Fig. 1.

3 Data and research method

3.1 Sample and data collection

Data analyzed in this research are collected from a questionnaire survey. To make the study sample representative, we cooperated with Aqara smart home experience company in Hefei, which has a smart home customer base scattered across China. Data collection unit asked Internal staff of Aqara company to help us send out questionnaires to their smart home customers through professional questionnaire survey (http://www.sojump.com). Some of their company's customers base have used smart

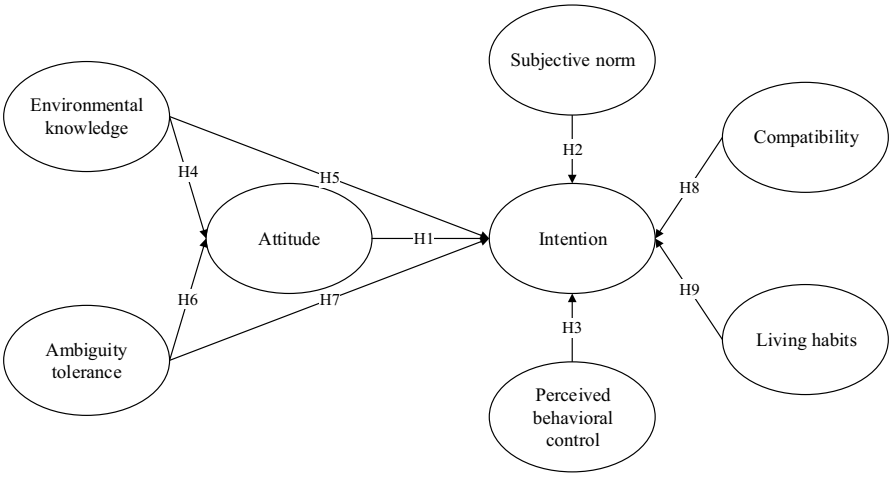

Fig. 1 The conceptual framework for the present study

home services, others have not. The front of the questionnaire clearly explained that this survey would be conducted for academic research purposes only. Demographic information provided by respondents included gender, age, educational background, income level, and adoption experience. The survey data were collected from mid-October to mid-December 2019. A total of 816 questionnaires were issued in this study. The questionnaire collection team rejected those samples with missing and highly repetitive answers and discarded the questionnaires that were completed in less than three minutes. In the end, 629 questionnaires met the standards with an overall response rate of 77.08%.

The demographic characteristics of respondents are presented in Table 1. The full survey contained 629 eligible representative participants, including 342 females (54.4%) and 287 males (45.6%). The age ranged widely from under 20 years old to older than 50 years old. Respondents who were 20–29 years old formed the largest group (53.9%). In terms of education level, 52.6% of the respondents earned a junior college or university degree, while 26.4% had a master's degree or PhD education background. The monthly income of 34% of the respondents ranged from RMB 2,000 to RMB 5,000 (USD 283 to USD 707), while the monthly income of 29.7% of the respondents ranged from RMB 5,001 to RMB 10,000 (USD 707 to USD 1,414). The respondents participating in the interview with experience in ESHS adoption

Table 1 Demographic profile of respondents

Demographics	Frequency	Percentage (%)
Gender		
Female	342	54.4%
Male	287	45.6%
Age		
Below 20	34	5.4%
20–29	339	53.9%
30–39	154	24.5%
40–49	81	12.9%
50 and over	21	3.3%
Education level		
Senior high school or below	132	21.0%
Junior college or university	331	52.6%
Master degree or PhD	166	26.4%
Personal monthly income		
Less than ¥2,000 ($283)	118	18.8%
¥2000 – ¥5000 ($283–$707)	214	34.0%
¥5,001 – ¥10,000 ($707–$1414)	187	29.7%
More than ¥10,000 ($1414)	110	17.5%
ESHS experience		
Yes	298	47.4%
No	331	52.6%
Total	629	100.00%

accounted for 47.4% of the sample. The remaining 52.6% had no experience with ESHS adoption.

3.2 Measures

The measurement items of this research were sourced from existing studies. The measurement of environmental knowledge was from the study of Dunlap et al. (2000). The measurement of ambiguity tolerance was based on the works of Furnham and Marks (2013) and Wang et al. (2018b). The measurement of compatibility was adopted from the research of Mohagheghi et al. (2013). The measurement of living habits was sourced from Wang et al. (2014). Then, the measurement of attitude, subjective norm, and perceived behavioral control came from the study of Taylor and Todd (1995) and Bhattacherjee (2000). Lastly, the measurement of intention was derived from the work of Davis et al. (1989). This study employs a five-point Likert scale to measure the items, that is, 1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree. "Appendix A" shows the detailed measurement scale items.

To test the validity and reliability of this questionnaire design, 50 questionnaires were circulated to conduct a pilot investigation. Questionnaire collection group randomly distributed questionnaires on Lei street, one of the busiest night markets in Hefei, Anhui province on Saturday and Sunday. The timing and location of questionnaire distribution were carefully considered. The questionnaire collection group randomly interviewed the population whether they were willing to fill out the questionnaire. After receiving a positive response from passers-by, we sent the questionnaire to the respondent. After the respondents completed the questionnaire, we asked them if they had any questions about the questionnaire. The measurement items were slightly revised for clarity on the basis of the feedback of the respondents. The results indicated that the validity and reliability of the pilot survey all met the criteria.

4 Data analysis and results

Common method variance (CMV) might be a potential threat in the hypothesized relationships because the constructs in this research were assessed through self-administered questionnaire (Buckley et al. 1990). Thus, Harman's one-factor test was used to determine the CMV. The results confirmed that all of the measurement items were separated into six factors with eigenvalues higher than 1.0. The first single accounted for 27.8% of the variance that was below the reference value of 50.0%, indicating that CMV was not a serious issue in this study. The values of Kaiser–Meyer–Olkin (KMO) are higher than the standard value of 0.5 and the significances of Bartlett's test are less than 0.01, indicating that there is a significant correlation between measure items, which can be used for factor analysis. Subsequently, partial least squares (PLS) structural equation analysis was introduced to check whether the survey data was in agreement with the conceptual model and to verify

the hypotheses further by using Smart-PLS 3.0 and SPSS 25.0 software. PLS analysis consists of measurement and structural models, where the former is first used to confirm the reliability and validity of the constructs, and the latter is employed to examine the relationship among constructs.

4.1 Measurement model analysis

Confirmatory factor analysis is used to determine the reliability and validity of the measurement model. The reliability of the constructs are measured by the values of Cronbach's alpha and composite reliability (Fornell and Larcker 1981). The results are shown in Table 2. The values of Cronbach's alpha range from 0.840 to 0.921, which exceed the benchmark of 0.70. Moreover, the values of composite reliability meet the minimum standard of 0.70. Accordingly, the reliability of the construct

Table 2 Results of confirmatory factor analysis

Construct	Item	Standard loading	Cronbach's alpha value	Composite reliability	AVE
Environmental knowledge (EK)	EK1	0.846	0.889	0.919	0.694
	EK2	0.841			
	EK3	0.855			
	EK4	0.850			
	EK5	0.771			
Ambiguity tolerance (AT)	AT1	0.885	0.875	0.923	0.800
	AT2	0.900			
	AT3	0.897			
Attitude (ATT)	ATT1	0.924	0.921	0.950	0.863
	ATT2	0.939			
	ATT3	0.925			
Subjective norm (SN)	SN1	0.884	0.869	0.920	0.793
	SN2	0.896			
	SN3	0.892			
Perceived behavioral control (PBC)	PBC1	0.874	0.840	0.904	0.758
	PBC2	0.888			
	PBC3	0.849			
Compatibility (COM)	COM1	0.872	0.857	0.913	0.778
	COM2	0.899			
	COM3	0.875			
Living habits (LH)	LH1	0.916	0.905	0.941	0.841
	LH2	0.946			
	LH3	0.889			
Intention to adopt ESHS (INT)	INT1	0.913	0.887	0.930	0.815
	INT2	0.898			
	INT3	0.898			

is confirmed. Average variance extracted (AVE) and factor loadings are adopted to examine convergent validity. Fornell and Larcker (1981) proved that if the values of AVE exceed 0.50, the convergent validity is good. Table 2 indicates that the minimum value of the factor loading is 0.771. The values for AVE range from 0.694 to 0.863, verifying the convergent validity of the constructs. Furthermore, with regard to discriminant validity, the correlation between constructs should be less than the square root of the AVE. On the basis of the test results (Table 3), we conclude that the discriminant validity of this research is satisfactory.

4.2 Structural model analysis

The structural equation model was used to investigate the relationship among the constructs. Path analysis was conducted to assess the path coefficients in this model through Smart-PLS 3.0. Empirical results are shown in Table 4. The results indicate that attitude ($\beta = 0.190$, $p < 0.001$) exerts significant and positive effect on consumers' intention toward ESHS, thus, H1 is supported. Perceived behavioral control ($\beta = 0.227$, $p < 0.01$) significantly and positively influences consumers' intention toward ESHS, H3 is also consistent with the original judgment. However, subjective norm fails to play a role in consumers' intention, H2 is not in the expected direction. Environmental knowledge positively affects consumers' attitude ($\beta = 0.349$, $p < 0.001$) and intention ($\beta = 0.084$, $p < 0.01$) toward ESHS. Accordingly, H4, H5 are supported. In addition, ambiguity tolerance also positively exerts influence on consumers' attitude ($\beta = 0.276$, $p < 0.001$) and intention ($\beta = 0.147$, $p < 0.001$) under ESHS context. Thus, H6 and H7 are in the expected direction. And compatibility ($\beta = 0.154$, $p < 0.001$) exerts positive effect on consumers' intention toward adopting ESHS, H8 is confirmed. However, living habits ($\beta = -0.300$, $p < 0.001$) negatively influence consumers' intention toward adopting ESHS, H9 is also supported.

5 Discussion, implications and limitations

5.1 Discussion

The research uses the extended TPB model to explore consumer intention to adopt ESHS. The results confirmed that consumer intention to adopt ESHS is predicted by attitude and perceived behavioral control toward ESHS. The results are in line with previous studies, which have verified the positive influences of attitude and perceived behavioral control on consumer intention (Yadav and Pathak 2016; Chen and Hung 2016; Wang et al. 2018b). If users hold a positive evaluation toward ESHS, then they are likely to embrace such services. However, subjective norm does not play an important role in the adoption intention of consumers as hypothesized. This finding is inconsistent with published works that have verified the positive role of subjective norm on the adoption intention of consumers (Wang et al. 2014; Ru et al. 2019). ESHS are relatively private, and the opinions of important people are less likely to influence consumer

Table 3 Mean and standard deviation of the constructs

Construct	Mean	SD	EK	AT	ATT	SN	PBC	COM	LH	INT
Environmental knowledge (EK)	3.59	1.08	**0.833**							
Ambiguity tolerance (AT)	3.26	1.25	0.563	**0.894**						
Attitude (ATT)	3.90	1.17	0.406	0.362	**0.929**					
Subjective norm (SN)	3.78	1.07	0.428	0.484	0.425	**0.891**				
Perceived behavioral control (PBC)	3.79	1.09	0.303	0.263	0.322	0.215	**0.871**			
Compatibility (COM)	3.84	1.02	0.226	0.366	0.423	0.322	0.263	**0.882**		
Living habits (LH)	2.59	1.26	− 0.456	− 0.415	− 0.332	− 0.356	− 0.372	− 0.326	**0.917**	
Intention to adopt ESHS (INT)	3.71	1.06	0.223	0.325	0.236	0.334	0.362	0.416	− 0.352	**0.903**

The diagonal (bold) elements are the square roots of AVEs, and the off-diagonal elements are the correlations among constructs

Table 4 Results of structural model testing

Path	Path coefficient	t-value	Hypothesis	Results
Path 1: ATT → INT	0.190	5.546***	H1	Supported
Path 2: SN → INT	0.013	0.387	H2	Not supported
Path 3: PBC → INT	0.227	5.758***	H3	Supported
Path 4: EK → ATT	0.349	4.842***	H4	Supported
Path 5: EK → INT	0.084	2.204**	H5	Supported
Path 6: AT → ATT	0.276	3.959***	H6	Supported
Path 7: AT → INT	0.147	4.910***	H7	Supported
Path 8: COM → INT	0.154	4.154***	H8	Supported
Path 9: LH → INT	-0.300	13.196***	H9	Supported

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

decisions compared with public goods or services. Moreover, the sample of this questionnaire survey mostly consists of young people, and they are less bound by group pressure.

The results also indicate that environmental knowledge exerts a positive influence on the attitude and intention of consumers toward ESHS, which is line with published literatures (Steg and Vlek 2009; Pothitou et al. 2016; Mohiuddin et al. 2018). If consumers have knowledge of environmental protection, they can determine that smart home services are eco-friendly solutions that mitigate environmental issues. Egoistic consumers are less likely to switch altruistic values to eco-friendly behavioral intentions and behaviors. Under the context of ESHS, if consumers have more environmental knowledge, they are more likely to adopt ESHS. Furthermore, this research verifies a significant and positive effect of ambiguity tolerance on consumer intention toward adopting ESHS. The high ambiguity tolerance of consumers increases their likelihood to adopt ESHS. Eco-friendly smart homes are new high-tech services, and many consumers have not been previously exposed to such services. Thus, they may perceive time risk, security risk, and performance risk toward adopting ESHS. If consumers' ambiguity tolerance is higher, they have a higher tolerance for the perceived uncertainty associated with using ESHS, the more likely they are to adopt ESHS.

This study confirms that compatibility positively influences consumer intention toward ESHS, and the result verifies the claims of previous studies (Susanto and Goodwin 2013; Hubert et al. 2019). The consistency of ESHS with existing systems is an important consideration for users to adopt such services. Moreover, compatibility reduces unnecessary installations and use risks of ESHS, thus increasing the psychological trust of consumers. If the compatibility of ESHS is higher, there are less barriers for consumers to use ESHS. However, living habits play a negative role in consumers' adoption intention under ESHS context. ESHS are novel for most consumers, and the new adoption will bring changes to their living habits. If they resist lifestyle changes, consumers are less likely to accept ESHS.

5.2 Implications

This research provides a new perspective on the adoption intention of consumers instead of the technological aspects ESHS. On the basis of the model verification results and research discussion in this study, several implications can be presented to ESHS providers to promote the application of ESHS and to create economic and social values. Attitude exerts significant and positive effect ($\beta = 0.190$, $p < 0.001$) on consumers' intention toward adopting ESHS. Governments can introduce smart equipment into public places to increase the publicity and guidance of smart home life concepts. ESHS suppliers can also establish smart home experience hall, and increase the advertising of smart home, which is conducive to consumers' formation of good attitude toward smart home.

Perceived behavioral control exerts positive effect ($\beta = 0.227$, $p < 0.01$) on consumers' intention under ESHS context. Governments can adopt reasonable policy measures to set guiding prices for ESHS. Reasonable prices and wider access promote the increased behavioral control of consumers. In addition, ESHS manufacturers can expand the supply channels of smart home and increase the consumers' contact with smart home. And whether it is online or offline sales channels, suppliers should guide consumers to use ESHS. This series of measures help to the enhancement of consumer's perceived behavioral control of ESHS.

Environmental knowledge significantly and positively influences ($\beta = 0.084$, $p < 0.01$) consumers' intention toward adopting ESHS. Government are supposed to increase the publicity of environmental protection knowledge and encourage more consumers to adopt energy-saving products or services. These initiatives help to increase the environmental knowledge of consumers. At the same time, ambiguity tolerance also positively affects ($\beta = 0.147$, $p < 0.001$) consumers' intention toward adopting ESHS. Considering the uncertain situation that consumers may face, providers can ease the resistance of consumers to ESHS by providing reliable products and excellent after-sale services. In addition, the perceived risks and insufficient understanding of consumers toward eco-friendly products and services are the sources of ambiguity. Providers should improve technical safety to eliminate consumer concerns.

Given that compatibility is an important consideration for consumers to adopt ESHS ($\beta = 0.154$, $p < 0.001$), providers should strive to improve the level of adaptability of ESHS to existing systems. In addition, living habits negatively influence ($\beta = -0.300$, $p < 0.001$) consumers' intention to adopt ESHS. Consumers who are used to their existing lifestyle and state are more reluctant to try new products or services. To encourage more consumers to adopt ESHS, living habits and preferences of potential consumers should be fully investigated and understood to reduce consumers' discomfort in the use of such services.

This paper also has some theoretical significance. First, this study is the one of the first to explore consumers' intention toward adopting ESHS in China, which expands the regional research on consumers' acceptance toward ESHS. Second, this study innovatively uses TPB theory to explore consumers' intention to adopt ESHS, while previous studies mostly use TAM theory to investigate consumers' adoption intention. Third, TPB has been criticized for being a rational theory, the integration

of environmental knowledge and into TPB can further consider the impact of irrational factor on consumers' acceptance toward new products or services. In addition, there are few studies exploring the influence of ambiguity tolerance on consumers' decision-making, the integration of ambiguity tolerance also includes the personal characteristic into TPB, which can further enhance the explanatory power of TPB. Moreover, this study provides a reference for further exploring the consumer behavior mechanism toward adopting ESHS in future.

5.3 Limitations and further research direction

This study provides a comprehensive picture in understanding consumer intention toward ESHS. However, several limitations need to be further addressed in future research. First, 53.9% of the respondents are between the ages of 20 and 29, while 52.6% of the respondents have earned a junior college or university degree. The distribution of age and educational background should be further balanced in later studies. Second, this study only explores the adoption intention of consumers toward ESHS. Although intention is an important indicator of behavior, a gap exists between the behavioral intention and actual behavior. Third, additional influencing factors should be explored more deeply than be limited to the variables added in this article. Finally, if this research can be conducted in different countries, scholars can further explore cultural differences in the context of ESHS adoption intention.

Appendix A

Measurement items and constructs.

Constructs and measurement items
Attitude
A1: It would be a wonderful idea to adopt eco-friendly smart home services
A2: I would have positive feelings toward eco-friendly smart home services
A3: It is better for me to adopt eco-friendly smart home services, as opposed to other services
Subjective norm
SN1: People who influence my behavior think that I should adopt eco-friendly smart home services
SN2: People who are important to me think that I should adopt smart home services
SN3: People whose opinions are valued to me would prefer that I should adopt eco-friendly smart home services
Perceived behavioral control
PBC1: I will be able to adopt eco-friendly smart home services
PBC2: Adopting eco-friendly smart home services is entirely within my control
PBC3: I have resources, time, and opportunities to adopt eco-friendly smart home services
Environmental knowledge
EK1: I know more about recycling than the average person
EK2: I understand the environmental phrases and symbols on product packaging
EK3: I know how to select products and packages that reduce the amount of waste ending up in landfills

Constructs and measurement items
EK4: I am very knowledgeable about environmental issues
EK5: Using environmentally sustainable products is a primary means to reduce pollution
Ambiguity tolerance
AT1: I am tolerant of ambiguous situations
AT2: I enjoy tackling problems that are complex enough to be ambiguous
AT3: I prefer a situation in that there is some ambiguity
Compatibility
COM1: Adopting eco-friendly smart home services is in compatible with my life
COM2: Adopting eco-friendly smart home services fits well with the way I like to manage my house
COM3: Adopting eco-friendly smart home services fits well with the way I want to interact with the components in my house
Living habits
LH1: Compared with the eco-friendly issue, I pay more attention to the comforts of life
LH2: I do not want to change my living habits for environmental protection
LH3: Eco-friendly issue has a great impact on my life, and disrupts my living habits
Intention to use
INT1: I recommend others to adopt eco-friendly smart home services for their houses
INT2: I am likely to continually adopt eco-friendly smart home services in my life
INT3: I intend to adopt eco-friendly smart home services as much as possible

References

Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50(2):179–211
Alam MR, Reaz MBI, Ali MAM (2012) A review of smart homespast, present, and future. IEEE Trans Syst Man Cybern Part C Appl Rev 42(6):1190–1203
Bhattacherjee A (2000) Acceptance of e-commerce services: the case of electronic brokerages. IEEE Trans Syst Man Cybern Part A-Syst Humans 30(4):411–420
Buckley MR, Cote JA, Comstock SM (1990) Measurement errors in the behavioral sciences: the case of personality/attitude research. Edu Psychol Meas 50(3):447–474
Budner S (1962) Intolerance of ambiguity as a personality variable. J Pers 30:29–50
Chen SC, Hung CW (2016) Elucidating the factors influencing the acceptance of green products: an extension of theory of planned behavior. Technol Forecast Soc Chang 112:155–163
Chen A, Peng N (2012) Green hotel knowledge and tourists staying behaviors. Ann Tour Res 39(4):2211–2216
Cheng EWL (2018) Choosing between the theory of planned behavior (TPB) and the technology acceptance model (TAM). Edu Tech Res Dev 67(1):21–37
Chong AYL, Ooi KB, Lin B, Tang SY (2009) Influence of interorganizational relationships on SMEs' e-business adoption. Internet Res 19(3):313–331
Davis FD, Bagozzi RP, Warshaw PR (1989) User acceptance of computer technology: a comparison of two theoretical models. Manag Sci 35(8):982–1003
Diekmann A, Preisendrfer P (2003) Green and greenback: the behavioral effects of environmental attitudes in low-cost and high-cost situations. Ration Soc 15(4):441–472
Dou K, Yang J, Wang L-X, Li J-B (2022) Theory of planned behavior explains males' and females' intention to receive COVID-19 vaccines differently. Hum Vaccin Immunother 18(5):2086393
Dunlap RE, Van Liere KD, Mertig AG, Jones RE (2000) 'New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. J Soc Issues 56(3):425–442

Flamm B (2009) The impacts of environmental knowledge and attitudes on vehicle ownership and use. Transp Res Part D-Transp Environ 14(4):272–279
Fornell C, Larcker DF (1981) Structural equation models with unobservable variables and measurement error: algebra and statistics. J Mark Res 18(1):382–388
Fu L, Sun Z, Zha L, Liu F, Jing X (2020) Environmental awareness and pro-environmental behavior within China's road freight transportation industry: moderating role of perceived policy effectiveness. J Clean Prod 252:119796
Furnham A, Marks J (2013) Tolerance of ambiguity: a review of the recent literature. Psychology 4(9):717–728
Geissdoerfer M, Savaget P, Bocken NMP, Hultink EJ (2017) The circular economy a new sustainability paradigm? J Clean Prod 143:757–768
Hammond JA, Hancock J, Martin MS, Jamieson S, Mellor DJ (2017) Development of a new scale to measure ambiguity tolerance in veterinary students. J Vet Med Educ 44(1):38–49
Hazen BT, Overstreet RE, Jones-Farmer LA, Feild HS (2012) The role of ambiguity tolerance in consumer perception of remanufactured products. Int J Prod Econ 135(2):781–790
Hidayat-ur-Rehman I, Alzahrani S, Rehman MZ, Akhter F (2022) Determining the factors of m-wallets adoption. A twofold SEM-ANN approach. PLoS ONE 17(1):e0262954
Hubert M, Blut M, Brock C, Zhang RW, Koch V, Riedl R (2019) The influence of acceptance and adoption drivers on smart home usage. Eur J Mark 53(3):1073–1098
Jena SK, Sarmah S (2015) Measurement of consumers' return intention index towards returning the used products. J Clean Prod 108:818–829
Kim Y, Park Y, Choi J (2017) A study on the adoption of IoT smart home service: using value-based adoption model. Total Qual Manag Bus Excell 28(9–10):1149–1165
Lee YH, Hsieh YC, Hsu CN (2011) Adding Innovation Diffusion Theory to the Technology Acceptance Model: Supporting Employees' Intentions to use E-Learning Systems. Educ Technol Soc 14(4):124–137
Li Q, Wu M (2020) Tourists' pro-environmental behaviour in travel destinations: benchmarking the power of social interaction and individual attitude. J Sustain Tour 28(9):1371–1389
Liu W, Zhang J, Bluemling B, Mol APJ, Wang C (2015) Public participation in energy saving retrofitting of residential buildings in China. Appl Energy 147:287–296
Liu P, Teng M, Han C (2020) How does environmental knowledge translate into pro-environmental behaviors?: The mediating role of environmental attitudes and behavioral intentions. Sci Total Environ 728:138126
Maichum K, Parichatnon S, Peng KC (2016) Application of the extended theory of planned behavior model to investigate purchase intention of green products among thai consumers. Sustainability 8(10):1–20
Marikyan D, Papagiannidis S, Alamanos E (2019) A systematic review of the smart home literature: a user perspective. Technol Forecast Soc Chang 138:139–154
Mashal I, Shuhaiber A (2019) What makes Jordanian residents buy smart home devices? Kybernetes 48(8):1681–1698
Matsumoto M, Chinen K, Endo H (2017) Comparison of US and Japanese consumers' perceptions of remanufactured auto parts. J Ind Ecol 21(4):966–979
Mohagheghi P, Gilani W, Stefanescu A, Fernandez MA (2013) An empirical study of the state of the practice and acceptance of model-driven engineering in four industrial cases. Empir Softw Eng 18(1):89–116
Mohiuddin M, Al Mamun A, Syed F, Mehedi Masud M, Su Z (2018) Environmental knowledge, awareness, and business school students' intentions to purchase green vehicles in emerging countries. Sustainability 10(5):1534
Montano DE, Kasprzyk D (2015) Theory of reasoned action, theory of planned behavior, and the integrated behavioral model. Health Behav: Theory, Res Pract 70(4):95–124
Moslehpour M, Chau KY, Du L, Qiu R, Lin C-Y, Batbayar B (2022) Predictors of green purchase intention toward eco-innovation and green products: evidence from Taiwan. Econ Res-Ekonomska Istrazivanja. https://doi.org/10.1080/1331677X.2022.2121934
Paetz AG, Elisabeth D, Wolf F (2012) Smart homes as a means to sustainable energy consumption: a study of consumer perceptions. J Consum Policy 35(1):23–41
Pal D, Funilkul S, Vanijja V, Papasratorn B (2018) Analyzing the elderly users' adoption of smart-home services. IEEE Access 6:51238–51252

Park HJ, Lee HS (2014) Product smartness and use-diffusion of smart products: the mediating roles of consumption values. Asian Soc Sci 10(3):54–61
Pothitou M, Hanna RF, Chalvatzis KJ (2016) Environmental knowledge, pro-environmental behaviour and energy savings in households: an empirical study. Appl Energy 184:1217–1229
Ru X, Qin H, Wang S (2019) Young people's behaviour intentions towards reducing PM2.5 in China: extending the theory of planned behaviour. Resour Conserv Recycl 141:99–108
Schill M, Godefroit-Winkel D, Diallo MF, Barbarossa C (2019) Consumers' intentions to purchase smart home objects: Do environmental issues matter? Ecol Econ 161:176–185
Shin J, Park Y, Lee D (2018) Who will be smart home users? An analysis of adoption and diffusion of smart homes. Technol Forecast Soc Chang 134:246–253
Shuhaiber A, Mashal I (2019) Understanding users' acceptance of smart homes. Technol Soc 58:101110
Steg L, Vlek C (2009) Encouraging pro-environmental behaviour: an integrative review and research agenda. J Environ Psychol 29(3):309–317
Sun H, Teh P-L, Linton JD (2018) Impact of environmental knowledge and product quality on student attitude toward products with recycled/remanufactured content: implications for environmental education and green manufacturing. Bus Strateg Environ 27(7):935–945
Susanto TD, Goodwin R (2013) User acceptance of SMS-based e-government services: differences between adopters and non-adopters. Gov Inf Q 30(4):486–497
Taylor S, Todd P (1995) Assessing IT usage: the role of prior experience. Manag Inf Syst Q 19(4):561–570
Wang Z, Zhang B, Li G (2014) Determinants of energy-saving behavioral intention among residents in Beijing: extending the theory of planned behavior. J Renew Sustain Energy 6(5):711–720
Wang J, Wang S, Wang Y, Li J, Zhao D (2018a) Extending the theory of planned behavior to understand consumers' intentions to visit green hotels in the Chinese context. Int J Contemp Hosp Manag 30(8):2810–2825
Wang S, Wang J, Yang F, Wang Y, Li J (2018b) Consumer familiarity, ambiguity tolerance, and purchase behavior toward remanufactured products: the implications for remanufacturers. Bus Strateg Environ 27(8):1741–1750
Wang C, Teo TSH, Liu L (2020) Perceived value and continuance intention in mobile government service in China. Telemat Inform 48:101348
Wilson C, Hargreaves T, Hauxwell-Baldwin R (2015) Smart homes and their users a systematic analysis and key challenges. Pers Ubiquit Comput 19(2):463–476
Xu H, Tracey TJG (2015) Ambiguity tolerance with career indecision: an examination of the mediation effect of career decision-making self-efficacy. J Career Assess 23(4):519–532
Yadav R, Pathak GS (2016) Young consumers' intention towards buying green products in a developing nation: extending the theory of planned behavior. J Clean Prod 135:732–739
Yang H, Lee H, Zo H (2017) User acceptance of smart home services: an extension of the theory of planned behavior. Ind Manag Data Syst 117(1):68–89
Yang H, Lee W, Lee H (2018) IoT smart home adoption: the importance of proper level automation. J Sens 2018:1–11
Yazdanpanah M, Forouzani M (2015) Application of the theory of planned behaviour to predict iranian students' intention to purchase organic food. J Clean Prod 107:342–352
Zhang W, Liu L (2021) Unearthing consumers' intention to adopt eco-friendly smart home services: an extended version of the theory of planned behavior model. J Environ Plan Manag. https://doi.org/10.1080/09640568.2021.1880379