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Consumer's intention to use and recommend smart home technologies: The role of environmental awareness

Laura Ferreira, Tiago Oliveira, Catarina Neves *

NOVA Information Management School (NOVA IMS), Universidade Nova de Lisboa, Campus de Campolide, Lisboa, Portugal

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ABSTRACT

Environmental sustainability is gathering further importance in various fields, including our homes. Smart home technologies are increasingly contributing to more efficient energy consumption, but their adoption rate remains lower than expected. This study proposes a theoretical model based on the extended unified theory of acceptance and use of technology (UTAUT2) to explore the effects of environmental awareness on individual intentions and behaviour toward smart home technologies. Data collected from 255 individuals were used to test the research model. The findings provide meaningful insights for researchers, marketers, and policymakers, by highlighting newer environmental approaches to these technologies.

1. Introduction

Smart home technology is expected to become omnipresent in households in the near future [1]. Smart homes are residences equipped with a variety of networked sensors, monitors, interfaces, appliances, and devices [2–4]. Accordingly, users can customize their household environment via automation as well as localized and remote controls [4–6]. Smart homes provide multiple benefits aimed at improving people's lives, linked with comfort, entertainment, wellness, finance, safety, security, and the environment [5,7–10], enabling numerous avenues of research.

The smart home market is soaring as demand increases. Leading IT companies like Google, Amazon, and Samsung are entering this new, competitive market, rushing to expand their range of smart home products and services [11–13]. Companies outside the IT field, such as IKEA, also realise the potential value of these disruptive innovations [14, 15]. In 2019, IKEA announced a new division dedicated to smart homes exclusively, comprising, for instance, intelligent lamps and curtains operated by voice commands. The global market for smart homes is forecast to grow to more than 53 billion U.S. dollars by 2022, while the number of smart homes is expected to surpass the 300 million USD mark by 2023 [6,16].

The rapid advances in smart home technology over the past few years have broadened its benefits and made it possible to reach mainstream markets and user segments [5]. Beyond comfort and security, one of the main advantages of smart home technologies highlighted across smart home research is the optimisation of energy consumption [5,7,13,17]. An expanding range of technologies allows consumers to monitor and control their energy usage at home, such as smart thermostats, lights, plugs, switches, and appliances [13,18]. Therefore, these smart objects have increased potential to foster sustainability through efficient energy consumption at an individual level [5,13]. This environmental characteristic of smart homes is the main focus of this study since its potential is still understudied, particularly in the context of smart homes' adoption [18]. In fact, there is a research gap in how this pro-environmental characteristic of smart home technologies might impact consumer behaviour [18]. If we investigate the most used and well-known acceptance/adoption models, none of them includes an environmental dimension. The pressing need to include this dimension only occurred recently. Therefore, to fill this gap, this research expects to deepen that understanding with the analysis of environmental awareness' direct and moderating effects within the scope of smart home adoption.

Despite all the potential and prospective growth, the spread of smart home technology, in general, has been slower than expected among consumers [4,11–13]. Thus, users' perceptions of smart homes need to be deeply investigated to accelerate their adoption and diffusion [5,7, 12]. An intention-behaviour gap has been identified in recent research, meaning there is a lacuna between consumers' intentions and their actual behaviour towards the purchase or use of smart home technologies [19]. Understanding the adoption process beyond intentions is, therefore, essential. Schill et al. [19] state that analysing the energy management role in smart home adoption requires a conceptual model

* Corresponding author.
E-mail addresses: m20170318@novaims.unl.pt (L. Ferreira), toliveira@novaims.unl.pt (T. Oliveira), cneves@novaims.unl.pt (C. Neves).

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of the adoption process that represents the full customer journey. Thus, this work intends to study consumer intentions, actual behaviour and extending it to a post-adoption phase – the intention to recommend the service/technology.

The contribution of this research is threefold. First, to expand the knowledge about the adoption process of smart home technologies by assessing the actual frequency of use of various smart home technologies for the first time, together with intentions to use and recommend them, using the UTAUT2 as the baseline framework. Analysing these variables will give companies valuable insights into consumer intentions and behaviour toward smart home products, which is needed to increase their adoption and consequently create more market value [10]. Second, the major contribution of this study is the inclusion of environmental awareness in the research model, both as a predictor and a moderating variable, to assess its possible effects on the intentions to use and recommend and on use behaviour regarding smart home technologies. With the growing attention to sustainable consumption in general [18], the analysis of environmental awareness intends to broaden the research of smart homes from an environmental perspective since, to the best of our knowledge, the moderating effects of this variable have never been tested before. Ultimately, this study expects to help researchers and organisations improve their understanding of the factors influencing the acceptance and use of smart home technology.

The study is structured as follows. The next section provides a theoretical background on the concepts of smart home technology, IT adoption, and environmental awareness. Then, the foundations for the research model and the derived hypotheses are presented. Afterwards, the research methodology is described, followed by the data analysis and results. Finally, the findings are discussed, highlighting the implications for theory and practice, and proposing possible future research.

2. Theoretical background

2.1. Smart home technology

Nowadays, smart objects are ubiquitous and increasingly more united with each other and people [1,15]. This network of Internet-connected objects is called the Internet of Things (IoT) [6,20]. In generic terms, smart homes refer to the applicability of IoT technology to the residential environment, and they are leveraging its potential [2,12,20]. According to the reviewed literature, a smart home can be defined in more detail as a residence equipped with connected electrical appliances and devices that can be remotely monitored and controlled and provide services and automation tailored to the inhabitants' needs [2,4,5].

The main goal of smart homes and IoT, in general, is to improve the quality of life [1,7,11,21]. There are smart home devices that enable users to execute tasks before arriving home and to lock or unlock doors and windows when on vacation [7–9]. Home systems, such as air conditioning, lighting, and heating, can be automated and manipulated according to the user's preferences and habits, which can help reduce energy consumption [5–7,9]. In fact, home automation systems represent the most common use of IoT for energy and environmental sustainability [21].

When at home, smart devices can be instantly triggered through simple voice commands or by using the touchscreen of a tablet or a smartphone [7]. Voice assistants, such as Alexa and Google Assistant, are increasingly gaining popularity, with the number of households holding at least one intelligent voice interface expected to reach 6.4 billion by 2023 [12,14].

2.2. Adoption models

Table 1 presents empirical studies that have focused on the adoption of smart home technology. Prior research is mainly quantitative, primarily resorting to structural equation modelling techniques. However,

Table 1
Empirical studies on smart homes' adoption.

Authors	IT	Theory	Drivers	Data
[2]	Adoption of IoT smart home service	VAM, TAM, UTAUT, and ELM	Perceived sacrifice, perceived benefit, perceived value, attitude, intention to use, and variety-seeking	269 survey responses from individuals
[11]	Adoption of smart home services	TAM	TAM: perceived usefulness, perceived ease of use, attitude, and behavioural intention Others: universal connectivity, automation, self-capability, compatibility, subjective norm, satisfaction, enjoyment, affordability, and security/privacy	239 survey responses from elderly individuals
[20]	Acceptance of IoT in a smart home environment	TAM	TAM: perceived usefulness, perceived ease of use, attitude, and intention to use Others: perceived enjoyment, perceived connectedness, perceived compatibility, perceived control, and perceived cost	15 professors and experts with expertise in the ICT market; 1057 survey responses from individual users
[12]	Adoption and diffusion of smart homes	TAM	TAM: perceived usefulness, perceived ease of use, attitude, and intention to use Others: compatibility and privacy	Adoption: 310 survey responses from South Korean smartphone users Diffusion: 2113 survey responses from smart home users
[19]	Intention to purchase smart home objects	VBN, TAM, and TPB	VBN: environmental beliefs and environmental concern TAM: perceived usefulness TPB: purchase intentions Others: success and happiness	641 survey responses from French individuals
[22]	Smart home acceptance	UTAUT2	UTAUT2: performance expectancy, effort expectancies, social influence, facilitating conditions, hedonic motivation, price value, and habit Others: safety and security, health, convenience and comfort, sustainability, and personal innovativeness	316 survey responses from French students of business and engineering schools

Notes: Value-based adoption model (VAM); Technology acceptance model (TAM); Unified theory of acceptance and use of technology (UTAUT);

Elaboration likelihood model (ELM); Value-belief-norm theory (VBN); Theory of planned behaviour (TPB); Extended unified theory of acceptance and use of technology (UTAUT2).

more recently, academics are starting to adopt a mixed-methods approach, including qualitative and quantitative techniques, to increase the understanding of the phenomenon under study. Overall, variables like performance and effort expectancy, social influence or habit have been identified as drivers for the adoption of smart home technologies, while factors like privacy concerns and safety have been investigated as barriers. More recently, some studies have explored smart home technologies' potential to promote sustainability [19,22] due to their ability to provide energy savings [17]. For example, Schill et al. [19] examined the moderating effects of materialism, measured by success and happiness, on the relationship between environmental concern and intentions to purchase smart home objects. The current study contributes to this area of research regarding environmental perceptions of smart homes by investigating the different effects of environmental awareness on the technology's acceptance and use.

The Technology Acceptance Model (TAM) [23] is directly or indirectly applied in all of the papers shown in Table 1, which is explained by its adequacy for analysing the adoption patterns of new technologies or services. The UTAUT2 is another theory about IT adoption that identifies seven constructs as determinants of behavioural intention and/or use behaviour: (i) performance expectancy, (ii) effort expectancy, (iii) social influence, (iv) facilitating conditions, (v) hedonic motivation, (vi) price value, and (vii) habit. The last three constructs (v, vi, and vii) were an addition to the baseline unified theory of acceptance and use of technology (UTAUT), which adjusted the model to a consumer use setting [24]. Additionally, it is also possible to conclude that most researchers find that theories of acceptance and/or use of technologies, like TAM and UTAUT2, might not be enough to comprehend the phenomena of smart home technologies. Therefore, many authors have implemented variables like privacy, automation, safety or environmental beliefs in their models. These have also been proven to be important drivers of smart home technologies' adoption and use, as shown in the fourth column of Table 1.

There are four main reasons why UTAUT2 was considered the most suitable adoption model at the individual level to investigate the adoption of smart home technologies in this study. Firstly, UTAUT2 is an extension of UTAUT, which, itself, is already a complete framework since it is based on eight well-known theories concerning IT acceptance, including the theory of planned behaviour (TPB) and TAM [25]. Such a combination of theories is relevant because it offers a deeper insight into the topic of adoption [26]. Secondly, UTAUT2 not only inherits the great qualities of UTAUT but also extends its generalisability from an organisational context to a consumer one [24].

Moreover, UTAUT2 can explain 74% and 52% of the variance in behavioural intention and use of technology, respectively [24], which is more than what UTAUT obtained in the Venkatesh et al. [25] study (70% and 48%, respectively). Lastly, considering the revised literature, both UTAUT frameworks are still rarely found in research about the adoption of smart home technology. Additionally, the use behaviour construct from UTAUT2 has never been tested before in the same context. Therefore, UTATUT2 seems suitable as a grounding theory. Nevertheless, as stated earlier, smart home technologies cannot be characterised in the same way as other technologies, given their capability to collect data and, for example, to contribute to a sustainable environment. Therefore, previous authors have also used variables like privacy, health and safety or environmental beliefs (see Table 1). However, the possible direct but predominantly indirect/moderating impact of the environmental dimension is still lacking in the literature. Hence, the next section will focus on the environmental aspect of smart home technologies.

2.3. Environmental benefits of smart home technology

Research on sustainable consumer behaviour has recently been extended to a wide range of industries, such as automobiles, fashion, food, and services [18,27]. From an eco-friendly perspective, this consumption behaviour includes the purchase of products with energy-saving, organic, or pollution-free characteristics [28]. In a residential context, sustainable consumption includes the use of smart technology that can modify household behaviours, reducing the environmental impact of homes [5,18,19]. Hence, the adoption of technologies that promote sustainable behaviours in households, such as energy efficiency, became an area of interest for researchers, marketers, and policymakers [29]. A wide selection of smart home products provides energy savings, including thermostats, plugs, lights, switches, and appliances [13,18,30]. This range of products enables users to monitor and control their consumption of resources, like energy and water, remotely or autonomously, allowing them to achieve efficient resource management at home [13,19]. Accordingly, users can reduce the environmental harm caused by their resource usage at home. For this reason, the authors Schill et al. [19] espouse the existence of environmentally friendly smart home objects. Smart thermostats, as an example of sustainable household technology, allow users to control, monitor and analyse their energy use concerning their heating and/or air conditioning systems [12,13,18].

The energy sector's development is an important factor affecting countries' sustainability and research and innovation [31,32]. The use of smart appliances could result in 3–6% of energy savings across smart refrigerators, room air-conditioners, and washing machines [33]. As a result, smart homes can be part of a future energy-efficient system [4,13]. Energy utility companies and regulatory bodies are investing in smart energy technologies, including smart home systems [13,34].

Previous research has shown that altruistic and pro-environmental motivation are important drivers of the adoption of eco-friendly products and green technologies [18,28,30,35]. Thus, the acceptance and use of smart home technology as an innovative measure to help reduce consumers' environmental impact, is likely to be influenced by their awareness and attitudes towards the environment, as prior studies suggest [19,22]. These studies have analysed environmental variables, such as sustainability, environmental beliefs, and green consumption values (Table 1). Nevertheless, most of them only analyse the impact of environmental factors on smart home acceptance [19,22], and none have studied their moderating effects. Therefore, as presented in the next section, our study tests if the awareness of individuals towards environmental problems influences not only their behavioural intention but also their use behaviour and intention to recommend smart home technologies in direct and moderating ways.

3. Research model

As explained in section *2.2. Adoption models* above, this study proposes a conceptual model based on the UTAUT2 framework introduced by Venkatesh et al. [24]. Intention to recommend was added to the research model as a dependent variable to contribute to a better understanding of the adoption phenomenon. This construct has been used in other studies regarding the adoption of relatively new technologies, such as mobile payments and e-participation [36,37]. Since smart home technologies are relatively recent, their recommendation to others is important to build consumers' trust and value perception regarding the technologies and accelerate their diffusion [37]. Therefore, our study extends the research to a post-adoption stage. Additionally, the research model is complemented by environmental awareness, introduced as an independent variable. According to Marikyan et al. [5], "*smart homes have become the state of the art in the reduction and monitoring of energy usage within a residential setting,*" supporting their benefits for environmental protection. Therefore, this study intends to assess the impact of environmental awareness in a smart home adoption context. The research model is presented in Fig. 1.

The effects of the seven UTAUT2 constructs on behavioural intention were not hypothesised in the research model, since they have already been tested among the previous studies included in Table 1. Furthermore, we want the focus of this model to rely on environmental awareness and its influence on smart home adoption. Nevertheless, the UTAUT2's relationship between behavioural intention and use behaviour has not yet been tested in a smart home consumer context. According to the literature, it is expected that behavioural intention has a significant positive impact on technology use [25]. Thus, it can be hypothesised that:

H1a. Behavioural intention to use smart home technologies will positively influence use behaviour.

3.1. Intention to recommend smart home technologies

Recommendation is an action particularly associated with post-adoption behaviour [38], which in many cases is a strong factor for the successful diffusion of new products and services [37]. Nowadays, consumer recommendations can be easily found on the Internet, including e-commerce websites and social networks. They can lead to the fast dissemination of technologies and be quite persuasive when it comes to the behaviour and attitude of other consumers [37]. In the smart home context, consumers' intention to recommend such technologies has not yet been used in adoption studies, to the best of our knowledge. Suppose consumers intend to use smart home technology or already have experience using it. In that case, they probably believe in their benefits, such as the environmental ones, and as a result, they are likely to recommend them to someone who seeks their advice and/or has the same interests. Thus, it can be postulated that:

H1b. Behavioural intention to use smart home technologies will positively influence the intention to recommend such technologies to others.

H2. The use behaviour of smart home technologies will positively influence the intention to recommend such technologies to others.

3.2. The role of environmental awareness

Recent data from the European Commission suggest that most Europeans believe that protecting the environment is important and that individual consumption is part of that task [19]. Emerging threats like climate change and global warming have increased interest in innovative and energy-efficient technologies, which are vital to reduce energy consumption [5,17,19,39]. Smart home technologies represent one of the innovative measures contributing to reducing individuals' environmental impact [19]. Their energy-saving benefits are made very clear across the literature [5]. In fact, previous research has examined the short and long-term benefits of these solutions (e.g. Refs. [40,41]). More related to the energy-saving perspective, prior studies divided them into two main perspectives. First, the long-term use of smart technologies would lead to a greater awareness of consumption habits and therefore change user behaviour and give rise to environmental sustainability [4,42]. The other is an immediate reduction in electricity expenses in the short term, making it possible to compare tariffs [43]. Therefore, greater control over energy usage on a nationwide scale can decrease carbon emissions [5]. In this context, this study suggests that the more aware individuals are of the current state of the environment, the more likely they will be to adopt smart home technologies as an attempt to act in a more environmentally conscious way [30]. Environmental awareness refers to environmental knowledge and the recognition of environmental problems [44], which may affect environmental behaviours directly and indirectly [30,45]. Noppers et al. [39] have addressed the environmental attributes of smart energy systems as determinants of sustainable innovation adoption, defining such systems as devices that monitor households' energy production and use and deliver feedback about it to their inhabitants. Accordingly, considering the energy benefits that smart home technologies can provide, it can be hypothesised that individuals with higher levels of environmental awareness will be

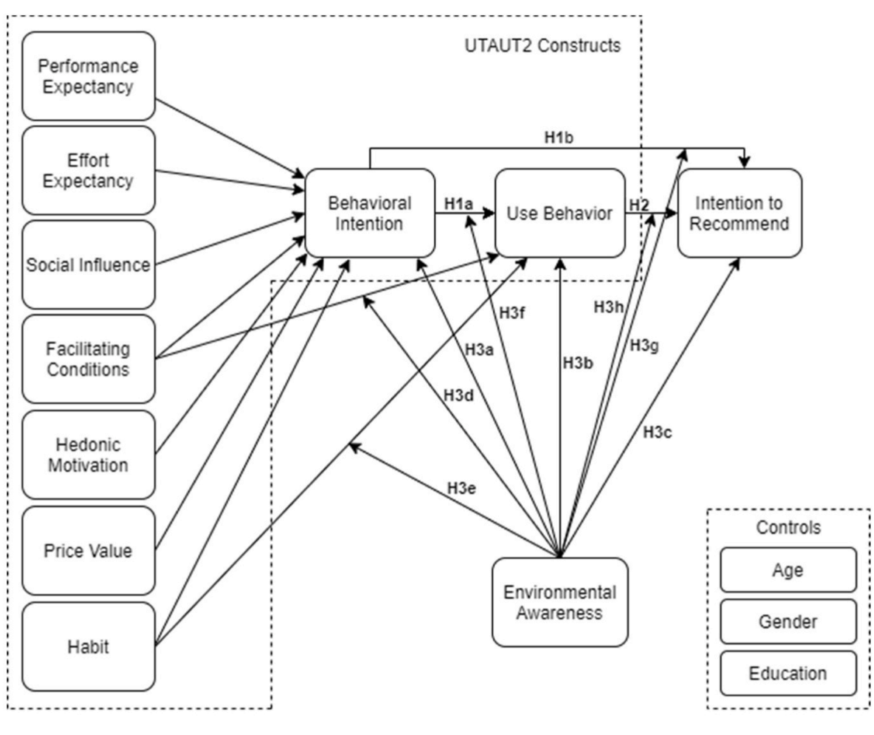

Fig. 1. Research model
Note: an extended unified theory of acceptance and use of technology (UTAUT2).

more willing to purchase and use these technologies. Furthermore, they will be more likely to recommend them to others who are also conscious of environmental problems. Thus:

H3a. Environmental awareness will positively influence behavioural intention to use smart home technologies.

H3b. Environmental awareness will positively influence the use behaviour of smart home technologies.

H3c. Environmental awareness will positively influence the intention to recommend smart home technologies to others.

There is still no evidence in the literature as to how environmental factors may moderate the adoption of smart homes. This study hypothesises that environmental awareness positively moderates the relationships of the smart home technologies' adoption process.

3.2.1. Impact on use behaviour moderated by environmental awareness

Environmental motivations are capable of changing consumers' behaviour [46], and that change will be more likely to happen if they have the necessary conditions [25]. Specifically, environmentally aware consumers need to have the right resources, including knowledge and support, to use smart home technologies properly. Otherwise, consumers might feel they are just wasting resources, which can go against their environmental values and negatively influence their use behaviour. Therefore, facilitating conditions will have a more substantial effect on use behaviour for more environmentally aware individuals:

H3d. Environmental awareness will positively moderate the relationship between facilitating conditions and use behaviour.

Habit, as one of the UTAUT2 predictors of use behaviour, alludes to intentions that are stored in the conscious mind of the consumer due to learning and repeated behaviour, which in turn result in automatic behaviour [47–49]. Smart home technologies are especially interconnected with users' preferences and habits of everyday life, as they provide the automation of domestic and routine tasks [7,9]. These technologies enable users, for example, to set up routines, such as automatically turning lights and appliances on or off at specific hours [13]. Smart thermostats will autonomously adapt rooms' temperatures according to users' needs, preventing them from consciously thinking about those tasks. Thus, consumers will increasingly get used to having these technologies at home, as they will start to blend them into their everyday lives, with the capacity to provide daily energy consumption reductions. This background leads to the hypothesis that habit will play a stronger role in use behaviour for consumers who are more environmentally aware.

H3e. Environmental awareness will positively moderate the relationship between habit and use behaviour.

The active promotion of green product innovation contributes to reducing environmental pollution [50]. In general, concern for the environment may lead to a more conscious consumption lifestyle and influence products' purchase intentions [19]. Previous research has argued the potential influence of environmental concern on consumers' intentions to adopt green technologies and innovations, such as alternative fuel vehicles [39,51]. The intention to use smart home technologies, which belong to green innovations [19], may, therefore, be more important for explaining use behaviour when consumers are environmentally aware:

H3f. Environmental awareness will positively moderate the relationship between behavioural intention and use behaviour.

3.2.2. Impact on intention to recommend moderated by environmental awareness

The intention of consumers to recommend smart home technologies is likely to be directly and positively influenced by their use intentions and behaviour (see section *3.2.* Intention to recommend smart home technologies), as well as by their environmental awareness. In addition to analysing the direct effect, this study also hypothesises that environmental awareness will moderate the impact of behavioural intention and use behaviour on intention to recommend. Moreover, the effect will be stronger for environmentally aware individuals:

H3g. Environmental awareness will positively moderate the relationship between behavioural intention and intention to recommend.

H3h. Environmental awareness will positively moderate the relationship between use behaviour and intention to recommend.

4. Research methodology

4.1. Measurement

An online survey was conducted to collect the data needed to evaluate the research model. The constructs in the questionnaire were adapted from published literature and measured using a seven-point numerical scale, ranging from "1 – Strongly disagree" to "7 – Strongly agree", except for use behaviour, whose scale ranged from "1 – Never" to "7 – Every time I need it". The survey instrument was first developed in English and afterwards independently translated into Portuguese by a research member and then translated back to English by a different translator to ensure translation equivalence [52].

4.2. Data collection

A pilot survey of both versions (English and Portuguese) was carried out with a total of 33 responses. Thus, it was possible to assess that no changes in structure or content were needed. The main survey of both Portuguese and English versions was shared online, namely on social media groups and forums related to the topic of smart homes, between August 2019 and January 2020. The survey was therefore open to all respondents regardless of country and prior knowledge on the topic. However, a special appeal was made to obtain responses from smart home users or people with some background on the subject. Additionally, smart home technologies were briefly introduced at the beginning of the questionnaire, with a short explanation of the purpose of the research. A total of 381 responses were obtained, 255 of which (67%) were considered to be valid and complete responses.

Concerning the gender of the individuals, 127 are male (50%), and 128 are female (50%). The average age is 30 years old. A total of 191 respondents (75%) are 34 years old or younger. Regarding their education level, 48% have a Bachelor's degree, 33% have a Master's or Doctoral degree, and 19% completed high school education or below. More detail about the respondent's characteristics is shown in Table 2.

5. Data analysis and results

Partial least squares structural equation modelling (PLS-SEM) was the method applied to the research model for data analysis. This technique is known for being variance-based and for its exploratory and predictive capabilities [53,54]. SmartPLS 3 [55] was the software used to evaluate both the measurement and structural models.

5.1. Measurement models

A measurement model was performed for the reflective constructs. All variables present composite reliability (CR) greater than 0.70 (Table 3), ensuring their reliability [56,57]. Indicator reliability was evaluated based on the criteria that all loadings should be greater than 0.7 and, when lower than 0.4, the indicators should be directly removed from the scale [53,56]. The indicators' loadings, as shown in Table 4 (in bold), are all above 0.7, except for two items (SI3 and EA2), which are nevertheless greater than 0.4 and close to 0.7. Therefore, indicator

Table 2
Sample characteristics.

Age	N = 255	%	Gender	N = 255	%	Education	N = 255	%
<18	3	1.2%	Male	127	49.8%	Below high school	1	0.4%
18–24	97	38.0%	Female	128	50.2%	High school	49	19.2%
25–34	91	35.7%				Bachelor's degree	122	47.8%
35–44	31	12.2%				Master's degree	69	27.1%
45–54	22	8.6%				Doctoral degree	14	5.5%
55–64	8	3.1%						
>64	3	1.2%						

Table 3
Constructs' descriptive statistics, composite reliability (CR), square root of average variance extracted (AVE), and correlations.

	Mean	SD	CR	PE	EE	SI	FC	HM	PV	HB	EA	BI	UB	IR
PE	4.80	1.58	0.95	**0.94**										
EE	5.38	1.29	0.95	0.46	**0.90**									
SI	3.80	1.43	0.88	0.57	0.31	**0.84**								
FC	4.98	1.43	0.88	0.38	0.68	0.33	**0.85**							
HM	5.00	1.59	0.97	0.70	0.53	0.48	0.43	**0.96**						
PV	3.77	1.35	0.93	0.57	0.37	0.44	0.43	0.57	**0.91**					
HB	3.01	1.72	0.93	0.60	0.32	0.54	0.44	0.61	0.56	**0.91**				
EA	5.55	1.27	0.82	0.19	0.08	0.21	0.04	0.17	0.10	0.06	**0.78**			
BI	5.04	1.83	0.95	0.72	0.45	0.55	0.47	0.76	0.57	0.65	0.22	**0.93**		
UB	3.55	1.77	NA	0.53	0.42	0.39	0.49	0.61	0.52	0.70	0.08	0.62	NA	
IR	4.71	1.76	0.96	0.75	0.47	0.49	0.43	0.75	0.59	0.67	0.28	0.80	0.73	**0.94**

Notes: Performance Expectancy (PE); Effort Expectancy (EE); Social Influence (SI); Facilitating Conditions (FC); Hedonic Motivation (HM); Price Value (PV); Habit (HB); Environmental Awareness (EA); Behavioural Intention (BI); Use Behaviour (UB); Intention to Recommend (IR); Standard Deviation (SD); values in diagonal (bolt) are the square root of AVE.

Table 4
Loadings and cross-loadings.

Construct	Item	PE	EE	SI	FC	HM	PV	HB	EA	BI	IR
PE	PE1	**0.94**	0.47	0.56	0.39	0.71	0.56	0.59	0.19	0.72	0.74
	PE2	**0.94**	0.42	0.51	0.32	0.62	0.54	0.54	0.14	0.63	0.68
	PE3	**0.93**	0.41	0.52	0.35	0.63	0.48	0.55	0.18	0.67	0.69
EE	EE1	0.36	**0.90**	0.25	0.63	0.37	0.26	0.21	0.05	0.34	0.34
	EE2	0.45	**0.88**	0.25	0.55	0.52	0.33	0.30	0.09	0.44	0.47
	EE3	0.38	**0.90**	0.29	0.64	0.50	0.37	0.31	0.05	0.39	0.40
	EE4	0.45	**0.91**	0.33	0.62	0.49	0.37	0.32	0.09	0.43	0.44
SI	SI1	0.50	0.25	**0.92**	0.29	0.38	0.39	0.54	0.18	0.50	0.45
	SI2	0.49	0.22	**0.91**	0.28	0.38	0.40	0.48	0.15	0.48	0.41
	SI3	0.45	0.35	**0.66**	0.28	0.46	0.31	0.30	0.21	0.39	0.36
FC	FC1	0.30	0.44	0.35	**0.86**	0.35	0.39	0.48	0.02	0.45	0.38
	FC2	0.29	0.69	0.18	**0.84**	0.35	0.31	0.27	0.01	0.33	0.35
	FC3	0.37	0.63	0.29	**0.84**	0.40	0.36	0.34	0.06	0.40	0.38
HM	HM1	0.65	0.51	0.43	0.41	**0.96**	0.52	0.57	0.15	0.73	0.71
	HM2	0.72	0.54	0.47	0.45	**0.97**	0.58	0.60	0.18	0.77	0.76
	HM3	0.63	0.46	0.47	0.38	**0.94**	0.55	0.60	0.15	0.68	0.69
PV	PV1	0.36	0.31	0.31	0.44	0.46	**0.85**	0.45	0.06	0.42	0.42
	PV2	0.57	0.37	0.47	0.40	0.55	**0.94**	0.53	0.10	0.55	0.58
	PV3	0.59	0.34	0.40	0.34	0.54	**0.94**	0.53	0.12	0.56	0.59
HB	HB1	0.61	0.41	0.49	0.53	0.63	0.57	**0.91**	0.11	0.71	0.72
	HB2	0.51	0.21	0.47	0.33	0.49	0.48	**0.92**	−0.02	0.52	0.56
	HB3	0.49	0.20	0.50	0.30	0.51	0.44	**0.88**	0.06	0.50	0.51
EA	EA1	0.20	0.07	0.23	0.01	0.18	0.11	0.10	**0.82**	0.21	0.26
	EA2	0.02	0.17	0.05	0.13	0.04	0.03	−0.09	**0.66**	0.08	0.10
	EA3	0.15	0.01	0.15	0.02	0.12	0.07	0.04	**0.84**	0.18	0.23
BI	BI1	0.69	0.42	0.49	0.42	0.72	0.54	0.61	0.26	**0.95**	0.79
	BI2	0.71	0.42	0.53	0.44	0.70	0.55	0.65	0.23	**0.97**	0.79
	BI3	0.62	0.43	0.52	0.47	0.71	0.50	0.57	0.12	**0.88**	0.65
IR	IR1	0.74	0.43	0.48	0.47	0.71	0.58	0.71	0.21	0.75	**0.95**
	IR2	0.64	0.42	0.42	0.30	0.66	0.48	0.50	0.34	0.70	**0.90**
	IR3	0.73	0.46	0.47	0.44	0.74	0.59	0.67	0.23	0.78	**0.97**

Notes: Performance Expectancy (PE); Effort Expectancy (EE); Social Influence (SI); Facilitating Conditions (FC); Hedonic Motivation (HM); Price Value (PV); Habit (HB); Environmental Awareness (EA); Behavioural Intention (BI); Use Behaviour (UB); Intention to Recommend (IR).

reliability is satisfied. The average variance extracted (AVE) was calculated to assess the convergent validity of the constructs. The AVE is greater than 0.50 for all constructs (Table 3), indicating convergent validity [53,58].

The constructs' discriminant validity was assessed using three measures [59]. First, the Fornell-Larcker criterion establishes discriminant validity if the square root of each construct's AVE is greater than its highest correlation with any other construct [53,58]. Table 3 confirms this criterion. The second criterion postulates that the indicators' loadings on the associated construct should be greater than the cross-loadings [60]. One of the indicators of facilitating conditions (FC4) did not fulfil this criterion. The item was therefore removed from the model. As the final results in Table 4 show, the loadings (in bold) are greater than the cross-loadings. Lastly, the heterotrait-monotrait ratio (HTMT) values are all lower than the threshold of 0.90 (Table 5). Thus, the three criteria are satisfied, confirming the discriminant validity of the constructs.

The research model has one formative construct, use behaviour, from UTAUT2. The variance inflation factor (VIF) was calculated to assess multicollinearity. Table 6 shows that the VIF values are all below the threshold of 5, demonstrating the lack of multicollinearity among the formative variables [53]. Regarding significance of weights, six items (UB1, UB2, UB6, UB11, UB12 and UB13) are statistically significant ($p < 0.01$ and $p < 0.05$) (Table 6). The remaining seven items (UB3, UB4, UB5, UB7, UB8, UB9, and UB10) do not have statistically significant weights; however, their loadings are statistically significant ($p < 0.01$) (Table 6), and therefore, they should remain in the model [53].

The results from the measurement models support the fit of both the reflective and formative constructs to test the structural model.

5.2. Structural model

Before estimating the structural model, the levels of collinearity between the predictor constructs were assessed using the VIF measure. The VIF values are below the threshold of 3.3 (ranging from 1.10 to 2.59); thus, there is no evidence of multicollinearity among the variables [61]. The results from the structural model estimation are shown in Fig. 2, namely the R^2 values, indicating the explained variance, and the path coefficients with the corresponding significance level.

The model explains 70% of the variation in behavioural intention. Environmental awareness ($\widehat{\beta} = 0.09; p < 0.05$) is statistically significant to explain intention to use smart home technologies. Thus, H3a is supported.

Additionally, the model explains 58% of the variance in use behaviour. From the UTAUT2, behavioural intention ($\widehat{\beta} = 0.22; p < 0.01$) is statistically significant to explain use behaviour, and therefore, H1a is confirmed. However, environmental awareness ($\widehat{\beta} = -0.03; p > 0.10$) is not statistically significant, and thus H3b is not confirmed.

Concerning intention to recommend, the model explains 75% of its variance. All of its predictor variables are statistically significant – behavioural intention ($\widehat{\beta} = 0.51; p < 0.01$), use behaviour ($\widehat{\beta} = 0.40; p < 0.01$), and environmental awareness ($\widehat{\beta} = 0.13; p < 0.01$). Respectively, H1b, H2, and H3c are supported.

Environmental awareness moderates both the relationships of facilitating conditions and habit with use behaviour ($\widehat{\beta} = 0.12; p < 0.01$; $\widehat{\beta} = -0.10; p < 0.10$; respectively). The moderating effect is negative for the habit relationship and positive for the facilitating conditions; therefore, H3e is not confirmed, but H3d is. Moreover, environmental awareness negatively moderates the relationship between use behaviour and intention to recommend ($\widehat{\beta} = -0.09; p < 0.10$), thus, H3h is not confirmed. The moderating effect of environmental awareness is not confirmed between behavioural intention and use behaviour (H3f; $\widehat{\beta} = -0.02; p > 0.10$), neither between behavioural intention and intention to recommend (H3g; $\widehat{\beta} = 0.06; p > 0.10$).

Table 7 shows the results of all the mediating effects found in the structural model. According to Carrión, Nitzl, & Roldán [62], the main characteristic of a mediating effect is the presence of a third variable that acts as an intermediate between an independent variable and a dependent variable. The authors also describe the different possible types of effects. The results from Table 7 show that use behaviour partially mediates the relationship between behavioural intention and intention to recommend, indicating that both direct and indirect effects are statistically significant and point in the same (positive or negative) direction. Nevertheless, no mediating effects of use behaviour were found between environmental awareness and intention to recommend since the indirect effect is not statistically significant. Regarding behavioural intention, this construct acts as a complementary partial mediator of the relationships between facilitating conditions and use behaviour, habit and use behaviour, and environmental awareness and intention to recommend. In addition, behavioural intention fully mediates the relationship between environmental awareness and use behaviour, which means the indirect effect is statistically significant while the direct effect is not.

Table 6
Formative measurement model evaluation.

Formative construct	Item	Weight	Loading	VIF
Use Behaviour	UB1	0.13 **	0.34 ***	1.25
	UB2	0.30 ***	0.68 ***	1.42
	UB3	0.02	0.45 ***	1.54
	UB4	−0.05	0.35 ***	1.52
	UB5	0.09	0.73 ***	2.31
	UB6	0.20 **	0.82 ***	2.97
	UB7	0.08	0.57 ***	1.91
	UB8	−0.04	0.61 ***	2.33
	UB9	0.04	0.65 ***	2.11
	UB10	−0.01	0.49 ***	1.82
	UB11	0.21 **	0.80 ***	3.17
	UB12	0.20 **	0.81 ***	2.66
	UB13	0.20 **	0.82 ***	3.41

Notes: Variance inflation factor (VIF); ***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

6. Discussion

The research model proposed in this study uses the UTAUT2 framework as a baseline model to investigate the moderating impact of environmental awareness among the acceptance, use, and intention to recommend associated with smart home technologies. This analysis represents a particularly significant contribution to theory and practice

Table 5
Heterotrait-monotrait ratio (HTMT).

Construct	PE	EE	SI	FC	HM	PV	HB	EA	BI	IR
PE										
EE	0.49									
SI	0.67	0.38								
FC	0.43	0.81	0.42							
HM	0.74	0.55	0.57	0.49						
PV	0.61	0.41	0.52	0.50	0.61					
HB	0.65	0.32	0.64	0.49	0.65	0.61				
EA	0.19	0.14	0.25	0.11	0.18	0.11	0.14			
BI	0.77	0.48	0.65	0.54	0.81	0.62	0.70	0.24		
IR	0.81	0.50	0.57	0.50	0.80	0.63	0.72	0.31	0.85	

Notes: Performance Expectancy (PE); Effort Expectancy (EE); Social Influence (SI); Facilitating Conditions (FC); Hedonic Motivation (HM); Price Value (PV); Habit (HB); Environmental Awareness (EA); Behavioural Intention (BI); Intention to Recommend (IR).

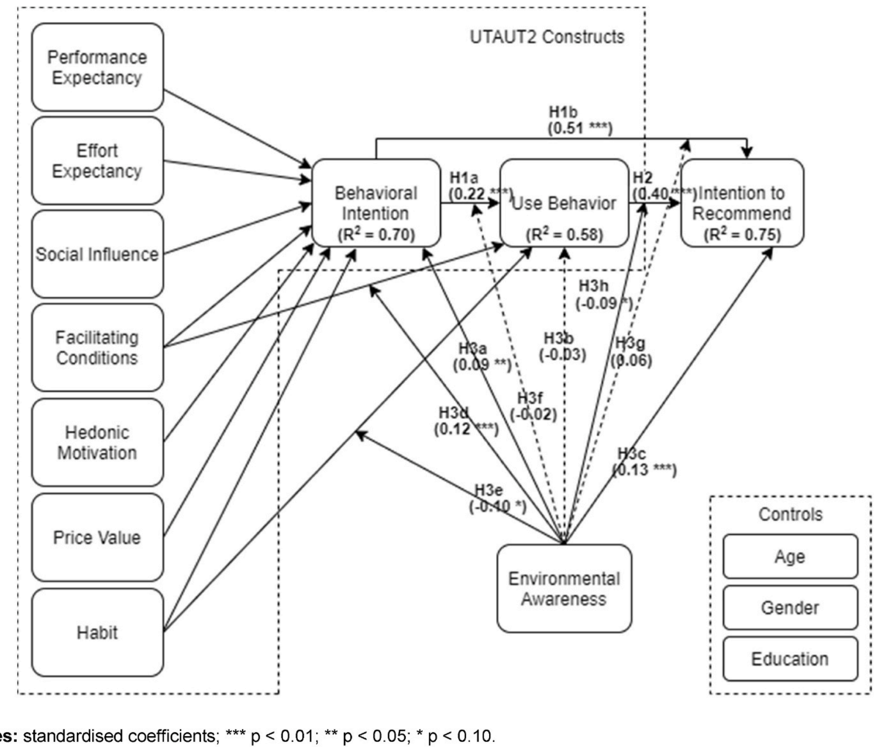

Fig. 2. Structural model results (variance-based technique) Notes: standardised coefficients; ***p < 0.01; **p < 0.05; *p < 0.10.

Table 7
Significance analysis of the direct and indirect effects.

Effect of	Direct effect	Indirect effect	Interpretation
BI → UB → IR	0.51 ***	0.09 ***	Complementary (partial mediation)
EA → UB → IR	0.13 ***	−0.01	Direct-only (no mediation)
FC → BI → UB	0.20 ***	0.03 *	Complementary (partial mediation)
HB → BI → UB	0.45 ***	0.03 **	Complementary (partial mediation)
EA → BI → UB	−0.03	0.02 *	Indirect-only (full mediation)
EA → BI → IR	0.13 ***	0.04 **	Complementary (partial mediation)

Notes: standardised coefficients; ***p < 0.01; **p < 0.05; *p < 0.10.

since no prior studies have reported on the moderating effects of environmental attitudes in the smart home adoption context.

In line with the literature [25], the results confirm the significant positive impact of behavioural intention on use behaviour. Furthermore, intention to recommend is positively influenced by behavioural intention and use behaviour. Although the positive impact of behavioural intention on intention to recommend is supported by previous research [37,63], no studies were found reporting on the positive causal relationship between use behaviour and intention to recommend.

The results demonstrate significant direct, indirect, and moderating effects of environmental awareness among the model's target variables, indicating its important role in the smart home adoption process. Regarding the hypothesised direct effects of environmental awareness, the results confirm its significant positive impact on behavioural intention and intention to recommend, but no direct effect was found on use behaviour. The observed significant effect on behavioural intention is in line with the results from Schill et al. [19] but contradicts the findings of Ahn et al. [18]. The remaining hypothesised effects have no literature comparison, as we tested them for the first time. Although environmental awareness does not directly impact use behaviour, a significant mediation effect is found between these two variables through behavioural intention. Thus, environmental awareness indirectly affects use behaviour by leveraging the positive impact of behavioural intention on use behaviour. These results indicate that the more consumers are aware of environmental problems, the more they will be willing to accept, use, and recommend smart home technologies.

Regarding the moderating effects of environmental awareness, three of the five proposed moderation relationships, illustrated in Fig. 3a, Figs. 3b, and Fig. 4, proved to be significant.

Fig. 3a shows the significant moderating effect of environmental awareness between facilitating conditions and use behaviour. The impact of facilitating conditions on use behaviour will be stronger for individuals with a higher level of environmental awareness. On the other hand, for individuals with a low level of environmental awareness, the facilitating conditions are not important to explain the use behaviour. Although the moderation relationships shown in Figs. 3b and 4 proved to be significant, they do not confirm the respective hypotheses (H3e and H3h) since the effects are negative instead of positive. As environmental awareness increases, habit becomes less relevant to explain use behaviour (Fig. 3b). Thus, higher levels of environmental awareness will reduce the predictive power of habit over individuals' use behaviour. This result is especially relevant in cases where it is not possible for the user to have some sort of trialability with the technology. As people feel more environmentally aware, they feel less need to have a trial or experience with the technology they might use. Therefore, this aspect might help increase the adoption and use of technologies that are more difficult to experience or try before buying.

Moreover, this result may also indicate that the usage of certain environmentally-related functionalities provided by smart home technologies, such as the regular monitoring and controlling of energy consumption levels, is not yet perceived as a natural *action for users.* The reason why habit is more important in explaining the use behaviour of individuals with low environmental awareness might be justified by using specific products that are more related to security and comfort benefits rather than energy ones, which is the case of smart TVs, door locks, and cameras. Furthermore, as smart home technologies provide

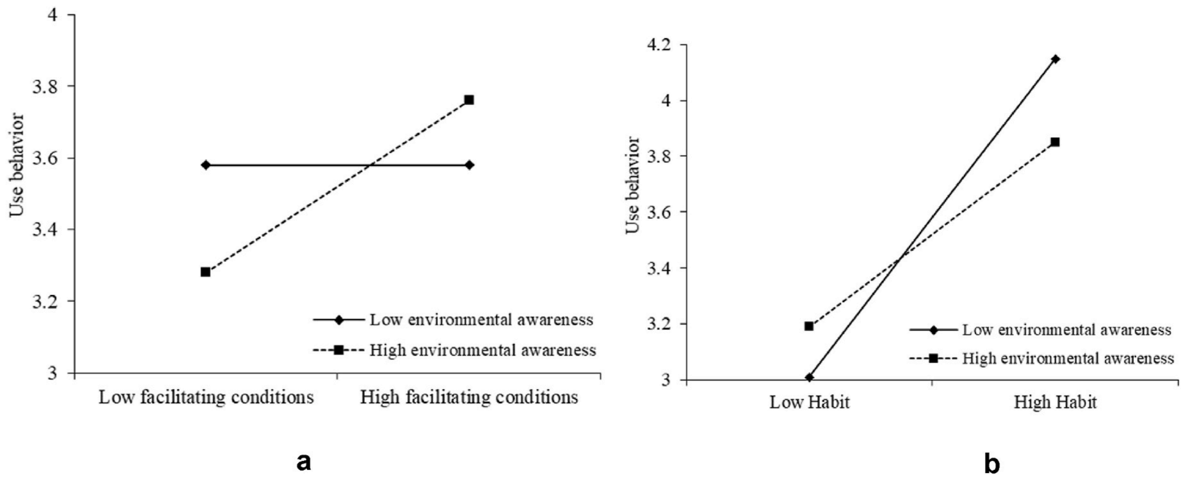

Fig. 3. a Moderating effect of environmental awareness between facilitating conditions and use behaviour, b. Moderating effect of environmental awareness between habit and use behaviour.

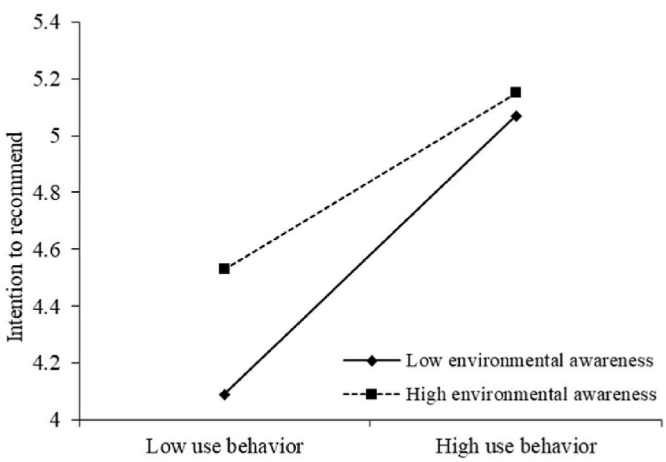

Fig. 4. Moderating effect of environmental awareness between use behaviour and intention to recommend.

users with task automation, such as smart thermostats that automatically regulate temperature and appliances that are built to operate in an energy-efficient way automatically, users with high environmental awareness might not realise the associated habit since they do not have to perform the tasks themselves.

Lastly, the impact of use behaviour on intention to recommend will be weaker among users with high environmental awareness (Fig. 4). This result also indicates that users might be mainly enjoying the non-energy benefits of smart home technologies, using them for different purposes.

6.1. Managerial implications

Brands constantly seek valuable insights to better understand their customers and identify potential new ones. The findings of this study provide marketers and decision-makers with several significant implications regarding smart home technologies. One is the substantial and relevant contribution of behavioural intention and use behaviour to drive intention to recommend. This effect indicates that, in general, individuals who have a good perception and/or experience regarding smart home technologies will very likely recommend them to friends and family, which can promote social network and word-of-mouth marketing – two powerful ways of increasing the technologies' adoption rate.

The major implications of this research are related to the effects of environmental awareness on adopting smart home technologies. These findings are especially relevant, as both companies and consumers are now, more than ever, aware of the environmental issues worldwide and are seeking out energy-efficient products. The following implications can provide marketers and policymakers with useful insights to support consumers' adoption of smart home technologies to promote sustainability. Firstly, the demonstrated direct positive effects of environmental awareness on intention to use and recommend the technologies, together with its indirect positive effect on use behaviour through behavioural intention, confirms that consumers' environmental attitudes indeed influence their intentions and actions towards smart home technology adoption beneficially. This facet indicates that companies should not launch and promote smart home products and services based solely on utility and self-centred benefits, such as convenience, comfort, and assistance, which are currently the main advertised features. As the results of this study suggest, brands need to increase consumers' recognition of these technologies as environmentally friendly products to accelerate their adoption. Accordingly, marketers should build a communication strategy that emphasises how smart home technologies can contribute to a more sustainable lifestyle and positively impact the environment by combating climate change. In particular, to achieve that communication more effectively, companies should specify, for instance, the amount of energy consumers can save monthly. The presence of energy-saving features in smart home technologies can make a critical difference in the consumers' purchasing decisions when choosing between products.

Secondly, interesting implications emerge from the significant moderating effects of environmental awareness in the adoption process of smart home technologies. The findings confirm that environmental awareness strengthens the importance of facilitating conditions to explain use behaviour, which reinforces the idea that product developers and marketing managers need to increasingly highlight the role of the energy-saving features in their smart home products and services to promote their use among consumers. Additionally, policies can be further developed towards reducing domestic energy consumption as a way of fighting environmental issues, which can encourage individuals to adopt these innovative technologies to achieve that goal. Another relevant implication of the moderating effects is that habit has less impact on use behaviour for individuals with higher levels of environmental awareness. This result suggests that when individuals are aware of environmental issues, there is no need to create a habit or experience with the technology to increase its use. This might be useful in the adoption stage, where it can be difficult for the consumer to experience the technology to help him decide whether to adopt it or not. This way, for more environmentally aware individuals, it might be easier for them to adopt smart home technology, even without the trialability or the creation of an experience with the technology. On the other hand, given the importance of habit for consumer adoption, marketers should increase consumers' familiarity with energy-saving features, demonstrating different use cases in stores, for instance. In addition, also among individuals with higher levels of environmental awareness, use behaviour plays a less important role in explaining the intention to recommend. All of these significant effects of environmental awareness over consumers' adoption of smart home technologies demonstrate that it is vital for marketers and policymakers to explore and emphasise the energy savings outcomes of those products or services. By doing so, the role of consumers' environmental motivations in the adoption of these technologies would be reinforced, accelerating their diffusion and success in the market.

6.2. Theoretical implications

There are important theoretical implications that can be drawn from this study. Firstly, this study goes beyond the findings of previous smart home research by empirically analysing use behaviour and intention to recommend, in addition to intention to use. Including these two variables provides a more in-depth look at the technologies' adoption process. Moreover, the results confirmed the suitability of UTAUT2 to explain the acceptance and use of smart home technologies.

Secondly, the analysis of the moderating effects of environmental awareness is a differentiating factor among previous research on IT adoption in general and smart home adoption in particular. Studying these effects improved the understanding of the role of environmental attitudes in the consumer adoption process of smart home technologies. The significant influence of environmental awareness was found in all the target variables considered and associated with the adoption of smart homes (behavioural intention, use behaviour, and intention to recommend). This finding is particularly important due to the current theoretical inconsistencies found across the literature regarding the impact of ecological beliefs on environmental behavioural intentions and actual pro-environmental behaviours [18,19]. This study supports the line of research that has confirmed a significant correlation between consumers' environmental attitudes and their pro-environmental purchase intentions and behaviours.

6.3. Limitations and future research

This study's findings must be examined considering some limitations. First, in terms of implementation, the data used for testing this study's research model was collected through a survey during a certain period, which might result in a current scenario, but not necessarily for the future. Especially in the adoption of new technologies, we must consider that this is a dynamic process. Thus, future research could conduct a longitudinal study to analyse consumers' intentions and behaviour for more than one moment in time and over an extended period. Secondly, the authors used UTAUT2, which, although a strong theory, might not include other potentially interesting factors. For instance, more environmental variables related to sustainable behaviour could be examined to understand consumers' environmental motivations towards smart homes more deeply. In fact, implementing mixed-methods research can increase the value of this type of investigation by helping identify some other relevant dimensions that can affect use behaviour regarding smart technologies. Thirdly, around half of the collected survey responses were from Portuguese individuals, which makes it difficult to generalise the results. Therefore, the authors suggest testing the proposed model in different countries and considering the inclusion of cultural factors. Finally, future investigations can also investigate the model's applicability to other technologies.

7. Conclusion

Based on the UTAUT2 framework, this study proposes a theoretical model that evaluates the various effects of environmental awareness on the acceptance, use, and intention to recommend smart home technologies. The findings confirm that, besides the direct effects, environmental awareness also works as a relevant moderator. Among individuals with high levels of environmental awareness, facilitating conditions have a greater impact on the technologies' use behaviour, while habit has a lower influence. Furthermore, for that particular segment of individuals, use behaviour becomes less important in explaining the intention to recommend. Interestingly, even though use behaviour is not directly explained by environmental awareness, the relationship is significant when mediated by behavioural intention. Besides the theoretical contributions, the results also show that the contributions of environmental awareness to successful consumer adoption of smart home technologies should be promoted and elaborated to foster sustainability in this field. Thus, we hope our findings inspire future studies to further investigate the role of environmental factors in a smart home context.

Credit author statement

Laura Ferreira: Conceptualization; Methodology; Software; Formal analysis; Investigation; Writing – original draft preparation. Tiago Oliveira: Conceptualization; Methodology; Investigation; Writing - Reviewing; Supervision. Catarina Neves: Formal analysis; Writing – Reviewing, and editing.

Declaration of competing interest

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

Data availability

The data that has been used is confidential.

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