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Wojciech Mrozik,
Newcastle University, United Kingdom

REVIEWED BY
Muhammad Ikram,
Al Akhawayn University, Morocco
Armand Faganel,
University of Primorska, Slovenia

*CORRESPONDENCE
Konstantinos Madias,
Konstantinos.madias@
phd.ue.poznan.pl

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The role of knowledge about water consumption in the context of intentions to use IoT water metrics

Konstantinos Madias*, Barbara Borusiak and Andrzej Szymkowiak

Department of Commerce and Marketing, Institute of Marketing, Poznan University of Economics, Poznań, Poland

Technological progress can contribute to a more conscious and sustainable consumption of water. This is especially important in the context of dwindling resources and climate change. The objective of the study is to investigate how consumers' perceived knowledge on water usage influences their intention to adopt smart (IoT-based) water meters, which deliver very precise data on the amount of water used in a household. We hypothesized that perceived knowledge on personal water usage exerts a direct and indirect influence on the intention to adopt a smart water meter. For the mediators, we used the intention to save water and variables derived from Value-Belief-Norm theory: awareness of consequences, ascription of responsibility and personal norm. We verified the hypotheses by applying structural equation modelling to a sample of 532 respondents. We found that perceived knowledge on water usage directly influences the intention to adopt a smart water meter, and that all considered variables worked to mediate the relationship between perceived knowledge and intention. Thus, based on our results perceived knowledge plays an important role on the relationship between values-beliefs-norms and intentions to apply smart water meters, which can be used for future research in order to reduce household water consumption by increasing the probability of installing smart water meters.

KEYWORDS

IoT, smart meter, water consumption, knowledge, sustainability

Introduction

Water is a fundamental resource to human life, integral to our personal survival and to everything that societies produce (Cosgrove and Loucks, 2015). Water is a finite resource that has no substitutes—and yet, there is growing proof that human activities are contributing to water scarcity across the globe (Fielding et al., 2012). Such activities include the expansion of businesses, urbanization, population growth, water pollution, increasing water demands, the overallocation of rivers flows, and climate change (Cosgrove and Loucks, 2015). The consequences of water scarcity are far-reaching, encompassing food insecurity, the destruction of eco-systems, the extinction of species and social stress (Addo et al., 2019). Past research has found that about one fifth of the world population lives in areas that lack sufficient water to meet all demands, while one third of the population does not have access to clean drinking water (Cosgrove and Loucks, 2015). As population growth spurs greater water usage, more and more parts of the world will face water stress.

One of the leading causes of water scarcity is increasing domestic water use—the demand for which is primarily driven by high consumption in urban centers, households and industrial sectors. In fact, domestic demand is said to comprise about 15% of the global water demand (Addo et al., 2019). Thus, governments, policymakers, and citizens are challenged to find ways to reduce household water consumption while satisfying the water demands of society at large (Lowe et al., 2015). In households, about half of water usage is dedicated to indoor activities, including toilets, showers, washing machines and other daily activities (Shan et al., 2015) and the other half of water consumption is dedicated to outdoor activities (Lee et al., 2011). According to past research, the factors that influence household water consumption are number of people in a household, education level, infrastructure, income, devices, usage patterns, lifestyle and consumer attitudes toward water consumption (Willis et al., 2011; Rondinel-Oviedo and Sarmiento-Pastor, 2020). Regardless of the reason, societies need to implement conservation practices in order to achieve sustainable water usage. Lee et al. (2011) advanced that applying water conservation as the residential level is important since households account for the majority of water demand in cities.

Despite the need to reduce household water consumption, there is a lack of research on the best ways to do so. This is primarily due to the complexity behind the drivers of water-saving behavior. According to Jorgensen et al. (2009), there are two groups of behavioral drivers: direct (climate variability, financial incentives and disincentives, regulations, property and household characteristics) and indirect (socio-economic factors, inter-personal factors and institutional trust). Both play an important role in water-saving behavior. We want to highlight that personal characteristics occupy both spaces: the intention to and knowledge of how to conserve water was found to be a direct driver, whereas environmental values and conservation attitudes are recognized as an indirect one.

Based on past literature review, the research area about household water conservation has been focused on consumers' demographics and characteristics, pricing, the efficient use of household appliances, and consumer-focused messaging (Madias and Szymkowiak 2022). Fielding et al. (2012) discovered that demographic variables are among the strongest predicts of conservation behaviors. Cary (2008) analyzed the ways to influence consumers' behavior and attitudes in order to reduce their water consumption. Similarly, Corral-Verdugo et al. (2003) found that consumers who are more concerned about the environment are more likely to adjust their water habits, such as limiting their time taking showers, washing dishes, watering plants, etc. Scholars have also established that water pricing plays an important role in consumers' conservation practices (Dupont and Renzetti, 2013). Likewise, residents will sometimes modify their water consumption in response to conservation messages (Addo et al., 2019).

Moving beyond consumers, research has examined methods of making household appliances more environmentally efficient (Belke et al., 2019; Boyano and Moons, 2020; Pakula and Stamminger, 2010) in order to counteract households' relatively high water usage. One of the way to achieve that is through Green Technology, which refers to technology that helps to achieve the international sustainable development goals and to minimize the environmental impact cause by economic growth (Ikram et al., 2022). Smart water meters are also considered as green technology as it is proven that they play an important role on reducing the household water consumption (Russell and Knoeri, 2020) as they can track people's real-time water consumption and detect any water possible leakage (Fuentes and Mauricio 2020). In fact, Sønderlund et al. (2014) found that households reduced their water consumption by an average of 19.6% when they received information from a smart water meter. Cominola et al. (2021) did not replicate the size of this effect, they still found an 8% reduction in water consumption among households with smart meters installed.

However, past research has not examined consumers' intentions to adopt smart water meters in their households which could help with understanding better the water consumption behavior but they mostly focus on the financial motives behind applying smart water meters (Montginoul and Vestier 2018). Thus, this paper focuses on how consumers' perceived knowledge about water usage shapes their intention to install smart (IoT-based) water meters. In this way, we address the scientific gap, as well as provide valuable insights for future research on smart water meters. We hypothesized that perceived knowledge (PK) on water usage in a household determines the intention to adopt smart water meters (IAW), both directly and indirectly. In this study, we followed other studies that treated water-saving as a pro-environmental behavior (Carmela and Damiano, 2016), which is aligned with some theory on perceived knowledge, so we assumed that perceived knowledge is also related to intention to save water and to VBN variables (Esfahani et al., 2015) which are usually adopted for explaining pro-environmental behavior. We also examined how consumers' perceived knowledge about household water usage is related to their personal norm about saving water, and whether that norm results from their awareness of the consequences and ascription of responsibility in relation to excess water usage.

This paper is structured as follows: The first section reviews the relevant literature in order to synthesize existing knowledge and construct our hypotheses. The second section details our methodology. The third section presents our results, while the fourth discusses and interprets them. The final section summarizes our main contributions and outlines future research directions.

Hypotheses development

In order to construct our hypotheses we adopted the Value-Belief-Norm model by Stern et al. (1999) and extended it by adding the moderator of perceived knowledge. VBN model is primary used for examining green behaviors by researching individuals' values, beliefs and norms (Ghazali et al., 2019). The variables that the model is using in order to investigate the pro-environmental intentions of consumers are: ascription of responsibility, awareness of consequences and personal norms. However, in this study we extend the VBN model by adding the moderator or perceived knowledge. Thus, the hypotheses are constructed based on an extended version of VBN model.

Our primary focus is on consumers' perceived knowledge and its influence (both direct and indirect) on their intention to adopt smart water meters. Past research has established that consumers' knowledge and perceived knowledge are key factors in their decision-making, especially in relation to the environment (Lee et al., 2006). Indeed, knowledge in general determines behavioral intentions (Martono et al., 2019), while environmental knowledge in particular is related to pro-environmental behavior (Levine and Strube, 2012; Suryanda et al., 2021). According to Min-Seong Kim et al. (2018), environmental knowledge can be categorized into two parts: real knowledge and perceived knowledge (i.e., someone's feeling of knowing something). Here, we focus on the latter category in relation to water consumption.

Perceived knowledge on water usage reflects people's opinions on two issues: their perception of absolute water consumption and how much they use relative to the average person. Previous studies have highlighted a discrepancy between perceived and actual water consumption (Beal et al., 2013). However, we assume that consumers who are more confident in their perceived knowledge (regardless of its accuracy) will be more interested in possessing precise data about their water usage—and thus will be more willing to adopt smart water meters. To that end, we formulated our first hypothesis:

H1. Perceived knowledge on personal water usage is positively related to the intention to adopt smart water meters.

We know from past research that perceived knowledge can compel consumers to make environmentally friendly decisions (House et al., 2004; Kim et al., 2018). From this, we postulate that consumers with higher perceived knowledge on water usage will have higher intentions to save water:

H2. Perceived knowledge on personal water usage is positively related to the intention to save water.

Past research focusing on water meters have proved that smart-water meters may reduce the household water consumption on an average rate of 19.6% (Sønderlund et al., 2014) while Davies et al. (2014) found out a reduction of 1.05 kl per month in water consumption when smart water meters were applied. Thus, we assume that consumers who have higher intentions to reduce their water consumption are more likely to have high intentions of adopting smart water meters. Formally:

H3. The intention to save water is positively related to the intention to adopt smart water meters.

In numerous previous studies, pro-environmental behaviors and behavioral intentions have been explained by personal norm (Schwartz, 1977; De Groot and Steg, 2009; Jansson et al., 2017): an internalized behavioral standard (Bamberg, 2012) that is contrasted with subjective norms. Personal norm is a key construct in two theories used to explain pro-environmental behavior. Schwartz's (1977) Norm Activation Theory (NAT) focuses on moral (personal) norm as a main motivator of altruistic behaviors, including pro-environmental ones. The theory posits that individuals undertake pro-environmental actions due to a personal belief that environmental conditions pose a threat to other people and all other species (awareness of consequences) and those harmful consequences can be prevented by their actions (ascription of responsibility). According to NAT, these types of actions are often rewarded by a sense of pride, security, fulfilling one's duty and experiencing joy as a result, as well as enhanced self-esteem. Meanwhile, Stern et al. (1999) Value-Belief-Norm (VBN) theory extends NAM to a broader context by establishing causal links between the following variables: values (especially altruistic ones); beliefs about the environment and the effects of human activity on it; an awareness of consequences; the ascription of responsibility; personal norms concerning pro-environmental behavior, the willingness to sacrifice, and consumer behavior. Both the intention to and action of saving water should be considered highly pro-environmental and pro-social behavior (Sulaeman et al., 2018). Thus, we assume that pro-environmental personal norms about saving water influence the intention to reduce household water consumption. This leads to our fourth hypothesis:

H4. The personal norm about saving water is positively related to the intention to save water.

Regarding the influence of perceived knowledge on pro-environmental behaviors, Bamberg (2012) concluded that perceived knowledge about environmental problems is highly predictive of people's norms development personal Similarly, Onel and Mukherjee (2016) found that the former is a better predictor for the latter than actual scientific and environmental knowledge. Hamzah and Tanwir (2021) established that environmental knowledge (which can be defined as perceived knowledge based on how they measured the variable) is a moderator of perceived green value, green purchase attitude, perceived behavioral control, subjective norms and their impact on green purchase intention. From this, we hypothesize that perceived knowledge on environmental issues is related to the intention to save water:

H5. Perceived knowledge on water usage is positively related to the personal norm about saving water.

According to both NAT (Schwartz, 1977) and VBN (Stern et al., 1999), personal norm is predicted by both an awareness of environmental consequences and the ascription of responsibility (Esfahani et al., 2015). The ascription of responsibility is defined as the feeling of responsibility for the negative consequences of failing to act pro-socially (De Groot and Steg, 2009). It also reflects an opinion about who should be responsible for something (Stern, 2000). According to VBN, this factor mainly arises from the awareness of consequences, but it can also be driven by other factors like one's internal locus of control (Pavalache-Ilie and Unianu, 2012). Given previous findings that knowledge and problem awareness influence pro-environmental attitudes and behaviours (Bamberg and Möser, 2007), we formulated the following hypothesis:

H6. Perceived knowledge on water usage is positively related to the ascription of responsibility for excessive water usage.

Based on both NAT and VBN (Schwartz, 1977; Stern et al., 1999), we expect to find a positive relation between the ascription of responsibility for excessive water usage and the personal norm about saving water. This leads us to the next hypothesis:

H7. Ascription of responsibility for excessive water usage is positively related to the personal norm about saving water.

The awareness of consequences is the belief that taking (or failing to take) a given action will be harmful for others (De Groot and Steg, 2009; Kiatkawsin and Han, 2017). In this study, we assume that consumers' perceived knowledge about water usage will influence their awareness of consequences. Formally:

H8. Perceived knowledge on water usage is positively related to the awareness of consequences about excessive water usage.

Previous studies (Vining and Ebreo, 2002; Shin et al., 2018) have argued that the awareness of consequences is an antecedent to ascription of responsibility, as individuals tend to feel responsible for negative consequences when they are aware of inflicted harm. In our study, we assume that individuals who are aware of the consequences of excessive water usage will take personal responsibility for said consequences. Formally:

H9. The awareness of consequences about excessive water usage is positively related to the ascription of responsibility for using too much water.

Lastly, prior research has uncovered that consumers' awareness of consequences for taking (or not taking) a certain activity determines their personal norm about a given behavior (Liu et al., 2017). Thus, we hypothesized the following:

H10. The awareness of consequences of excessive water usage is positively related to the personal norm about saving water.

We built the following research model (Figure 1) to visualize our hypotheses.

Methods

We designed a three-part study to empirically verify the above model. In the first part, participants received basic information about smart water meters. The description only contained technical information about the meter's mechanical operation, without any emphasis on or reference to possible benefits. The description also showed example pictures of current devices on the market, which are targeted at individual customers, as well as a visualization of web and mobile applications, through which device users can access consumption information. This description was especially important for estate the credibility of the research, as it allowed users to obtain knowledge in the field of smart water metrics solutions. Moreover, it is related to the fact that such solutions are treated as a product and process innovation, so they are not widely known to all consumers.

In the second part, respondents used one to seven scales (where 1 = I strongly disagree and 7 = I strongly agree) to give their opinion on various statements. We derived the statements from previously validated scales: The study by Shin et al. (2018) was used to evaluate Ascription of responsibility for using too much water (AOR), which was measured on three items, as well as the Awareness of the consequences of using too much water (AOC) (e.g., I think that using too much water supports environmental degradations). In addition, personal norm concerning saving water (PN) was examined on three items derived by Shin et al. (2018) (e.g., "I believe I have a moral obligation to save water"). We measured Perceived Knowledge (PK) on personal water usage using a modified four-item scale proposed by Joshi and Rahman (2017) (e.g., "I am very knowledgeable about my water usage"). To evaluate the Intention to reduce water usage (IP) and the Intention to adopt IoT water meters (IAW), we adopted questions from Han et al. (2010) and Chen and Tung (2014) (e.g., "I will make an effort to reduce water usage", "I plan to apply IoT based water meters in my household") (Appendix A1). In the final part, respondents answered questions about their demographics.

We conducted the survey over Amazon Mechanical Turk (hereafter, Mturk). Although MTurk data has proven to be of good quality, we still undertook a multistage verification

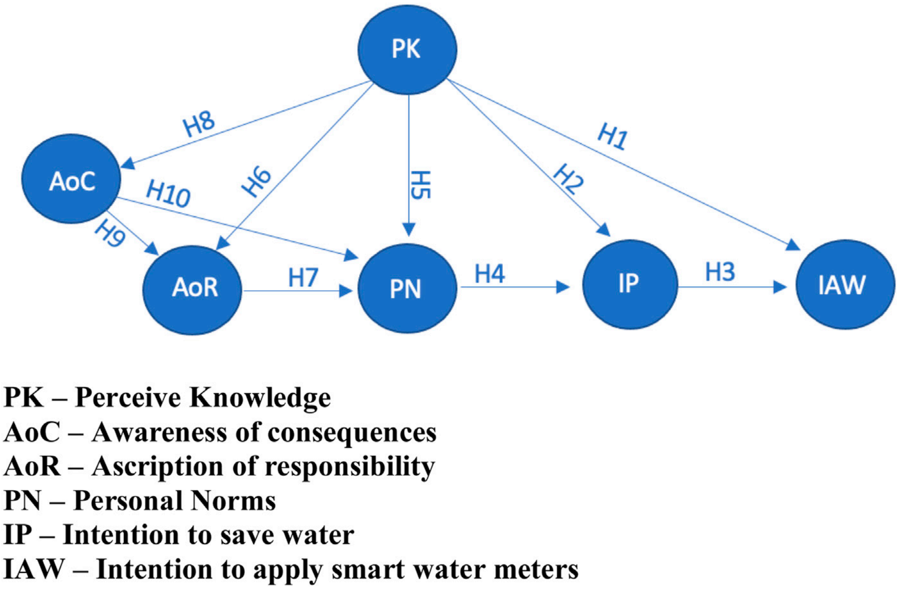

FIGURE 1
Research model.

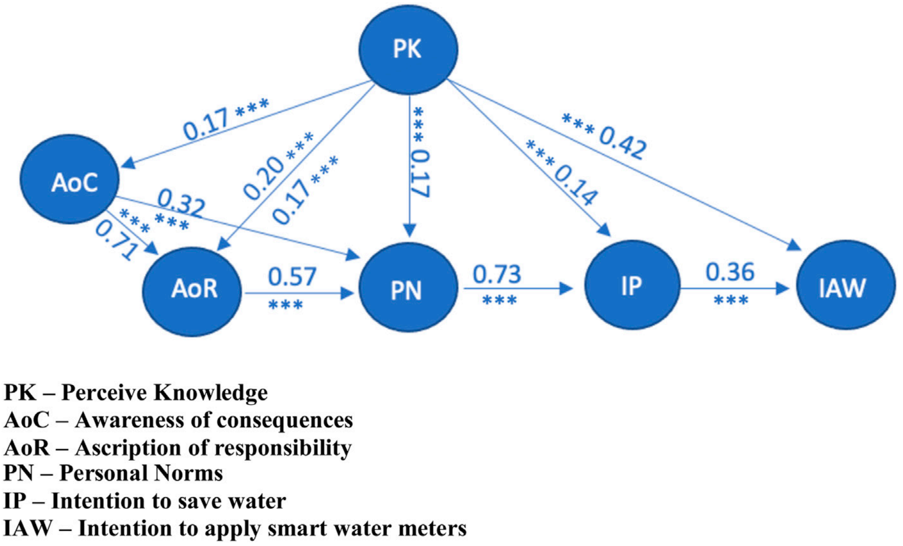

FIGURE 2
SEM results.

procedure. We limited the participant pool to English-speaking United States residents, as well as those users with a high rate of completed tasks (over 90%). In addition, we eliminated anyone who completed the first part (reading the information about smart water metrics) in less than 15 s, as well as so-called “speed runners” who answered the main questions faster than 80% of the average pre-test time. Moreover, we implemented two attention check questions to verify careful reading and removed any respondents who failed them. In the last step, we excluded any participants who gave unlikely answers to open-ended

TABLE 1 Respondent characteristics.

Characteristic	Category	Frequency	Percent
Education	Bachelor's degree	283	53.195
	Doctorate	12	2.256
	High school degree or equivalent	117	21.992
	Master's degree	108	20.301
	Other	12	2.256
Income	\$20.000 - \$29.999	55	10.338
	\$30.000 - \$39.999	64	12.030
	\$40.000 - \$49.999	59	11.090
	\$50.000 - \$59.999	65	12.218
	\$60.000 - \$69.999	99	18.609
	\$80.000 - \$89.999	48	9.023
	\$90.000 ≥	101	18.985
	≤ \$19.999	41	7.707
Status	Employed full-time	331	62.218
	Employed part-time	63	11.842
	Retired	34	6.391
	Self-employed	34	6.391
	Student	14	2.632
	Unable to work	13	2.444
	Unemployed	43	8.083
Residence	Apartments	147	27.632
	Multi-family homes	13	2.444
	Single-family home	372	69.925
	Total	532	100.000

questions (e.g., listing 1,111 years as their given age). Through this process, we achieved 532 responses for the core analysis. This final sample differed in terms of age (m = 40.1, SD-13.46, min. = 18, max. = 76), gender (male-44.55%, female-55,45%), household size (M = 3.0, SD = 1.39, min. = 1, max. = 9) income, education, status and type of residence. Table 1 presents the detailed respondent data.

Results

We analyzed the data in two stages using structural equation modeling. Following recommendations by Bagozzi and Yi (2012), we first evaluated the convergent and discriminant validity of individual items, as well as the composite reliability of the variables. A confirmatory factor analysis indicated that all factor loadings for the individual items achieved values above 0.821, in excess of the recommended 0.6 threshold (Chin et al., 1997). Next, we measured scale reliability by applying Cronbach's α: The values ranged from 0.89 to 0.93, representing good to very good consistency according to Hair et al. (2014). To measure convergent and discriminant validity, we used standardized factor loading along with two parameters: Composite Reliability (CR) and Average Variance Extracted (AVE). The AVE values were between 0.73 and 0.83 (Table 2), which is above the acceptable limit of 0.5 as recommended by Hair et al. (2014). The CR values also exceeded the acceptable limit of 0.6 (ranging from 0.89 to 0.93), which indicates the internal consistency of multiple indicators (Bagozzi and Yi 2012). We used the HTMT ratio of correlations to assess the discriminant validity: As shown in Table 3, the ratios of each construct were below 0.9, and thus established discriminant validity (Henseler et al., 2014).

Following Schumacker and Lomax (1996), we applied three types of fit indices to evaluate the model: absolute fit, parsimonious fit, and incremental fit. All the obtained fit indices met the suggested ranges like CMIN/df = 2.47, RMSEA = 0.538, GFI = 0.978, AGFI = 0.911, CFI = 0.964 and NFI = 0.911 (Hair et al., 2014).

After confirming the reliability and validity of the measurement model, we performed path analysis to evaluate the relationships among the latent variables. We used the R programming environment and Lavaan, Psych package for this purpose, incorporating bootstrapping (2,000 re-samples) to improve the reliability of the results.

TABLE 2 Confirmatory factor analysis.

Construct	Item	Loading	*p* Value	Cronbach's α	CR	AVE
AOR	AOR1	0.83	***	0.89	0.89	0.74
	AOR2	0.84	***			
	AOR3	0.89	***			
IAW	IAW1	0.93	***	0.93	0.93	0.82
	IAW2	0.82	***			
	IAW3	0.93	***			
AOC	AOC1	0.87	***	0.89	0.89	0.73
	AOC2	0.82	***			
	AOC3	0.86	***			
PN	PN1	0.92	***	0.93	0.93	0.83
	PN2	0.90	***			
	PN3	0.89	***			
PK	PK1	0.80	***	0.93	0.94	0.79
	PK2	0.91	***			
	PK3	0.87	***			
	PK4	0.93	***			
IP	IP1	0.88	***	0.93	0.93	0.81
	IP2	0.89	***			
	IP3	0.92	***			

TABLE 3 SEM analysis.

Endogenous variable	Exogenous variable	Beta	B	Se	*p*-value	CI lower	CI upper
AOC	PK	0.17	0.18	0.05	***	0.08	0.28
AOR	PK	0.20	0.31	0.07	***	0.19	0.45
AOR	AOC	0.71	1.10	0.14	***	0.84	1.41
PN	AOR	0.57	0.83	0.16	***	0.58	1.21
PN	AOC	0.32	0.73	0.17	***	0.40	1.08
PN	PK	0.17	0.39	0.06	***	0.26	0.51
IP	PN	0.73	0.53	0.08	***	0.39	0.69
IP	PK	0.14	0.23	0.06	***	0.12	0.36
IAW	IP	0.36	0.29	0.05	***	0.20	0.39
IAW	PK	0.42	0.57	0.07	***	0.44	0.71

The applied structural model explains the high variability of the IP ($R^2 = 0.636$), PN ($R^2 = 0.810$) and IAW ($R^2 = 0.44$) (Table 4). In line with hypotheses H1 and H2 (Figure 2), we confirmed that the PK of water consumption influenced both the intention to use smart water metrics (b = 0.42, $p < 0.001$) and the intention to reduce water (b = 0.14, $p < 0.001$). Additionally, the study confirmed hypothesis H3: The Intention to save water was positively related to the intention to adopt smart water meters (b = 0.36 $p < 0.001$). Further, we established the direct influence of all theoretical variables on Personal Norms, i.e., AOR (b = 0.57 $p < 0.001$), AOC (b = 0.32 $p < 0.001$), and PK (b = 0.17 $p < 0.001$). In line with hypothesis H4, the Personal Norm on saving water was positively related to the intention to save water (b = 0.73, $p < 0.001$). We also found that PK influenced AOR (b = 0.17 $p < 0.001$) and AOC (b = 0.20, $p < 0.001$), in respective alignment with H5 and H6. As we assumed, AOC had a strong direct effect on AOR (b = 0.71, $p < 0.001$) and on PN (b = 0.32, $p < 0.001$), in accordance with H8 and H9, respectively. Lastly, AOR seemed to influence PN, in support of H10 (b = 0.57, $p < 0.001$).

Discussion

This study found that consumers' perceived knowledge about personal water usage has both a direct and indirect impact on

TABLE 4 Discriminant validity (HTMT).

	AOR	IAW	AOC	PN	PK	IP
AOR	1.00					
IAW	0.49	1.00				
AOC	0.75	0.30	1.00			
PN	0.85	0.52	0.77	1.00		
PK	0.34	0.58	0.18	0.43	1.00	
IP	0.72	0.55	0.60	0.78	0.46	1.00

their intentions to adopt smart water meters. The direct impact of perceived knowledge on intentions to apply smart water meters was indicated by an effect of strength 0.42. From this result, we assume that people who are more aware of their water consumption (which proxies their general interest and involvement in this issue) are also more willing to adopt smart meters that will provide more precise data.

We also uncovered that perceived knowledge indirectly influences the intention to save water. This corroborates prior research arguing that knowledge influences pro-environmental behaviors (Levine and Strube, 2012; Suryanda et al., 2021). It follows that consumers who are willing to save water are also more eager to implement smart meters that can help them achieve that goal (Sønderlund et al., 2014). In order to calculate the strength of the indirect effect, we multiplied the direct effects of intentions to save water towards intentions to apply smart water meters with the indirect effect of perceived knowledge to intentions to save water.

Notably, perceived knowledge exerted an indirect impact in several ways. The first was through personal norms. Personal norms are significantly connected with people's perceived knowledge of personal water use and also impact the intention to reduce water (and by extension, adopt smart meters). Thus, our results affirm prior studies positing that personal norms can explain pro-environmental behaviors (Schwartz, 1977; De Groot and Steg, 2009; Jansson et al., 2017).

In addition, perceived knowledge impacts the ascription of responsibility and the awareness of consequences, in support of the VBN theory. However, VBN argues that personal norms arise from both the awareness of consequences and ascription of responsibility. By contrast, we found that ascription of responsibility is individually, indirectly and significantly impacting personal norms. Thus, ascription of responsibility is impacting personal norms which influence the intention to reduce water consumption which impacts the intentions to apply smart water meters.

Furthermore, perceived knowledge of personal water use is also indirectly impacting the intentions to implement smart water meters through ascription of responsibility and awareness of consequences of excessive water use, we calculated the strength of this effect by multiplying the indirect and direct impacts. These variables are based on the Norm Activation model. Based on our founding knowledge is impacting both of these variables. Awareness of consequences requires some knowledge on the effects of water consumption in order to be determined, meanwhile ascription of responsibility is requiring awareness of consequences of excessive water consumption in order to be determined. Moreover, based on our results and the original model ascription of responsibility and awareness of consequences are impacting personal norms, which are influencing the intentions to reduce water which leads to higher intentions to implement smart water meters in order to reduce water consumption. Our results also serve to extend the VBN model. According to this theory, personal norms stem from the awareness of consequences and the ascription of responsibility. However, our research suggests that personal norms do not necessarily require this connection, and can instead be impacted by other variables, such as perceived knowledge.

Lastly, we want to highlight that the majority of past research has focused on people's real environmental knowledge without considering their perceived knowledge (Bang et al., 2000; Mostafa, 2006; William et al., 2009). For instance, Levine and Strube (2012) sought to determine whether environmental knowledge encourages environmentally friendly behavior; however, they adopted a questionnaire from NEETF that used questions such as "what is biodiversity" to measure real environmental knowledge. However, previous research suggests that green behaviors are associated more with perceived knowledge than objective knowledge (House et al., 2004). Kim et al. (2018) confirmed that perceived knowledge is a strong predictor of environmental friendly behavior. Our results contribute to this latter stream by affirming that perceived knowledge can directly and indirectly influence the intention to engage in environmental behaviors, such as adopting smart water meters.

Conclusion

The main aim of this research paper was to broaden our understanding and extend the scientific knowledge about consumer behavior when it comes to pro-environmental decisions such as applying smart water meters in order to reduce their water consumption. Based on our results, we can say that perceived knowledge is an important variable that can directly and indirectly influence consumers' intentions to adopt smart water meters in their households. In addition, we demonstrated that different variables impact consumers' decision to implement smart water meters. Thus, our findings may hold value for future studies on implementing smart water meters at the household level. Contrary to traditional water meters, the use of IoT gives residents the insight to constantly and precisely measure the place, time and context of water use, including the possibility of determining the possibility of determining an individual residents' water consumption. This knowledge can increase individual responsibility and possibly translate into a more efficient use of resources. Moreover, this research managed to verify that perceived knowledge of consumers in addition to their values-beliefs-norms can influence consumers to behave in a more sustainable manner.

In addition, based on our results, not only we managed to extend the scientific knowledge about consumers' behavior towards water consumption but also to find ways in order to influence them to behave more sustainably by applying smart water meters and reducing their water consumption. The results could be used not only from researchers in order to extend the research area, but also from policy makers in order to create successful campaigns aiming on reducing household water consumption which plays an important role on the global water scarcity matter. IoT water meter manufactures could also use the results to not only make their product more appealing but also to contribute in water scarcity. The results present that there are ways to influence consumers to behave more sustainably and that could help with the global issue of water scarcity.

That said, our study features several limitations that may spur further research. First, we did not determine if any participants were living in water-stressed areas and how that might have influenced their answers. Second, most of our participants were well educated people, whereas as it was found out that socio-economic characteristics of consumers influenced their perceived water usage (Beal et al., 2013), so as more of our responders are well educated that may impact our findings. We also did not examine the source of respondents' perceived knowledge: We assumed that it was connected with people's general interest in the quantity of water used, but it could also stem from a general belief in one's knowledge superiority.

Regarding future research directions, scholars could explore other predictors of the intention to adopt smart water meters: for instance, by using theories of technology acceptance as the main theoretical framework, like the Technology Acceptance Model, the Unified Theory of Acceptance and Use of Technology (UTAUT2), or the Theory of Planned Behavior. Additionally, future research could investigate the influence of some moderating variables (e.g., environmental concern, frugality, or personal innovativeness) on the relationship between the perceived usefulness and ease of IoT water meters and the intention to adopt them. Lastly, while our research underscores the role of one's willingness to save water in the decision to adopt smart water meters, future research could assess how various motives (e.g., financial, environmental) shape this relationship.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by The Committee of Ethical Science Research of Poznan University of Economics provided us with approval for the research. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

KM and BB contributed to the conception and design of the study. AS organized the database. AS performed the statistical analysis. KM wrote the first draft of the manuscript. KM, BB, and AS wrote sections of the manuscript. BB and KM reviewed the manuscript. BB found funding for the research. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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APPENDIX TABLE A1 Survey questions.

Variables	Questions	Sources
Intention to apply IoT water meters	IAW1. I plan to apply IoT-based water meters in my household	Chen and Tung (2014)
	IAW2. I am willing apply IoT water meters in my household	
	IAW3. I will make an effort to apply IoT water meters in my household	
Ascription of responsibility for using too much water	AOR1. I believe all consumers need to take responsibility for water resource usage	Shin et al. (2018)
	AOR2. I think that every consumer is partly responsible for water resource deterioration caused by human kind	
	AOR3. Everyone must take responsibility for the amount of accessible water	
Awareness of consequences of using too much water	AOC1. I believe that using too much water can help increase the tempo of exhaustion of natural resources	Shin et al. (2018)
	AOC2. Using too much water can possibly have a negative impact on the environment	
	AOC3. I think that using too much water supports environmental degradations	
Personal norm concerning saving water	PN1. I believe I have a moral obligation to save water	Shin et al. (2018)
	PN2.Saving water is consistent with my moral principles	
	PN3. My personal values encourage me to save water	
Perceived knowledge on personal water usage	EK1. I have more knowledge on my water usage than an average person	Joshi and Rahman (2017)
	EK2. I know how much water I use every week on average	
	EK3. I have the knowledge about my personal usage of water dedicated for the sustainability symbols used on product packages	
	EK4. I am very knowledgeable about my water usage	
Intention to reduce water usage	IP1. I plan to reduce water usage	Chen and Tung (2014)