Explaining Willingness to Pay for Solar Panels in Finland

D. Kuperstein-Blasco.[1], S.J. Mäkinen[2]
[1] Industrial Engineering and Management, Tampere University, Tampere, Finland
[2]Department of Mechanical and Material Engineering, University of Turku, Finland
(deborah.kupersteinblasco@tuni.fi)

Abstract – **This manuscript investigates the role of the preventive quality of photovoltaic (PV) systems in willingness to pay (WTP). We build on existing studies to investigate which factors influence WTP behavior through a survey with 284 respondents in Finland. We find that higher WTP is associated with higher concerns for preventing emissions and climate change, the need for more public talk on environmental issues, and an overall favorable attitude towards PV technologies. Since WTP behavior concerning PV panels is highly context-specific, we discuss our findings with earlier WTP studies of different contexts and provide future research avenues.**

Keywords – **Willingness to pay, solar panel, photovoltaic systems**

I. INTRODUCTION

Willingness to Pay (WTP) is a commonly utilized factor to understand the adoption of climate change mitigation innovations. Earlier research confirms that this is the case with renewable energy innovations, such as photovoltaic systems [1]–[4]. However, earlier studies have shown predictors of willingness to pay to be context specific; variables significantly explaining the willingness to pay in a certain location are not necessarily generalizable to another location. Hence, this manuscript investigates the willingness to pay for photovoltaic systems in Finnish households. With this, we seek to shed light on how willingness to pay can be explained in a Nordic country. We compare our findings to other findings around the world and identify relevant similarities and differences.

II. THEORETICAL BACKGROUND

Preventive quality of photovoltaic systems

Studies in the adoption of innovations considering their preventive quality and the benefits gained from prevention have been mostly directed toward health innovations [5], [6]. However, there are various innovations with underlying goals of prevention whose adoption has not been widely studied considering the role of prevention, for example, environmental innovations.

Photovoltaic (PV) systems can be studied through their preventive quality due to their underlying goals to prevent greenhouse gas emissions, or prevent energy disruptions [7]. PV systems convert light into electricity through interconnected photovoltaic cells, a mounting structure, an inverter, a storage battery, and a charge controller [8, p. 4].

The adoption of PV systems is considered an important part of the sustainability transition, for which several studies have sought to identify factors that influence adoption. These studies rely on the diffusion of innovations theory as well as social behavioral theories.

Factors that influence adoption include normative factors (subjective norms, past experiences, attitudes) [9]–[14], socioeconomic background [10], [15], attributes of the innovation [14], [16], costs of the PV system [1], [11], [17], environmental attitudes and concerns [9], [10], and incentive systems [2].

Willingness to Pay

In behavioral economics, Willingness to Pay (WTP), describes the price at which consumers will purchase a product. WTP can be also utilized to capture public preferences regarding climate strategies where factors that shape patterns of WTP include operation and installation costs, environmental attitudes, sociodemographic factors, and political views [18].

Previous studies on predictors of WTP have identified variables that contribute to WTP across the globe. When studying WTP in Italy, Bragolusi & D'Alpaos [1] identified energy efficiency as the most valued characteristic of PV systems as it yields cost savings. In Norway, Cherry [2] identified WTP depends on knowledge among households, clarity with grid tariffs, and support systems. In Korea [12], WTP was influenced by the public's need for safe and eco-friendly surroundings which could be explained by the Fukushima nuclear accident. In Japan [3] WTP increased as adopters were familiar with the technology and systems become more efficient. In India [15], sociodemographic factors were identified as predictors for WTP. In Mexico [13], WTP was influenced by normative factors around solar power. Finally, in Britain [4], WTP was influenced by capital costs, subsidies, and regulatory requirements. As shown, multiple factors influence WTP and these are all different across the globe, which signals WTP is context-specific and not easily generalizable across national or local contexts.

Currently, the diffusion of PV systems in Finland is limited as the production of solar electricity represents an average of 0.3% of total electricity production in the country [19] and about 4% of the production during summertime [20]. Karjalainen & Ahvenniemi [21] identified that adoption of PV systems by households in Finland is influenced by access to trustworthy information, and advice from experts or other adopters. Furthermore, this decision is not motivated by economic profitability, but by the "pleasure" of producing pollution-free energy. Furthermore, Haukkala [22] identified vested interests, path dependency, and lock-in with the existing systems as barriers to the adoption of solar energy in Finland.

III. METHODOLOGY

A. Research setting

The context of this research is the willingness to pay for PV systems. We consider the case where the respondent is willing to purchase a PV system without state subsidies; response options varied from less than 300€ to over 9000€. We study the influence of the preventive quality of PV systems related to climate change mitigation and prevention of energy production and consumption security issues.

B. Data collection

Our data was collected through an online survey distributed through the website of a local electricity company in central Finland from September to November 2021. Four researchers were involved in survey creation, translation, testing, and implementation. Our final sample size was 284. We used multiple regression to explain dependent variable behavior with independent predictors described below. Our approach was as follows: first, we designed multiple regression models for control variables, then independent predictor variables, and then all variables, utilizing the simple enter method in SPSS (models 1 to 3 in Table 1). This way, we were able to see how much the traditional multiple regression could explain the variance of our dependent variable. Further on, to explore the dynamics of independent predictors, we chose backward elimination regression to find the best arrangement of predictors explaining WTP for solar panels. Backward regression eliminates from an original list of predictors first the predictor with the highest p-value and runs the multiple regression again. We removed predictors until all remaining variables had p-values less than or below 0.10. This is represented by Model 4 in Table 1.

C. Variables

Our dependent variable: *"How much would you be willing to pay for a photovoltaic system?"* measured the investment that respondents would be willing to make for the PV system (without government subsidies). We built on earlier research to have baseline models explaining the behavior of our dependent variable. We derived our independent predictors from earlier research, as described with representative references below. We asked respondents to answer each question as they agree with the statements with a 5-point Likert scale from 1= strongly disagree to 5= strongly agree. Q_2-Q_7 describe demographic variables of gender, education, and income levels, among others; the rest are as follows:

Q_8 Switching to a solar electricity contract will make a good impression on other people [23]. Q_9 Switching to a solar electricity contract will make me feel good [24].

Q_10 I think a solar contract is expensive. Q_11 It is economically feasible for me to switch to a solar contract [24]. Q_12 I know more than one person who has switched their electricity contract to a solar electricity contract [25]. Q_13 Before changing my electricity contract, I would like to talk to someone who has already switched to a solar electricity contract [25]. Q_14. I have enough information about the solar electricity contract to decide to switch [26]. Q_15 I know where I can get reliable information about my solar contract [11]. Q_16 Many people who are important to me think it would be good if I switched my electricity contract to a solar electricity contract [24]. Q_17 It is entirely up to me to change my electricity contract [14]. Q_18 It is important to me to protect nature [27]. Q_19 It is important to use renewable energy to reduce emissions [28]. Q_20 I feel an obligation to reduce the negative consequences of my energy consumption [29]. Q_21 I find it easy to switch to a solar contract [11]. Q_22 I Switching to a photovoltaic contract allows me to save natural resources and reduce greenhouse gas emissions [30]. Q_23 People like me should do all they can to reduce emissions and prevent climate change [31]. Q_24 Solar energy is a reliable way to generate electricity [32]. Q_25 Solar energy as a way of generating electricity is a new and advanced technology [33]. Q_26 I welcome solar energy [14]. Q_27 The photovoltaic contract allows me to increase local energy production [34]. Q_28 It is not sunny enough where I live for solar panels to produce well [25]. Q_29 It is important to me that all people have equal opportunities to pursue happiness [27]. Q_30 It is important to me to do things that I enjoy [27]. Q_31 High wealth is important to me [27]. Q_32 There is too much public debate on environmental issues [35].Q_33 The state should take greater responsibility for environmental protection [35]. Q_34 Buying electricity from fossil energy sources makes me feel guilty [36].

IV. RESULTS

In Table 2 (see Appendix 1) we highlight descriptive statistics and correlations for all variables. Table 1 shows the results of the regression analyses through non-standardized coefficients. Models 1 to 3 relied on multiple regression with enter method used and Model 4 was generated through the backward elimination method.

Our selected model included a series of variables that were significantly associated with WTP. By looking at the unstandardized coefficients and their signs we can identify how these variables contribute to respondents' willingness to pay for PV systems.

First, there is a high meaning of control variables. This, as such, is not that surprising as earlier investigations have shown similar tendencies that basic demographic and respondent characteristics explain their behavioral intentions and WTP [9], [10].

Second, we find that independent variables have low explanatory power in Model 2. However, there are quite a few significant independent variables.

Third, control and independent variables together in Model 3 increase the explanatory power to 38,4%. However, quite a few previously significant variables turn out to become insignificant. This can be explained by correlations between variables.

Finally, by observing adjusted R2 values and F-values and based on the above Model 3 results, we decide to further interpret Model 4 as both adjusted R2 and F-value are better than all other models.

TABLE I
REGRESSION ANALYSIS RESULTS

	Model 1 *Std. B*	*Model 2* *Std. B*	*Model 3* *Std. B*	*Model 4* *Std. B*
	3,152**	0.833	0.524	1.247
Q_2	1,024**		1,193**	1,28**
Q_3	-0,271**		-0,213*	-0,199*
Q_4	0,189**		0,164*	0,21**
Q_5	-0,378*		-0,525**	-0,664**
Q_6	0,005*		0.005	
Q_7	-0,554*		-0.386	-0,48*
Q_8		-0.236	-0.274	-0.216
Q_9		0.014	-0.051	
Q_10		0,43**	0.067	
Q_11		0,275*	0.107	
Q_12		-0.129	-0.055	
Q_13		0.105	0.184	0.17
Q_14		0.289	0,33*	0,27**
Q_15		0.003	-0.164	
Q_16		0.091	0.079	
Q_17		-0.082	-0.036	
Q_18		0.173	0.196	
Q_19		0.283	0.159	
Q_20		-0.088	-0.087	
Q_21		-0.013	0.033	
Q_22		-0.15	0.119	
Q_23		0.109	0.15	0,257*
Q_24		-0.016	0.135	
Q_25		-0,476*	-0.266	
Q_26		0,561**	0.297	0,399**
Q_27		0.342	0.183	
Q_28		-0,41**	-0.239	-0,252*
Q_29		-0.172	-0.008	
Q_30		-0.3	-0.183	
Q_31		0,401**	0.196	0.18
Q_32		-0.253	-0,328*	-0,361*
Q_33		-0.245	0.009	
Q_34		0.092	-0.01	
N	284	284	284	284
Adj R^2	0.274**	0.183**	0.384**	0.399**
F	18.798	3.344	6.35	15.429

*p<0.05, **p<0.01

In Model 4 we find that Q_7, Q_28, and Q_32 are negative and significant. However, Q_32 is reverse coded; this signals that respondents that think there is too much public discussion of environmental issues have lower WTP. This is in line with earlier findings that people who think more environmental issues should be raised have higher WTP [9]. In Q_7 respondents who have their household/housing centrally managed to have lower WTP. So, respondents who own houses or semi-detached housing have higher WTP than those renting a home.

Positive significant independent variables include Q_14, Q_23, and Q_26. Q_14 signals that respondents that consider themselves knowledgeable in the PV issues have higher WTP, this finding is in line with previous studies on factors for PV system adoption in Finland [21]. Q_23 brings the preventive attitude of respondents as a significant issue for WTP as this shows that respondents that think similar people should do all they can to prevent pollution and climate change. Also, Q_26 signals a favorable attitude towards PV technology, and a favorable attitude results in higher WTP.

V. DISCUSSION

This study sought to identify the willingness to pay for photovoltaic systems in Finnish households. We find six highly significant (p<0.05) predictors, described above. When we compare these findings to earlier studies on WTP we find similarities between ours and those in Asia, where environmental concerns [12] and information about the technology [3] influenced WTP. The influence of sociodemographic factors is a common finding across the globe [13], [15]. One main difference is that potential adopters' WTP in Finland are not motivated by financial matters, as happened in Italy [1] or Britain [4], but there is a strong environmental emission reduction and climate change prevention component. This need for eco-friendly surroundings was also identified as a factor influencing WTP in Korea [12].

Limitations of our study include the geographic and demographic distribution of our respondents, as they were predominantly in central Finland. This is not a representative sampling of the whole country as southern and northern parts differ from one another concerning yearly sunshine and the utility of PV panels.

Future research settings seek to study prevention as an independent construct influencing the adoption of innovations. Additionally, studies could focus on other innovations with preventive qualities that have been studied globally in a similar comparative setting.

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Appendix 1

TABLE II. COEFFICIENT CORRELATIONS

	Mean	Std. Dev.	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7	Q_8	Q_9	Q_10	Q_11	Q_12	Q_13	Q_14	Q_15	Q_16	Q_17	Q_18	Q_19	Q_20	Q_21	Q_22	Q_23	Q_24	Q_25	Q_26	Q_27	Q_28	Q_29	Q_30	Q_31	Q_32	Q_33	Q_34
Q_1	3.04	2.342	1																																	
Q_2	1.36	0.523	,304**	1																																
Q_3	4.23	1.378	-0.083	,206**	1																															
Q_4	4.2	1.915	,244**	-0.017	-0.03	1																														
Q_5	2.22	1.01	-,413**	-,270**	0	-,188**	1																													
Q_6	90.83	61.988	,389**	,260**	0.079	,203**	-,673**	1																												
Q_7	1.44	0.595	-,334**	-,219**	-,161**	-,210**	,462**	-,434**	1																											
Q_8	3.12	1.096	0.026	-0.038	0.01	-,126*	0.015	-0.035	0.059	1																										
Q_9	3.42	1.133	0.113	-,255**	-0.081	-0.054	-0.028	0	0.017	,662**	1																									
Q_10	3.57	0.924	0.067	,213**	-0.095	0.042	-,269**	,253**	-,151*	-,266**	-,339**	1																								
Q_11	3.16	1.181	,222**	0.111	0.023	,157**	0.068	0.022	-,178**	,143*	,147*	-,269**	1																							
Q_12	1.65	0.941	0.018	,129*	,165**	-0.085	0.04	-0.073	-0.073	,284**	,205**	-,168**	,166**	1																						
Q_13	3.03	1.29	-0.05	-0.069	,177**	-0.005	0.103	-,124*	0.032	,155**	0.114	-,181**	0.092	,166**	1																					
Q_14	2.85	1.24	,152*	,206**	0.045	-0.071	-0.06	0.034	-0.112	0.084	0.036	-0.009	,304**	,280**	-,196**	1																				
Q_15	3.34	1.168	,131*	0.076	-,127*	-0.044	-0.111	,141*	-,122*	0.1	,129*	-0.023	,221**	,174**	-,155**	,600**	1																			
Q_16	2.64	1.036	0.08	-0.059	0.104	-0.093	-0.002	-0.033	-0.002	,555**	,534**	-,294**	,167**	,380**	,183**	,138*	,155**	1																		
Q_17	4.03	1.292	-0.012	0.114	0.067	-0.07	0.035	-0.03	-0.106	0	-0.043	0.065	,203**	0.012	-0.024	,204**	,166**	0.072	1																	
Q_18	4.44	0.779	0.106	-,273**	-0.108	-0.05	,125*	-0.074	0.008	,265**	,348**	-,168**	,161**	0.013	-0.01	0.023	0.088	,228**	-0.021	1																
Q_19	4.25	0.84	,152*	-,224**	-,138*	-0.006	0.084	-0.054	0.029	,262**	,441**	-,172**	0.087	-0.057	0.028	-0.057	0.074	,199**	-0.089	,402**	1															
Q_20	3.85	1.081	0.103	-,310**	-0.112	-0.057	,124*	-0.021	0.077	,338**	,517**	-,264**	,141*	0.072	0.064	-0.041	-0.004	,345**	-0.113	,444**	,642**	1														
Q_21	3.38	0.876	0.102	0.076	-,221**	-0.017	0.017	-0.003	-0.023	0.04	0.083	-0.06	,292**	,126*	-,152*	,393**	,417**	0.06	,195**	-0.003	0.016	0.032	1													
Q_22	3.89	1.146	0.08	-,353**	-,152*	-0.053	,183**	-,160**	,154**	,455**	,653**	-,388**	,152*	0.112	0.043	-0.019	0.081	,407**	-0.091	,481**	,473**	,583**	0.045	1												
Q_23	3.74	1.081	,122*	-,296**	-0.041	-0.042	,169**	-0.069	0.082	,322**	,470**	-,255**	,149*	0.017	0.046	-0.046	0.046	,344**	-0.047	,450**	,649**	,765**	0.009	,587**	1											
Q_24	3.67	1.058	,129*	-,234**	0.029	-0.016	0.097	-0.047	0.052	,424**	,543**	-,366**	,207**	,129*	0.049	0.074	,174**	,417**	0.046	,346**	,348**	,402**	,193**	,562**	,472**	1										
Q_25	4.06	0.905	0.041	-,202**	0.017	-0.099	,121*	-0.056	0.075	,381**	,389**	-,227**	,176**	0.108	0.104	0.09	0.114	,306**	0.08	,348**	,366**	,374**	,167**	,442**	,438**	,563**	1									
Q_26	4.33	0.919	,210**	-,131*	-0.073	0.008	0.055	-0.022	-0.011	,357**	,457**	-,209**	,139*	0.045	0.009	-0.023	0.042	,301**	-0.03	,429**	,436**	,385**	,149*	,561**	,411**	,592**	,592**	1								
Q_27	3.79	1.016	,183**	-0.114	-0.066	0.035	0.049	-0.006	0.018	,474**	,552**	-,295**	,247**	,153**	0.086	,131*	,220**	,413**	-0.041	,360**	,387**	,373**	,157**	,614**	,383**	,507**	,510**	,516**	1							
Q_28	2.98	1.076	-,221**	0.001	0.037	-0.015	0.017	-0.035	0.004	-,124*	-,227**	,268**	-,159**	-0.056	0.11	-0.106	-,138*	-,172**	-0.045	-,128*	-,197**	-,228**	-,130*	-,208**	-,226**	-,419**	-,260**	-,250**	-,179**	1						
Q_29	4.31	0.949	-0.07	-,192**	0.011	-0.084	,186**	-0.092	0.091	,117*	,134*	-0.082	0.049	0.001	0.078	0.053	0.062	0.076	-0.057	,364**	,237**	,232**	0.012	,187**	,252**	,131*	,196**	,193**	,151*	0.038	1					
Q_30	4.48	0.68	-0.073	-,217**	-,232**	-0.016	,125*	-0.067	0.049	0.07	0.087	0.016	-0.027	-0.061	0.007	0.013	,176**	-0.003	0.059	,271**	,232**	0.089	0.112	,153**	0.113	0.081	0.114	,164**	,134*	0.101	,413**	1				
Q_31	2.66	1.137	,194**	,282**	-0.041	0.105	-,133*	,161**	-,258**	0.03	-0.016	,180**	0.115	,149*	0.005	0.063	0.045	0.004	-0.046	-,140*	-0.102	-0.094	0.028	-,140*	-0.069	-,134*	-0.08	-0.079	-0.005	,150*	-0.091	0.05	1			
Q_32	2.36	1.244	-,127*	,283**	,197**	0.076	-,128*	0.066	-,180**	-,182**	-,324**	,183**	-0.055	0.109	0.099	,238**	0.048	-0.07	0.096	-,383**	-,443**	-,445**	0.076	-,404**	-,518**	-,272**	-,236**	-,328**	-,196**	,251**	-0.1	-0.085	,180**	1		
Q_33	3.89	1.041	-0.033	-,361**	-,204**	-,157**	,262**	-,214**	,172**	,164**	,238**	-,194**	0.018	-0.077	-0.045	-0.079	-0.05	,123*	-0.095	,362**	,510**	,503**	-0.092	,425**	,564**	,181**	,266**	,228**	,218**	-0.09	,211**	,176**	-,197**	-,534**	1	
Q_34	3.06	1.283	0.078	-,201**	-0.116	-0.104	0.074	-0.041	0.044	,389**	,498**	-,270**	0.096	0.073	-0.069	-0.001	0	,322**	-0.082	,352**	,448**	,590**	0.02	,526**	,508**	,288**	,198**	,307**	,319**	-,119*	,170**	0.028	-,168**	-,441**	,444**	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).