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Do Perceived Risk, Perception of Self-Efficacy, and Openness to Technology Matter for Solar PV Adoption? An Application of the Extended Theory of Planned Behavior

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Abstract: Solar PV (photovoltaic) technology has gained considerable attention worldwide, as it can help reduce the adverse effects of CO_2 emissions. Though the government of Pakistan is adopting solar PV technology due to its environmental friendliness nature, studies focusing on consumer's acceptance of solar PV are limited in the country. This research aims to close this knowledge gap by looking into the various considerations that may influence consumers' willingness to adopt (WTA) solar PV for household purposes. The study further contributes by expanding the conceptual framework of the theory of planned behavior by including three novel factors (perceived risk, perception of self-efficacy, and openness to technology). The analysis is based on questionnaire data collected from 683 households in Pakistan's provincial capitals, including Lahore, Peshawar, Quetta, Gilgit, and Karachi. The proposed hypotheses are investigated using the state-of-the-art structural equation modeling approach. The empirical results reveal that social norms, perception of self-efficacy, and belief about solar PV benefits positively influence consumers' WTA solar PV. On the contrary, the perceived risk and solar PV cost have negative effects. Notably, the openness to technology has an insignificant effect. This study can help government officials and policymakers explore cost-effective, risk-free technologies to lessen the environmental burden and make the country more sustainable. Based on research results, study limitations, as well as prospective research directions, are also addressed.

Keywords: solar PV technology; consumers; willingness to adopt; theory of planned behavior; structural equation modeling; Pakistan

1. Introduction

Climate change is a global environmental challenge, and to minimize its negative impacts, governments are implementing environmentally friendly technologies worldwide [1]. The persistent advancement in the population and globalization development has increased the energy demand [2,3]. Although being more technologically evolved than ever before, most countries still depend purely on crude oil to generate electricity [4]. About two-thirds of the world's increasing energy demand is owing to fossil fuels [5]. The continuous use of traditional sources in electricity generation is the primary cause of global climate change [6]. As a result, to combat global warming, the world must transition to clean energy sources [7,8]. Solar PV, a form of clean energy, has become more common in recent times and reached a global installed capacity of 303 GW, with a healthy annual

33-percent growth rate [9]. By 2025, solar PV is projected to meet 4% of the global electricity demand [10].

Similarly to other developing countries, Pakistan is facing environmental degradation and the worst energy crisis [11]. Due to Pakistan's massive population and economic growth, the energy demand has increased over the last two decades [12]. Pakistan's existing energy structure is heavily dependent on costly imported fuels such as oil and gas. Fuel imports from other countries are the only choice because Pakistan's domestic fuel supplies are inadequate to meet the country's energy demands. The country spends nearly 60% of its foreign exchange on fossil fuel imports [13]. An enormous dependence on traditional electricity generation methods is the main cause of environmental problems and a burden on economic development [14]. Solar PV is being introduced in Pakistan to address climate change issues and provide a long-term strategy for resolving the country's energy crisis [15].

Solar PV, a novel energy green technology, effectively decreases the cost of imported oil and minimizes CO_2 emissions [16]. Different countries have taken steps to raise the proportion of solar energy in their portfolio structure [17,18]. According to the sustainable global progress report 2020, solar PV rose 12% and generated electricity of 115 GW in 2019. Until 2019, the estimated worldwide solar PV output reached 627 GW [19].

Solar PV projects are believed to boost the quality of life for residents in numerous ways, such as providing job opportunities for people [15], they can help to reduce CO_2 emission [20], and it is the cheapest source of renewable energy and would be helpful to sustain the prices of electricity [21]. Electricity is considered a vital component in economic growth [22]. Solar PV technology helps to generate electricity at the household level and minimize carbon emissions [23]. The value of solar PV is highlighted by the fact that home appliances are one of the largest sources of CO_2, accounting for 70% of global emissions [24]. Fossil fuels (coal, oil, and gas) are the major energy sources of Pakistan [25]. The country spends USD 7 M annually on importing such costly energy sources [26]. According to the Pakistan Economic Survey, households are one of the largest energy consumers in Pakistan, with a share of 49.1% [27]. Other industries and sectors, including construction, transportation, and agriculture, also have a major share in energy consumption and carbon emission. As the country's energy structure is primarily based on fossil fuels, environmentally and economically friendly technologies are needed to minimize carbon emissions, on the one hand, and reduce the import of costly fossil fuels, on the other hand [28].

Solar PV is the most sustainable energy alternative for meeting the rising energy demand while also preserving the climate. Furthermore, the importance of solar PV adoption in Pakistan is demonstrated by [29], who claim that if 20% of the land in Baluchistan were covered in solar panels, then Pakistan's total electricity demand could be met. This demonstrates the considerable capability of solar PV technology to meet Pakistan's electricity needs. However, persistent electricity shortages can be addressed at the household level by using solar PV. Despite its enormous potential, solar PV has a low acceptance rate in Pakistan.

Several researchers have examined the dwellers' willingness to adopt solar PV in developed countries. Previous studies were conducted in economies where the governments already have defined strategic policies to achieve zero carbon emissions. Polo Lopez, Lucchi, and Franco [30] examined the potential, barriers, assessment criteria, and acceptance of building integrated photovoltaic in heritage buildings and landscapes. The authors concluded that it is necessary to protect the compatibility requirements for architecture and landscape. The possibilities of emerging solar products, which are currently not well-introduced in the market, are endless, thanks to advanced customization capabilities that enable a better integration into contexts of special heritage-protected buildings, thereby preserving their cultural and essential values. In another study, [31] established a conceptual framework for integrating solar energy systems into heritage sites and buildings to preserve their cultural and natural values, while lowering primary energy consumption,

increasing comfort levels, mitigating environmental impacts, and enhancing the technical quality and economic outlays. The authors of [32] found that Australia attains 6% of its necessities from renewable resources. The authors concluded that Australia has diligently used renewable resources in recent years, which has had a positive environmental impact. According to the report of [33], the share of solar PV to generate electricity globally has increased by 28.3%. Irfan et al. [22] examined consumers' acceptance of solar energy by employing the theory of planned behavior from a Chinese perspective and discovered that consumers are positively influenced by awareness, self-efficacy, and the belief in the benefits of solar energy. Consumers' willingness to adopt solar PV is considered as the crucial factor to determine social acceptance [34]. Subsequent studies also identify the factors that may affect consumer's acceptance. Likewise, [35] investigated that acceptance is high when consumers believe that solar PV could mitigate carbon mission, benefit society, and increase job opportunities for people. Their study further revealed that descriptive factors such as age, income, education, and location also affect social acceptance [36].

A few scholars have conducted studies in developing countries as well to analyze the consumers' willingness to adopt solar PV. Alrashoud and Tokimatsu [37] examined considerations that may either empower or dissuade Saudi Arabian people from purchasing solar photovoltaic (PV) systems. The research found that education had the greatest positive effect, while the installation cost was the greatest barrier to adoption. Another study conducted by [38] in Ethiopia found that consumers have a high willingness to pay for solar energy to generate electricity, and the tendency to pay is positively influenced by economic variables such as age, income, and education. Likewise, [39] examined the solar PV social acceptation in six major states of India. They found that villagers show concern about the cost of solar PV, and they consider that solar PV is the best alternative, but it is more expensive in villages than in urban cities.

Along these lines, former researchers considered solar PV adoption from the following standpoints: (i) economic sustainability [40], (ii) social and environmental factors [41–43], (iii) barriers and drivers [29], (iv) the moderating role of policy and propaganda [24], (v) and financial incentives and subsidies [44]. Despite former researchers' long-standing interest, the inclination to find consumers' risk perceptions, self-efficacy, and openness to technology regarding solar PV adoption has been largely ignored. This research gap prompted us to add to the existing literature by evaluating the influence of these novel factors that could shape households' willingness to adopt solar PV. The study makes three major contributions in this regard. First, we considered all possible factors that may affect consumers' willingness to adopt (WTA) solar PV. Second, we added three new factors to the theory of planned behavior (TPB), including the perceived risk, perception of self-efficacy, and openness to technology. Previous studies have never taken these considerations into account in any context before, which is another contribution of this study. Third, unlike previous studies, the current research findings went beyond the previous research findings. For instance, the perceived risk appeared to be a significant factor in the acceptance of solar PV. Similarly, self-efficacy perception remains a vital component of TPB's theoretical structure. On the other hand, openness to technology plays a minor role in solar PV acceptance.

This study examines the willingness of Pakistani consumers to adopt solar PV using both existing and proposed novel factors. Pakistan has plenty of solar power resources, and if they are used properly, they can meet all of the country's current and potential energy needs [45]. However, as a developing country, Pakistan faces significant challenges in developing solar energy, including technological constraints, developers' reluctance to invest in solar PV generation, policies, and economic woes [46]. In addition, our research provides a robust conceptual framework by extending the TPB model and adding novel factors to better understand consumers' acceptance of solar PV.

The rest of the research is organized as follows: The theoretical framework is explained in Section 2. The formulation of hypotheses is shown in Section 3. Research methods are depicted in Section 4. The study's findings and implications are mentioned in Section 5. A

discussion of research results is included in Section 6. Section 7 concludes the study, offers valuable policy guidance and discusses study limitations.

2. Theoretical Framework

To investigate the buying behavior of consumers, various theoretical models have been used in the literature, such as TPB, the theory of reasoned action (TRA), and theory of self-efficacy (TSE) [47,48]. However, TPB is a commonly used model that predicts and identifies consumer behavior [49]. Professor Ajzen was the first one to study behavioral intention, notably with Fishbein. The TPB model suggests that a person's behavioral intentions control his or her actions [50]. TPB explains that individuals' behavior is shaped by their notable beliefs and the subsequent evaluations of a particular action. Several researchers have employed this theory to evaluate consumer behavior in different fields and contexts (see Table 1).

Table 1. Usage of TPB in different fields and contexts.

Theoretical Model	Country	Industry	Proposed Factors	Author
TPB	Portugal	Travel	Perceived behavioral control, subjective norm, and attitude	[51]
TPB	Denmark	Food	Perceived behavioral control, subjective norm, and attitude	[52]
TPB	Australia	Health	Perceived behavioral control, subjective norm, and attitude	[53]
TPB	Australia	Education	Attitude, social norm, and behavioral intentions	[54]
TPB	Lithuania	Solar	Attitude, environmental concern, and subjective norm	[55]
TPB	Malaysia	Solar	Attitude, subjective norm, and behavior	[56]
TPB	The Netherlands	Agriculture	Behavior, normative, and control belief	[57]
TPB	China	Solar	Perception about self-effectiveness, belief of solar energy benefits, and perception of neighbors' participation	[58]
TPB	Pakistan	Health	Risk perceptions of the pandemic, perceived benefits of face masks, and unavailability of face masks	[59]
TPB	Pakistan	Health	Self-efficacy, perceived risk, pandemic knowledge, and ease of pandemic prevention adoption	[60]

As previously stated, TPB's model can identify and forecast consumer behavior adoption. Several researchers have added additional variables to the model to enhance behavior prediction and clarify why certain people find it hard to put their good intentions into effect [61–63]. The TPB model can incorporate other critical variables that specifically affect behavior and intention, in addition to the factors that make up the theory itself. Based on the justification from the literature, we added three additional factors (perceived risk, perception of self-efficacy, and openness to technology) with existing factors (belief about solar PV benefits, solar PV cost, and social norms) to the TPB model to investigate consumers' WTA solar PV. The study's framework is portrayed in Figure 1. Consumers' adoption was negatively influenced by perceived risk. Perceived risk was the customers' assessment of the probability of safety and security incidents and the corresponding consequences. Reasonably, perceived risk may negatively influence the dwellers' willingness. Perception of self-efficacy indicated "a person's assessment of how easy or difficult it is to conduct a specific action". Individuals believed that they had the requisite expertise, resources, or opportunities to adopt new technology successfully. The perception of self-efficacy plays a crucial role and positively influenced consumers' adoption. The third factor was openness to technology that was defined as "whether consumers try new technologies or stick with existing ones". We examined households' opinions by determining their willingness to adopt solar PV (see Figure 1).
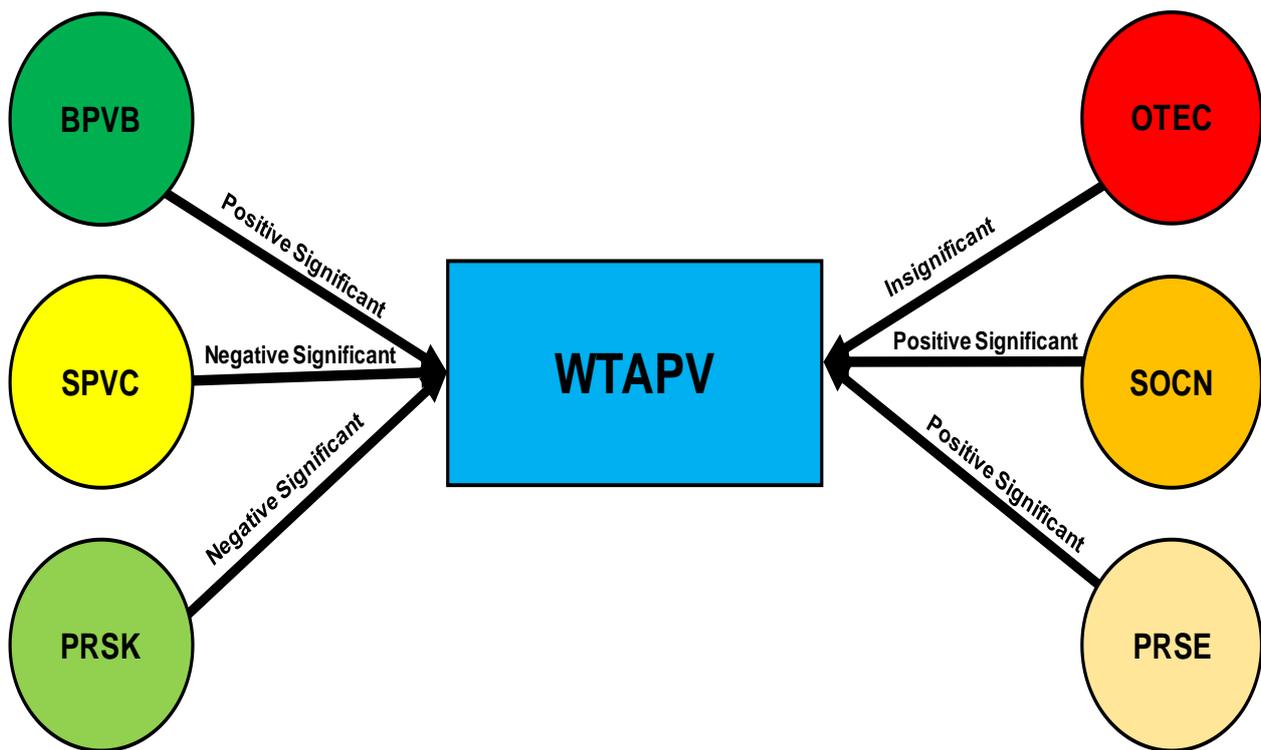
Figure 1. Study framework depicting the adoption of solar PV. Notes—BPVB: belief about solar PV benefits; SPVC: solar PV cost; PRSK: perceived risk; OTEC: openness to technology; SOCN: social norms; PRSE: perception of self-efficacy; WTAPV: willingness to adopt solar PV.

3. Development of Research Hypotheses

3.1. Belief about Solar PV Benefits (BPVB)

Belief about solar PV benefits (BPVB) was defined as consumers' perceptions about solar PV that it has various benefits such as energy protection measures, combating climate change, and energy-saving [64]. The study found that farmers' assumptions about perceived benefits had a major impact on their adoption in India [65]. People distinguished between traditional and renewable energy sources, making purchasing decisions based on their socio-economic status [66]. As a result, initiatives are required to increase residents' understanding of the advantages of solar power use, such as improved air quality and lower carbon emissions, as well as to educate them about the negative consequences of dependence on energy that is based on fossil fuel [67]. Further research carried out by [68] in Sweden found that folks who are constantly aware of the benefits of solar PV and how it helps to alleviate the burden of electricity are highly motivated to adopt solar PV. In light of these considerations, we formulated the following hypothesis:

Hypothesis 1 (H1). *Consumers' willingness to adopt solar PV is positively influenced by BSPVB.*

3.2. Solar PV Cost (SPVC)

As per the results of previous studies, there is a negative correlation between the cost of solar energy and its public acceptance. For instance, [69] concluded that solar PV was still more costly than traditional electricity. During purchasing circumstances, consumers also think about cost details to address monetary deficits [70]. Solar energy is relatively expensive since solar PV projects necessitate a large initial investment [15]. According to [38], rising prices are discouraging customers from adopting solar PV. Rising prices are the major deterrent to solar PV deployment [71]. Another study was conducted to determine consumers' desire to adopt solar home systems and solar PVs. The research

results indicate that respondents are discouraged by high costs [72]. As a result of these findings, we came up with the following hypothesis:

Hypothesis 2 (H2). *Consumers' willingness to adopt solar PV is negatively impacted by SPVC.*

3.3. Perceived Risk (PRSK)

In this context, perceived risk refers to a customer's belief that solar PV technology is risk-oriented. Consumers utilizing a new service or product were concerned about safety risks. This has a significant effect on consumers' interest in that particular product or service and, thus, on the acceptance of that technology [73]. A study by [74] reported that consumers should feel comfortable when interacting with technologies to increase adoption. Furthermore, results revealed that customers were hesitant to implement internet of things (IoT) services due to a lack of protection. Lee [75] discovered that security risk negatively affects consumers' attitudes toward online banking. In terms of customer confidence in adoption, the security risk is frequently cited as a major concern. Similarly, [76] also found that attitudes toward smart meter adoption were negatively influenced by perceived danger, to which privacy and safety issues are important antecedents. The study suggests the following hypotheses based on the preceding literature review:

Hypothesis 3 (H3). *Consumers' willingness to adopt solar PV is negatively influenced by PRSK.*

3.4. Openness to Technology (OTEC)

Individual judgments about the usefulness of technology would be influenced by their willingness to try new things [77]. In recent years, research has increasingly focused on the impact of transparency on people's interactions with technology. Openness to technology has been linked to an inquiring mind, intelligence, and intellectual interests because it reflects the responsiveness of an individual to new perspectives [78]. High openness to technology is described as a desire to learn and understand things that are new to them, and embrace innovative ways to solve problems and adopt new technology [79]. Individuals vary in their level of openness towards technology due to their diverse backgrounds and life experiences [80]. Watjatrakul [81] found that students eager to learn new things want to do so in a constantly changing world. The practical importance of online learning is positively influenced by openness to technology. Students who can take risks and try new things are more concerned about the content of online learning. Based on these study findings, we formulated the hypothesis as follows:

Hypothesis 4 (H4). *Consumers' willingness to adopt solar PV is positively impacted by OTEC.*

3.5. Social Norms (SOCN)

Social norms refer to the social influence on consumers' WTA solar PV [82]. Every country has its specific economic characteristics and individual culture [83]. Researchers observed that farmers inspired other farmers to engage in conservation initiatives by recommending them to attend agro-environmental programs [84]. It means that social pressure is often present during the execution of a specific action [85]. Another study conducted by [86] in three villages of South Korea's Geumsan county examined how residents who engage in the rural landscape development program have a substantial effect and motivation on other residents' perceptions. The majority of participants demonstrated an interest in and involvement in group activities. Lopes et al. [87] found a significant link between SOCN and residents' energy conservation behavior. According to [88], the actions of society have a huge influence on residents' intentions to purchase solar PV. Subsequently, it is essential to look at the impact of this crucial factor on WTA solar PV in Pakistan. Thus, we formulated the hypothesis as follows:

Hypothesis 5 (H5). *Consumers' willingness to adopt solar PV is positively impacted by SOCN.*

3.6. Perception of Self-Efficacy (PRSE)

In the context of solar PV, understanding regarding self-efficacy refers to how convenient or difficult it is for consumers to adopt solar PV [89]. PRSE has been shown in many studies to have a substantial impact on consumers' decisions. According to a study, PRSE has a favorable impact on customer perceptions of solar PV adoption [90]. Talpur et al. [91] revealed that PRSE was discovered to be a significant factor in the acceptance of solar PV. Another study conducted by [92] provides support for applying the theory of planned behavior in the United States on adolescents' perceptions of competence to protect themselves in their future occupational workforce. Similarly, PRSE influences customers' decision making, as per [93]. According to the analysis, PRSE plays a significant role in buyers' decisions to support solar PV. Thus, we formulated the hypothesis as follows:

Hypothesis 6 (H6). *The willingness of consumers to adopt solar PV is positively influenced by PRSE.*

4. Research Methods

4.1. Target Population: Provincial Capitals of Pakistan

The study's target population included residents of all five provincial capitals (Lahore, Peshawar, Quetta, Gilgit, and Karachi). As the Pakistani government intends to develop provincial capitals and make them the mainstream regions of the country, the urbanization trend has been steadily growing. The majority of the population is migrating from rural areas to the country's capital centers, searching for better jobs, education, and healthcare opportunities. In view of the economic, energy, and resource structure, these provincial capitals represent the country's unique characteristics, and the energy demand is increasing day by day in these capitals [94]. For instance, Lahore, the provincial capital of Punjab, is usually recognized as the cultural capital of Pakistan. This is Pakistan's second-largest city, with a population of 12,642,000 in 2020 [95]. Due to the rapid increase in population, the city faces a huge electricity shortage. Peshawar is the provincial capital of KPK. It is located next to the eastern terminus of the historic Khyber Pass near to the Afghan border. The city covers an area of 1257 km^2 and has a population of about 2 M [96].

On the other hand, Baluchistan is Pakistan's largest province by area, with Quetta as the provincial capital and the province's most urbanized city, hosting 29% of the province's total urban population. Provincial capital Karachi is the largest city in Sindh province and is known as the business center of Pakistan and the world's second-largest Islamic city with a population of about 24 M [97]. Gilgit is the fifth provincial capital of Pakistan. It possesses an enormous economic potential through tourism, tremendous renewable energy resources, minerals, and precious stones, and its strategic location that facilitates Pakistan's only road-to-road trade link with China: the CPEC's linchpin [98].

The survey description is provided in Table 2. The following three criteria were considered while conducting the questionnaire survey. (i) Due to COVID-19's second wave, Pakistan's government imposed a smart lockdown in all of the country's cities at the end of December 2020. Therefore, the authors used an online survey to collect data. (ii) We chose 800 participants using a convenient random sampling methodology [99], and a total of 683 responses were received. (iii) We followed the Comfrey and Lee's scale to determine the adequacy of sample size. For instance, [100] recommended the following scale: (very poor—50), (poor—100), (fair—300), (very good—500), (excellent—1000 or more). According to this scale, our study sample size (683 respondents) falls under the "excellent" category, ensuring that the sample size represents this research and supports its findings.

Table 2. Survey description.

Parameters	Value
Time frame	January, February, March (2021)
Location of the survey	Provincial capitals of Pakistan
Size of the sample	800
Valid responses	683
Response rate	85.4%

4.2. Questionnaire Development

The questionnaire's items were mainly adopted from past studies that had been checked through a thorough review. The sources of data used to calculate each item and the development of the questionnaire are mentioned in Table 3. The self-administered questionnaire consisted of two parts: one for profiling and another for the elements that were used to assess each construct. In Section A, there were six questions about gender, age, marital status, as well as education, household income, and occupation. Section B had 39 questions, including seven questions for belief about solar PV benefits, social norm, and perception of self-efficacy—five questions were about solar PV cost and perceived risk. Four questions were asked about openness to technology and willingness to adopt solar PV. Section B items were rated on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The detailed questionnaire is reported in Appendix A.

Table 3. Measurement source.

Constructs	Items	Source
BPVB	7	[101]
SPVC	5	[101]
PRSE	7	[101]
PRSK	5	[102]
OTEC	4	[103]
SOCN	7	[104]
WTAPV	4	[105]

5. Data Analysis and Empirical Results

To investigate the research hypotheses and model that were considered, SEM was used by employing SPSS and AMOS version 26. SEM is a realistic method that provides reliable and concrete results when determining the relationship between various variables [106]. The method has several advantages over conventional techniques. A precise estimation of measurement errors and observed variables is used to estimate latent factors and validate the model for pattern evaluation and execution [107]. Furthermore, the majority of multivariate methods implicitly ignore the measurement error. On the other hand, the SEM measures all dependent and independent variables by taking the measurement error into account [108]. The technique produces reliable and eloquent results due to its robustness and reliability [109]. Considering the benefits of SEM, we used it in our research because it was the most efficient way to evaluate the relationship between all of the variables under consideration. The descriptive statistics of the data are presented in Table 4. The descriptive statistics were scrutinized by means and standard deviations.

Table 4. Descriptive statistics of the data.

Variables	Observations	Items	Mean	Std. Dev	Coefficient of Variation (CV)
BPVB	683	7	3.630	0.590	0.162
SPVC	683	5	2.811	1.509	0.536
PRSK	683	5	3.324	0.154	0.046
OTEC	683	4	3.919	0.574	0.146
SOCN	683	7	2.603	0.661	0.253
PRSE	683	7	2.906	1.563	0.537
WTAPV	683	4	2.472	0.367	0.148

Notes: Dependent variable—WTAPV.

5.1. Respondents' Profile

The survey peculiarities of the 683 respondents are summarized in Table 5. Male respondents outnumbered female respondents, with 398 male respondents accounting for 58.27% of the overall sample and 285 female respondents accounting for 41.72% of the total sample. In addition, the vast majority (459, 67.20%) were married, followed by unmarried respondents (224, 32.79 percent). Nearly 42.75 percent of respondents were between the ages of 26 and 35, followed by 36 to 45-year-olds (19.91 percent), 46 to 55 (11.71 percent), up to age 25 (16.39 percent), and those aged 56 and more (9.2 percent). The majority of respondents (45%) had an MS/MPhil degree, followed by a Ph.D. (16%), master's (29%), bachelor's degree (8%), and people with intermediate or below qualifications (4 percent). Furthermore, 287 (42.02 percent) respondents had a monthly household income of PKR 26,000–45,000, and 326 (47.73 percent) had their own business. See Table 5.

Table 5. Respondents profile N = 683.

Characteristics	Option	Frequency	Percentage
Gender			
	Male	398	58.27%
	Female	114	41.72%
Age			
	Up to 25	112	16.39%
	26–35	292	42.75%
	36–45	136	19.91%
	46–55	80	11.71%
	56 and above	63	9.22%
Marital Status			
	Single	224	32.79%
	Married	459	67.20%
Education			
	PhD	112	16%
	MS/MPHIL	295	45%
	Master's	195	29%
	Bachelor's	55	8%
	Intermediate or below	26	4%
Income (PKR)			
	Up to 25,999	82	12%
	26,000–45,999	287	42.02%
	46,000–65,999	156	22.84%
	66,000–85,999	102	14.93%
	Above 86,000	56	8.19%
Occupation			
	Government employee	112	16.39%
	Private Job	156	22.84%
	Own business	326	47.73%
	Farmer	89	13.03%

5.2. Measurement Model Testing

The measurement model was evaluated using a validity and reliability test. There were two types of validity tests, one was convergent validity, as determined by average variance extracted (AVE), and discriminant validity calculated by Heterotrait–Monotrait ratios (HTMT) [110]. Outer loadings were used to calculate reliability, which included items reliability.

Table 6 presents the discriminant and convergent validity test. Discriminant validity determined that construct measures should not be highly correlated with one another theoretically and were not found to be highly correlated. HTMT is the most robust approach for determining discriminant validity. As a result, HTMT criteria were used to assess the discriminant validity [111] assert that if the values of (HTMT) were greater than 0.90, there were some validity problems. Kline [112] argues that there is discriminant validity if values are greater than 0.85. Table 6 indicates that all values were within the recommended criteria, measuring constructs were not overlapping each other and justified the discriminant validity test. Convergent validity refers to the degree to which two measures of constructs that should be related theoretically are actually related. The convergent validity test acceptability criteria are that AVE's value is well above the suggested value of 0.5 [113]. In Table 6, all measuring constructs had values greater than 0.5, indicating that they were highly related.

Table 6. Correlation, discriminant validity, and convergent validity analysis.

Factors	OTEC	PRSE	SOCN	BPVB	PRSK	SPVC	WTAPV	AVE	MSV
OTEC	(0.708)							0.501	0.126
PRSE	0.268	(0.822)						0.676	0.274
SOCN	0.327	0.491	(0.823)					0.678	0.327
BPVB	0.355	0.523	0.376	(0.751)				0.564	0.274
PRSK	0.175	0.419	0.545	0.305	(0.776)			0.603	0.524
SPVC	0.341	0.187	0.258	0.329	0.229	(0.832)		0.693	0.116
WTAPV	0.299	0.507	0.572	0.418	0.724	0.244	(0.737)	0.544	0.524

Notes: Diagonal values in parentheses represent the root square of AVEs.

Furthermore, the factor loadings and composite reliability (CR) test was performed to assess the consistency and stability of all variable elements. Table 7 presents the analysis of outer loadings and composite reliability. The recommended value of 0.5 was met by all outer loadings [114]. Composite reliability was used to ensure that the scale item was internally consistent. The criteria to check the reliability analysis were acceptable and have been used in numerous research [115]. Furthermore, Table 7 demonstrates that CR and Cronbach α values were far above the acceptable limit of 0.7, indicating that all scale items were internally consistent [113]. The outcomes of the measurement model demonstrated that the data were reliable and valid.

An Exploratory Factor Analysis (EFA) was used to find the detrimental conceptual model. Before performing EFA, the Kaiser–Meyer–Olkin (KMO) and Bartlett's sphericity tests (BTS) were used to assess the data fit [116]. The KMO test was used to determine the proportion of variance shared by variables. If the proportion was lower, more data were suitable for the factor analysis. The value should have been as close to 1.0 as possible. If the value was less than 0.50, it indicated that data were unsuitable for factor analysis. Table 8 evidences that the KMO value was 0.918, suggesting that a factor analysis could be performed [117]. Similarly, BTS generated a significant value of 9985.49 [118], satisfying the EFA requirement (see Table 8). The data were then scrutinized using the confirmatory factor analysis (CFA) to ensure that it was suitable for the proposed research context. The measurement model's content validity was verified since all items were substantially loaded on their respective constructs (see Figure 2).

Table 7. Factor loadings and results of reliability analysis.

Factors	Items	Standard Loadings	CR	Cronbach-α
Belief about solar PV benefits			0.900	0.902
	BPVB1	0.563		
	BPVB2	0.834		
	BPVB3	0.722		
	BPVB4	0.661		
	BPVB5	0.896		
	BPVB6	0.899		
	BPVB7	0.613		
Solar PV cost			0.918	0.916
	SPVC1	0.726		
	SPVC2	0.776		
	SPVC3	0.902		
	SPVC4	0.865		
	SPVC5	0.823		
Perception of self-efficacy			0.935	0.937
	PRSE1	0.638		
	PRSE2	0.834		
	PRSE3	0.797		
	PRSE4	0.857		
	PRSE5	0.855		
	PRSE6	0.673		
	PRSE7	0.726		
Perceived risk			0.883	0.890
	PRSK1	0.887		
	PRSK2	0.973		
	PRSK3	0.675		
	PRSK4	0.664		
	PRSK5	0.567		
Openness to technology			0.800	0.873
	OTEC1	0.728		
	OTEC2	0.740		
	OTEC3	0.673		
	OTEC4	0.671		
Social norms			0.936	0.928
	SOCN1	0.774		
	SOCN2	0.800		
	SOCN3	0.939		
	SOCN4	0.967		
	SOCN5	0.829		
	SOCN6	0.728		
	SOCN7	0.740		
Willingness to adopt SPV			0.826	0.818
	WTAPV1	0.655		
	WTAPV2	0.665		
	WTAPV3	0.661		
	WTAPV4	0.616		

Notes: extraction method–maximum likelihood; rotation method–Promax with Kaiser normalization.

Table 8. KMO and Bartlett's test.

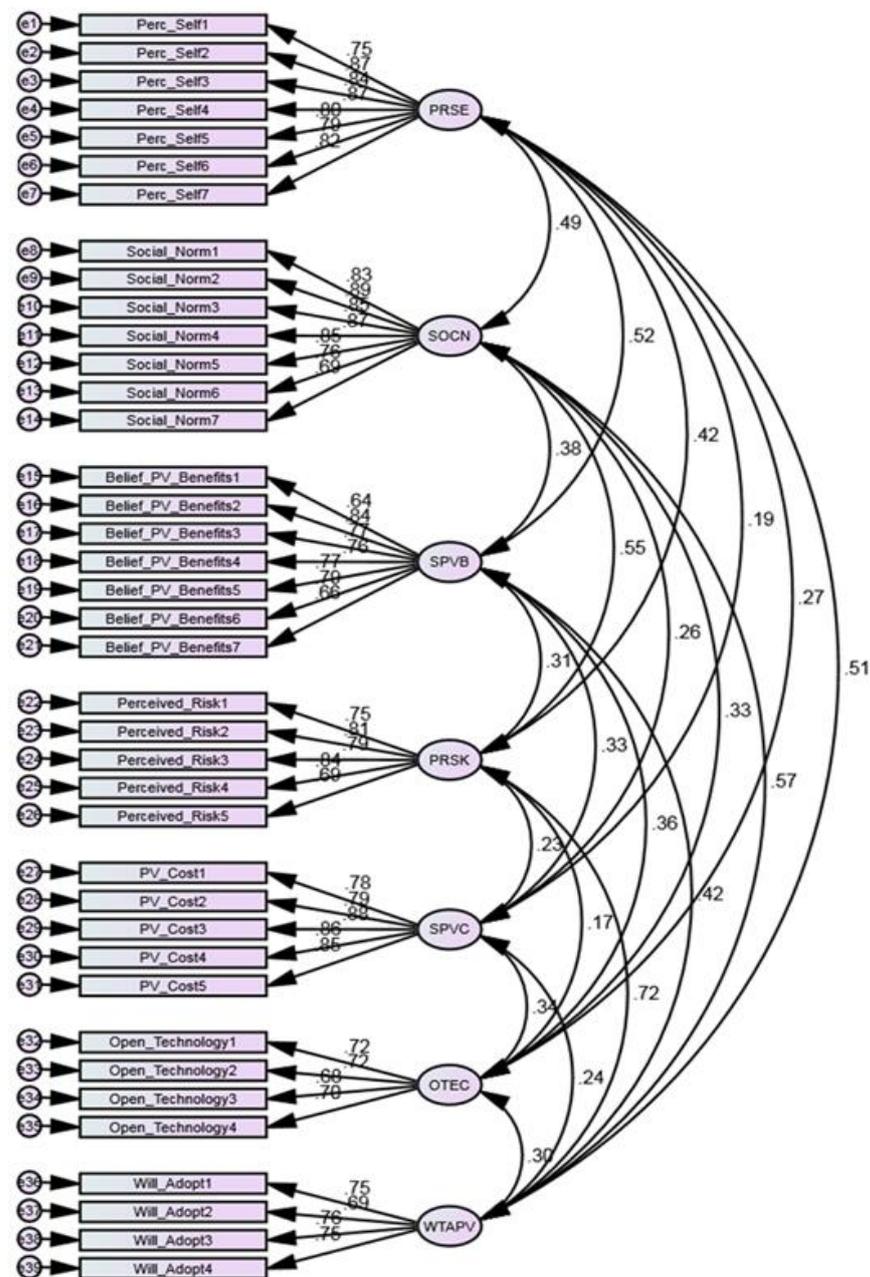| **Kaiser–Meyer–Olkin Measure of Sampling Adequacy**		**0.918**
Bartlett's Test of Sphericity	Approx. Chi-Square	9985.49
	df	741
	Sig.	0.000

Figure 2. Confirmatory factor analysis, representing that all items substantially loaded on the respective constructs.

5.3. Structural Model Testing

Upon reviewing the measurement model, we determined the structural model and evaluated the hypotheses. The collinearity diagnostic is shown in Table 9. Collinearity is a predictor–criterion concept that can be used to determine whether or not proposed variables calculated the same constructs. The collinearity test was recommended as a viable alternative for detecting common method bias. If the variance inflation factors (VIFs) are less than 10, the model is stated to be free of common method bias [119]. As a result, every latent variable had its VIFs generated. The results showed that the VIFs of all latent variables were less than 10. Our model was found to be free of common method bias. Table 10 illustrates the communalities finding. Osborne, Costello, and Kellow [120] define that communalities greater than 0.4 are acceptable. To determine the number of variables, only those with an eigenvalue greater than one were considered (see Table 11).

Table 9. Collinearity diagnostic test.

Variables	Collinearity Statistics	
	Tolerance	VIF
BPVB	0.619	1.615
SPVC	0.782	1.279
PRSK	0.565	1.770
OTEC	0.723	1.382
SOCN	0.536	1.865
PRSE	0.565	1.769

Notes: Dependent variable—WTAPV.

Table 10. Communalities findings.

Variables	Communalities	
	Initial	Extraction
BPVB	1.000	0.501
SPVC	1.000	0.640
PRSK	1.000	0.871
OTEC	1.000	0.510
SOCN	1.000	0.516
PRSE	1.000	0.664
WTAPV	1.000	0.803

Notes: extraction method–maximum likelihood.

Table 11. Eigenvalues and cumulative variance.

Variables	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.353	31.673	31.673	11.838	30.354	30.354
2	3.879	9.946	41.620	3.459	8.869	39.224
3	3.472	8.903	50.522	3.185	8.166	47.390
4	2.413	6.187	56.710	2.067	5.301	52.690
5	2.142	5.493	62.203	1.833	4.701	57.392
6	1.932	4.955	67.157	1.550	3.975	61.367
7	1.147	2.941	70.098	0.793	2.032	63.399

Notes: rotation method—Promax with Kaiser normalization; cumulative variance—63.399%.

The Path diagram of the structural model is shown in Figure 3. There were three different levels of significance considered: (***) indicates significance at the 0.1% ($p = 0.001$), (**) signifies significance at the 1% level ($p = 0.01$), whereas (*) signifies significance at the 5% level ($p = 0.05$). Insignificant paths are denoted by dotted lines, while constant lines denote significant paths. The belief about solar PV benefits H1 ($\beta = 0.09$, $p = 0.01$) and perception of self-efficacy H6 ($\beta = 0.10$, $p = 0.01$) were statistically significant at 5% and had a positive influence on dwellers' adoption of solar PV, according to the path diagram. Thus, we accepted the *H1* and *H6* hypotheses. Consumers' willingness to adopt solar PV was negatively influenced by perceived risk H3 ($\beta = -0.4$, $p = 0.05$) and positively influenced by social norms H5 ($\beta = 0.12$, $p = 0.05$). On the other hand, solar PV cost H2 ($\beta = -0.01$, $p = 0.001$) substantially influenced customer willingness at the 1% significance level. The path coefficient did not validate the hypothesis H4 ($\beta = 0.80$) because the variable "openness to technology" did not substantially impact dwellers' willingness to adopt, and it was refuted. The path of structural models and hypothesis significance are depicted in Table 12. The R^2 value was determined to be 0.73, indicating a significant interpretation because it exceeded the 0.35 value suggested by (Cohen, 2013). Various fitness measurements were also used to see whether the data were well-fitting for the proposed model. All fit

index values were in line with the prescribed requirements [121], according to the findings reported in Table 13. The Heckman test was used to analyze endogeneity to preserve that the findings were reliable [122]. Our findings showed that there was no endogeneity bias in our findings (see Table 14).
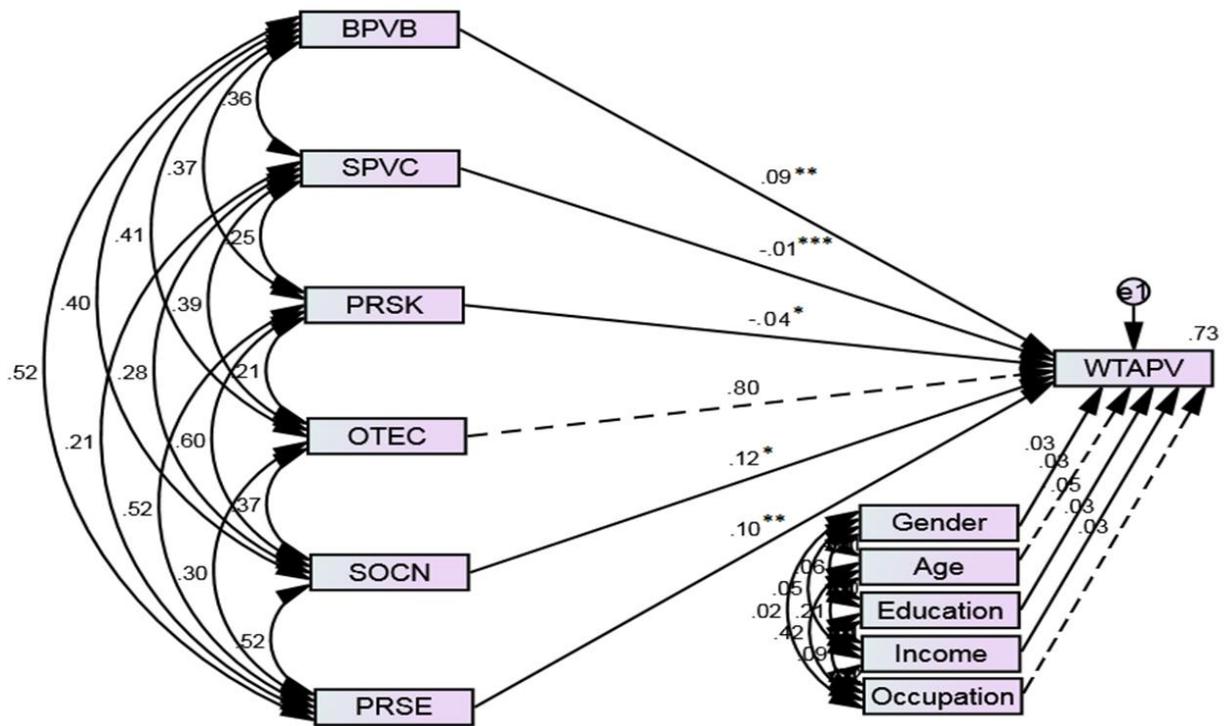

Figure 3. Diagram of structural model's path. Notes: *** $p < 0.00$, ** $p < 0.01$, * $p < 0.05$.

Table 12. Results of hypotheses.

Hypotheses	Structural Paths			β-Value	f-Value	Result	R^2
H1	BPVB	$\rightarrow$	WTAPV	0.09 **	227.4 ***	Accepted	0.73
H2	SPVC	$\rightarrow$	WTAPV	-0.01 ***	178.6 ***	Accepted	
H3	PRSK	$\rightarrow$	WTAPV	-0.04 *	131.4 ***	Accepted	
H4	OTEC	$\rightarrow$	WTAPV	0.80	235.9 ***	Rejected	
H5	SOCN	$\rightarrow$	WTAPV	0.12 *	130.5 ***	Accepted	
H6	PRSE	$\rightarrow$	WTAPV	0.10 **	149.7 ***	Accepted	

Notes: *** $p < 0.00$, ** $p < 0.01$, * $p < 0.05$.

Table 13. Goodness-of-fit indices values of the measurement and structural model.

Fit Index	Description	Recommended Criterion	Values Based on a Structural Model
CFI	Comparative fit index	>0.9 good fit	0.994
NFI	Normed fit index	>0.9 good fit	0.969
IFI	Incremental fit index	>0.9 good fit	0.973
TLI	Tucker–Lewis index	>0.9 good fit	0.986
GFI	Goodness of fit	>0.9 good fit	0.983
RMSEA	Root mean squared error of approximation	<0.08 good fit	0.026
X^2/df	Chi-square	<3 good fit	1.245
SRMR	Standardized root mean squared residual	<0.09 good fit	0.020

Table 14. Endogeneity test.

Hypotheses	Structural Paths			β-Value	t-Statistics	Description
H1	BPVB	$\rightarrow$	WTAPV	0.052 **	2.955	Not dissimilar
H2	SPVC	$\rightarrow$	WTAPV	−0.376 ***	−8.702	Not dissimilar
H3	PRSK	$\rightarrow$	WTAPV	−0.693 *	−1.471	Not dissimilar
H4	OTEC	$\rightarrow$	WTAPV	0.305 ***	3.487	Not dissimilar
H5	SOCN	$\rightarrow$	WTAPV	0.083 *	6.761	Not dissimilar
H6	PRSE	$\rightarrow$	WTAPV	0.671 **	5.613	Not dissimilar

Notes: *** $p < 0.00$, ** $p < 0.01$, * $p < 0.0$.

6. Discussion and Implications

6.1. Belief about Solar PV Benefits and Willingness to Adopt Solar PV

The analysis results validated that consumers' WTA solar PV the is significantly influenced by their beliefs about its benefits. The findings of [66] also demonstrated that buyers' buying decisions were established on a solid faith in the advantages of the specific thing they needed to buy. Likewise, another recent study in Zambia factors influencing households' intention to adopt solar energy solutions revealed that due to its numerous advantages and the region's vast solar energy generation potential, solar energy solutions have become an attractive alternative to grid-based electricity, and many households are influencing their adoption [123]. Consumers can adopt solar PV if they can see the real advantages of using it over non-renewable resources. Similarly, a study conducted in India found that consumers are more receptive to adopting new technologies if they believe in the innovative benefits of technology [124]. Thus, in the early stages of its implementation, the Pakistani government must emphasize the advantages of solar PV, and consumers' confidence in solar PV will grow over time.

6.2. Solar PV Cost and Willingness to Adopt Solar PV

The study's findings added to the body of knowledge by indicating that SPVC negatively influenced dwellers' acceptance. Users' intentions to install a solar PV system were mostly influenced by price, and previous studies back up these findings [125,126]. Due to the higher cost of rooftop solar PV, a recent study in the United States discovered that low- and moderate-income (LMI) households are less likely to install it. The findings indicate that when financial incentives, PV leasing, and property-assessed financing are used, PV adoption among LMI households in established markets increases and solar installation expansion is facilitated [127]. As a response, policymakers should consider price value when developing and implementing energy policies in Pakistan. Household tax relief and other incentive programs are needed. In addition, solar PV companies should spend more on technology and research to tackle the technology's perceived price issue.

6.3. Perceived Risk and Willingness to Adopt Solar PV

The results confirmed that consumers' perceptions of risk had an adverse influence on their adoption of solar PV. Past research also supports this result [73,74]. Physical and health protection has indeed become a global regulatory concern. As a result, Pakistan's government should empower solar PV companies to manufacture risk-free technology and employ personnel with experience and a willingness to assist and support their clients, even after they have purchased their products. Simultaneously, marketers can provide consumers with sufficient knowledge and advice on operating a solar PV system. The removal of these risk beliefs gives people more interest in adopting new technologies, which can be a key factor in the future.

6.4. Openness to Technology and Willingness to Adopt Solar PV

Openness is a personality trait that indicates that individuals with a high openness level are intellectually curious and receptive to unique ideas and pro-environmental practices. These individuals are more apt to take risks. Additionally, they are more susceptible

to adopting new technologies quickly and easily. As per results, hypothesis four had no substantial effect on willingness to adopt solar PV. This result differed from previous research findings, which showed that customers with a high degree of openness were enthusiastic about emerging technology, and their acceptability was high [128,129]. Previous studies conducted in developed countries show that the adoption of new emerging technologies is common there. However, in Pakistan, literacy rates are relatively low, and people are more comfortable using technology. Thus, in Pakistan, purchasing decisions are not affected directly by the openness to technology.

6.5. Social Norms and Willingness to Adopt Solar PV

As per findings, SOCN had an important influence on dwellers' willingness to adopt solar PV. Research findings supported previous research by those who found that SOCN has a major influence on dwellers' intentions. Another study by [130] found that dwellers' behavior is directly affected by social norms. According to [131], the result of a consumer's product intake is predetermined by social norms. When people have a negative perception of a product, their intake of that product drops dramatically [132]. Nevertheless, the results showed that promoting conditions were determined by the outcome of social norms. Individuals who portray solar energy as having a positive environmental effect would be more likely to accept it [133]. Pakistan has a socially constructed structure, and the behavior of society and neighbors has a huge effect on people's minds. The previous impression of peers to the use of solar PV may influence dwellers' actions in such a way that a positive experience allows for solar PV acceptance. On the contrary, negative experiences have a different effect. Each country has its distinct social characteristics. As a result, companies use corporate governance as a social tool. If community members believe that the norms are fair or in everyone's best interest, they will share and adhere to them, as well as adopt those technologies. Similarly, researcher explore the corporate governance in the Romanian economy using the Bucharest Stock Exchange's corporate governance code. Corporate governance refers to the procedures and policies that a business uses to accomplish its stated goals. In conclusion, implementing a corporate governance code in the Romanian energy system has increased companies' overall liquidity, which contributes to an increase in the overall performance [134]. As a result, SOCN plays a key role in the decision-making framework.

6.6. Perception of Self-Efficacy and Willingness to Adopt Solar PV

The findings revealed that consumers' perceptions of self-efficacy had a positive impact on their willingness. This conclusion is backed up by previous research [135–137]. Another study conducted in Telangana revealed that ease of use plays a vital role in customers' attitude towards solar energy [138]. The energy efficiency, energy savings, and environmentally friendly solar PVs inherent characteristics are all factors that may encourage residents to use it. PVs for domestic use are also handy and simple to install, with such a long lifespan. Dwellers' assessments of technology and understanding about how to use it would boost dweller's interest in solar PV as vital developments in the near future.

7. Conclusions and Policy Recommendations

Being an environmentally friendly technology, solar PV has the potential of reducing carbon emissions; however, studies examining consumers' WTA solar PV technology are limited. This study focused on this research gap by incorporating novel factors (perceived risk, self-efficacy, and openness to technology) with existing factors (social norm, solar PV cost, and belief of solar PV benefits) in the conceptual framework of TPB to comprehensively investigate the consumer's adoption mechanism. Data were gathered from Pakistan's provincial capitals and analyzed using SEM. The research findings revealed that social norms, perception of self-efficacy, and belief about solar PV benefits positively affected consumer willingness to adopt solar PV. On the other hand, perceived risk and solar PV

cost negatively affected consumers' willingness. Interestingly, openness to technology had an insignificant impact.

Pakistan, such as other developing countries, is facing environmental degradation issues. Global recognition has been accorded to sustainable energy technologies. Additionally, a number of countries are putting in significant amounts of investment in these technologies. This study's conclusions have significant ramifications for the government and solar PV vendors' efforts to promote solar PV deployment in Pakistan. An alternative energy board and the Ministry of climate change should create awareness programs for the public and promote the benefits of solar PV. They should reassure the public that solar PV provides sustainable solutions for combating climate change and the planet's ongoing degradation. As a consequence, dwellers will consider solar PV more beneficial and will feel more confident installing and using it.

The study's findings are instructive for policymakers and developers. Cost was a significant concern for many users; therefore, the Pakistani government should provide subsidies and sufficient financial assistance in collaboration with solar PV companies. Make sure the availability of financial incentives, such as grants, assist people install home solar PV systems. Solar PV companies must develop risk-free technologies and recruit a knowledgeable workforce which could provide sufficient technical support to their customers. Furthermore, in order to attract multinational businesses, the government should provide tax relief; this would increase market pressure, causing companies to boost product quality. When consumers are weighing the pros and cons of different solar PV options, such initiatives will help them decide to adopt solar PV. The importance of perceived risk, self-efficacy, and the price were highlighted in the conceptual context for this analysis, and the results were robust for Pakistan, indicating that the findings may be transferable to other countries.

There were a few limitations to this study that should be considered in future works. First, the analysis only considered provincial capitals, where the infrastructure and quality of living are much superior to other cities. This flaw can be addressed in future research by incorporating consumer input from other cities. Second, we approached the analysis from the consumer's perspective; future research can explore the supply side. Third, due to the country-wide lockdown situation during COVID-19, conducting a large-scale questionnaire survey was impossible. In this respect, a sample of 683 respondents was insufficient for a country with a 37 M population. Subsequent researchers should extend the sample size to overcome this constraint. Finally, it would be interesting to perform a cost–benefit analysis and determine the Levelized cost of electricity. This critical feature may be addressed in future investigations in order to add to the existing body of knowledge.

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Acronyms and Abbreviations

BPVB   Belief about solar PV benefits
OTEC   Openness to technology
PRSE   Perception of self-efficacy
PRSK   Perceived risk
SEM   Structural equation modeling
SOCN   Social norms
Solar PV   Solar photovoltaic
SPVC   Solar PV cost
TPB   Theory of planned behavior
WTAPV   Willingness to adopt solar PV

Appendix A. Questionnaire Survey

Part A: Demographics	Options	
Gender	Male	Female
Marital status	Single	Married
Age	Up to 25	26–35
	36–45	46–55
	56 and above	
Qualification	PhD	MS/MPhil
	Master;s	Bachelor's
	Intermediate or below	
Income (PKR)	Up to 25,999	26,000–45,999
	46,000–65,999	66,000–85,999
	Above 86,000	
Occupation	Government Employee	Private Job
	Own Business	Farmer

Part B. Factors Influencing Consumers' Willingness to Adopt Solar PV

Perceived Risk	1	2	3	4	5	6	7
Solar PV adoption would come with a lot of safety risks							
Adopting solar PV energy at home is risky, as it may not provide the optimal energy solution							
Due to malfunctions or misuse, solar PV may cause some unpleasant physical side effects.							
There is a risk that electricity generation will decrease as a result of a lack of sunlight or snow covering solar panels for extended periods.							
There is a risk that components will generate less electricity than expected over time							
Solar PV cost							
Solar PV charges extra costs for production							
Solar PV installations require a high up-front cost.							
It is expensive to generate electricity from solar PV.							
It is not economically friendly							
The cost of solar PV is very high and I cannot afford it							
Openness to technology							
I am a friendly person, and I welcome new technologies with open arms							
I think deeply and I am constantly coming up with new ideas							
I am enthusiastic about new technologies and I prefer to use them							
I have a favorable attitude toward new technology that has the potential to benefit the environment							
Perception of self-efficacy							
I have the necessary information to adopt solar PV							
I have full power to adopt solar PV							

I have power over all resources to adopt solar PV
I have power over the adoption of solar PV services
My home has sufficient space for solar PV
Solar PV energy is not difficult to use; therefore, I am capable of adopting it
I would not have any difficulty adopting solar PV if I wanted to
Social norms
The majority of people who are important to me encourage me to use solar PV
Those who have my best interests at heart would prefer that I purchase solar PV
When it comes to energy-saving behavior, most of the people who matter to me believe that I should buy solar PV
People close to me believe that solar PV should play a significant role in reducing greenhouse gas emissions
People I care about adopt solar PV
Solar PV adoption is increasing among those in my close surroundings
Most of the people in my social network advise me to use solar PV.
Solar PV benefits
Adopting solar PV will help to reduce carbon emission.
Adopting solar PV will help to improve the clean environment..
The development of solar PV projects will aid in the reduction in greenhouse gas emissions and the creation of new job opportunities.
Solar PV adoption will aid in the improvement of the energy structure.
Solar PV is the most efficient source of energy.
Generally, solar PV systems do not require much maintenance.
Solar PV energy will assist in lowering electricity bills.
Willingness to adopt solar PV
I am willing to pay more for solar PV because it saves energy.
I am willing to adopt solar PV because I can afford it.
I strongly encourage others to adopt solar PV because it contributes to a clean environment
Solar PV appeals to me because it is eco-friendly

Notes: 1—strongly disagree; 2—disagree; 3—slightly disagree 4—neutral; 5—slightly agree; 6—agree, 7—strongly agree.

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