23 Sep 2021

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Recommended Citation

Fikru, M. (2021). Residential Photovoltaics Adopters versus Considerers in the United States. *Energy Research Letters, 4*(4) Elsevier.
The definitive version is available at https://doi.org/10.46557/001c.28129

Fikru, M. G. (2021). Residential Photovoltaics Adopters Versus Considerers in the United States. *Energy RESEARCH LETTERS*, *2*(4). https://doi.org/10.46557/001c.28129

Energy Economics

Residential Photovoltaics Adopters Versus Considerers in the United States

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Keywords: risk aversion, novelty seeking, economics of PV

https://doi.org/10.46557/001c.28129

Energy RESEARCH LETTERS

Vol. 2, Issue 4, 2021

Despite rising interest in residential photovoltaics (PV), the percentage of homeowners who have installed them remains low. This study seeks to understand systematic behavioral differences between *PV adopters* and *PV considerers*. PV considerers have talked to an installer but have not yet installed PV. Our results suggest that, compared to adopters, considerers have a lower degree of risk aversion, higher scores in terms of pro-environmental norms, and higher levels of novelty seeking and independent decision making.

1. Introduction

Despite growing interest in residential solar photovoltaics (PV), the actual rate of adoption is considerably low. In the United States, about 46% of homeowners reported having seriously thought about installing PV (Kennedy & Thigpen, 2019), but only 6% of homeowners have PV on their property. This study examines systematic behavioral differences between *PV adopters* and non-adopters who have previously contacted a solar installer about installation but did not install them (hereafter *PV considerers*). This is done by comparing the responses of PV adopters and considerers to a series of survey questions administered by Sigrin et al. (2017). In this study, PV considerers have already taken the initial step of talking to a solar installer (e.g., received price quotes) and have stated their current decision status as 1) still considering adoption or undecided, 2) having decided not to adopt, or (3) having decided to adopt but not yet having signed a contract.

Previous studies examine factors influencing homeowners' *intention* to adopt PV (Rai & Beck, 2015; Shakeel & Rajala, 2020). However, not many studies examine the differences between those that adopt versus those with intentions (Carrington et al., 2010). This is particularly true for the US solar market, where behavioral factors are less understood. Understanding the difference between intentions and actions would help identify potential adoption barriers (Hai et al., 2017; Lee et al., 2020; Palm & Eriksson, 2018; Sigrin et al., 2015) and help achieve climate change goals in the residential sector. Furthermore, solar installers can benefit by identifying traits or constraints that differentiate PV considerers from adopters. The results of this study reveal novel insights into the personal traits and characteristics of PV considerers and how they differ from PV adopters.

The remainder of the paper is organized as follows. Section 2 presents the data and methods. Section 3 discusses the results. Section 4 concludes the paper.

2. Data and methods

The analysis is based on two surveys collected by the National Renewable Energy Laboratory (Sigrin et al., 2017). The surveys were collected from single-family owner-occupied households in New York, New Jersey, Arizona, and California. Table 1 presents a summary of the survey questions used in this study. The complete survey and sampling strategy were obtained from Sigrin et al. (2017).

The dataset includes 1,649 PV adopters and 589 PV considerers. Adopters have a working PV system on their property, while considerers are homeowners who have talked to a PV installer but not installed them at the time of data collection. Considerers are heterogeneous with respect to their decision status, with 60% *undecided*, 11% who *decided not to adopt*, and 23% who *decided to adopt* but have not yet signed a contract.

We combine the two datasets to perform a pairwise comparison of the means of the variables, determining the differences in a sample of survey responses measuring individual traits and household characteristics. We perform the pairwise comparison of the means of the variables reported in Table 1 across four types of homeowners: 1) PV adopters and 2) PV considerers, the latter further categorized as those who are undecided, those who have decided to adopt, and those who have decided not to adopt. The null hypothesis of the test states that the means of the variables for any two pairs of homeowners are the same. We assume a common variance and adjust the confidence intervals and p-values to account for multiple comparisons using Bonferroni's method (Stata.com, n.d.).

We use four variables to proxy for behavioral and individual traits: 1) risk aversion, 2) novelty seeking, 3) independent decision making, and 4) pro-environmental personal norms. We use four variables to proxy for household characteristics: 1) income, 2) retirement status, 3) the presence of children in the household, and 4) a plan to move in less than a year.

To measure a homeowner's attitude toward risk, we as-

Table 1. Survey questions

Variables and questions	Responses and units of measurement
Risk aversion How much would you pay for a one in five chance at a $5,000 lottery?	Responses are used to calculate coefficient of relative risk aversion
Pro-environmental personal norms 1. I feel a personal obligation to do my part to move the country to a renewable energy future. 2. I feel guilty when I waste energy. 3. I feel a personal obligation to do my part to prevent climate change.	Likert scale from 1=strongly disagree to 5=strongly agree (average of 3 questions converted to z-scores)
Novelty seeking 1. I continuously look for new products. 2. I continuously look for new experiences. 3. I like to visit places where I am exposed to information about new products.	Likert scale from 1=not at all like me to 5=just like me (average of 3 questions converted to z-scores)
Independent decision-making 1. Before buying a new brand, I usually ask someone who has experience with the brand for advice. 2. Before buying a new brand, I often ask acquaintances about their experiences with that product. 3. When considering a new product or service I usually trust the opinions of friends who have used the product.	
Household characteristics 1. Plan to move in less than a year 2. Retired respondent 3. Household has children	Dummy variables: 1=yes, 0=no
4. Household annual income	Income bins converted to midpoints (dollars)

The table shows survey questions sourced from Sigrin et al. (2015). The first column shows the variables and corresponding survey questions, while the second column shows the responses and units of measurement.

sume a constant relative risk aversion utility function $U(y) = y^{1-\sigma}/(1-\sigma)$, where σ is the homeowner's coefficient of risk and y is income. For each homeowner, we calculate the level of risk aversion (σ) that makes the homeowner indifferent to playing a lottery game with one in five chances of winning $5,000. For all homeowners, we find $\sigma > 0$, indicating risk-averse homeowners, where a higher value represents greater risk aversion. The risk aversion coefficient is converted to a z-score to facilitate the comparison of means across groups and to perform t-tests (Andersen et al., 2008; Farsi, 2010; Qiu et al., 2017; Van Praag & Booij, 2003). Similarly, since the responses for novelty seeking, independent decision making, and pro-environmental personal norms are recorded with Likert scales, they are converted to z-scores to facilitate the comparison of the means.

Household income is measured in income bins. Households with retired respondents, children under the age of 18, and those with a plan to move in less than a year are identified by dummy variables.

3. Results

Table 2 presents the results from the pairwise comparison of means, and Figures 1 and 2 illustrate these findings. Figure 1 compares the four types of homeowners in the sample with respect to behavioral and individual traits, while Figure 2 presents the heterogeneity with respect to household characteristics.

We find that PV adopters have a higher degree of risk aversion compared to considerers who are undecided and who have decided not to adopt. This finding contrasts with studies that argue that risk-averse individuals are less likely to adopt efficient appliances and less likely to perform energy efficiency retrofits (Qiu et al., 2017). The findings of our study highlight the importance of examining whether and to what extent individuals view solar panels as a risk-reducing technology and not as a risky investment. If the average homeowner viewed solar panels as a risky investment, risk-averse individuals would be considerers and risk seekers would be solar adopters, but the evidence based on the sample suggests the opposite. One possible explanation

Table 2. Differences in means are calculated as adopter minus considerer

	Considerer: Decided not to adopt	Considerer: Undecided	Considerer: Decided to adopt
Behavioral and individual traits			
Risk aversion	**0.36[b]**	**0.30[a]**	0.15
Novelty seeking	0.02	**-0.61[a]**	**-1.17[a]**
Independent decision-making	0.12	**-0.19[a]**	**-0.72[a]**
Pro-environmental personal norms	0.28	0.12	**-0.34[a]**
Household characteristics			
Income of household	16,166	**12,268[b]**	3,859
Retired respondents	0.03	**0.17[a]**	**0.24[a]**
Households with children	0.09	**-0.14[a]**	**-0.30[a]**
Plan to move	-0.05	**-0.06[a]**	**-0.17[a]**

The table shows the differences in means calculated as adopter minus considerer. Statistically significant differences are indicated by [a] for 1% and [b] for 5% levels and bolded for emphasis.

for this finding is that homeowners in the sample are placing a higher value on the potential to protect themselves against rising electric prices and ensure a reliable onsite energy source during electricity outages. Thus, homeowners who believe that they are likely to benefit more from PV as insurance could be more likely to adopt them.

We find that PV adopters have a lower degree of novelty seeking and independent decision making compared to considerers who are undecided and considerers who decided to adopt but have not yet signed a contract. Although studies such as that of Lundheim et al. (2021) show that individuals drawn to new products and technologies are more likely to *develop strong interest* in solar adoption, our results suggest that, compared to considerers, solar adopters are less drawn to new products and technologies. Thus, even if novelty seeking helps explains why homeowners become interested in solar, these intentions may not be enough to explain the decision to immediately adopt PV.

While previous studies find mixed results regarding the role of environmental attitudes in the *intention to adopt* (Dharshing, 2017; Mundaca & Samahita, 2020; Schelly, 2014; Wolske et al., 2017), Table 2 indicates that homeowners who have decided to install but have not yet signed a contract have a statistically significant higher average score for pro-environmental personal norms, compared to PV adopters. This result suggests that 1) the lack of a moral obligation to act in the benefit of the environment is not necessarily a bottleneck for PV adoption, because adopters have a lower z-score in terms of pro-environmental personal norms, and 2) while having higher pro-environmental norms explains the strong intention to adopt, these intentions are not necessarily always immediately translated into adoption.

Compared to PV adopters, undecided considerers have, on average, lower household incomes, which suggests that income remains an important factor in the decision to install PV. In addition, PV adopters are more likely to be retired, less likely to have children in the house, and less likely to have the plan to move, compared to considerers

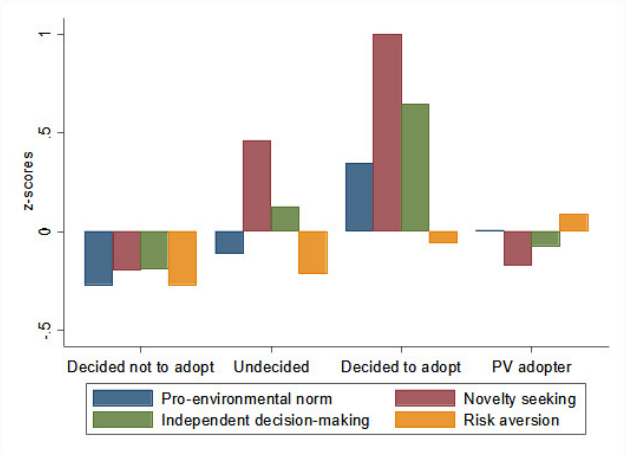

Figure 1. Differences in behavioral and individual traits across homeowners in the United States

The figure shows the differences in behavioral and individual traits across homeowners in the United States.

who are undecided and who have decided to adopt. This finding indicates that considerers are distinct from adopters with respect to their plan to move and their family and occupation status.

In addition, Table 2 suggests that families with children are increasingly interested in solar installation, as indicated by their decision to adopt. Figure 2 shows that most considerers who decided to adopt have children or plan to move. The solar industry could therefore benefit by designing marketing strategies customized for working families with children and those planning to move. For example, virtual PV permitting processes could be more streamlined and tools can be designed to improve the portability or transferability of the costs and benefits of PV.

4. Conclusion

While past studies focus on explaining the intention to adopt PV, this study examines systematic behavioral differences between homeowners who have made the initial step of talking to a solar installer, by comparing their traits and household characteristics to homeowners who have installed PV. Our findings reveal that PV adopters are more risk averse than solar considerers, and solar considerers exhibit a higher extent of novelty seeking and independent decision making than solar adopters. The findings also show that PV adopters and considerers differ significantly in terms of their plans to move, retirement status, and presence of children in the house, suggesting that there is room for the solar industry to modify its marketing strategies to increase adoption rates among homeowners who show interest in PV. More studies are needed to further understand the role of economic versus behavioral barriers in preventing PV considerers from adoption.

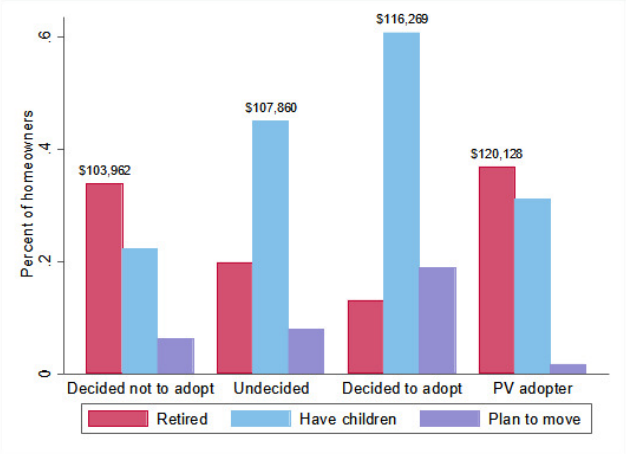

Figure 2. Differences in household characteristics across homeowners in the United States

The figure shows the differences in household characteristics across homeowners in the United States.

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