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Article

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GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

Determinants of solar technology adoption in rural households: The case of Belesa districts, Amhara region of Ethiopia

Yasin Ahmed¹, Seid Ebrahim² and Mohammed Ahmed^{3*}

Abstract: The adoption of modern energy such as solar energy has been recognized as, an important way to reduce carbon emissions and enrich the energy supply of rural households in Ethiopia. This study investigated the factors that determine the solar technology adoption in rural households in case of West Belesa and East Belesa districts of Ethiopia. Data were collected from 500 farm households which were selected using a multi-stage sampling technique procedure through a structured survey questionnaire with online KOBO application through the Computer-Assisted-Personal-Interview (CAPI) system. The data was collected through focus group discussions and key informant interviews. Binary logit models were utilized to analyze the data. The finding of the study revealed that seven independent variables were significant in explaining the factors affecting farmers' adoption of solar technology. These variables were education status, family size, participation in natural resource management activity, extension services, knowledge about solar technology, credit utilization, and perception of climatic change were the positive determinants of adoption. Based on the finding, the study recommends that the government should raise farmers' awareness through increase access of education and improved especially credit services to rural household's to increase the adoption of solar energy technology.



Yasin Ahmed

ABOUT THE AUTHOR

Yasin Ahmed was born in Assosa Woreda, Assosa Zone of Benishangul Regional State in February 1992. He also attended his elementary, secondary and preparatory school education at Assosa Secondary and Preparatory High School in Assosa zone. After completion of his high school education, he joined Wollo University College of Agriculture and Veterinary Medicine (WU) in October 2012 and graduated with BSc Degree in Agricultural Economics in July 03/2014. Soon after his graduation, Assistance Lecturer I employed him at Assosa University. After two year experience the author joined Bahir Dar University College of Agriculture and Environmental since in October 2018 to pursue of his MSc degree in Agricultural Economics in regular program. After the accumulation of my master degree I joined Assosa University College of agriculture and Natural Resource as Lecturer in department of Agricultural Economics.

PUBLIC INTEREST STATEMENT

Renewable energies such as solar are considered as clean sources of energy that minimize environmental impacts and are sustainable with regard to current and future economic and social needs. Solar Technology offers an attractive option for replacing the unsustainable usage of traditional energy sources such as firewood, cow dung, and charcoal challenges, mainly in rural areas. The current level of solar technology adoption and is not at its optimum level due to socio-economic and demographical factors. Therefore, the author is highly interested to recommend that the government and non-government organization work together provide credit service for rural households to increase the adoption of solar energy technology.

Subjects: Agriculture & Environmental Sciences; Economics; Environmental Economics

Keywords: Solar energy; adoption; determinates; rural households; Ethiopia

1. Introduction

Energy sustainability is one of the main agendas to achieve sustainable development goals toward 2030 and is also critical in tackling climate change and desertification (Amigun et al., 2012). Solar energy is among the cleanest, accessed with low prices, and it has a potential to mitigate GHG emissions and supply enough energy to meet the growing demand for energy (Mossie Zeru & Diriba Guta, 2020). Nevertheless, in 2013, about 1.2 billion lack access to electricity, and 2.64 billion people rely on traditional biomass for cooking (International Energy Agency, 2012). Sub-Sahara Africa (SSA) and South Asia accounted for 80% (Abdul-Salam, 2014; Malla and Govinda, 2014; Kowsari, 2013). Median, rural and urban access in SSA is about 17% and 59% respectively, This implies that lack of electricity service is disproportionately higher in rural settlements (International Energy Agency, 2012); (Abdul-Salam, 2014); (Arora et al., 2011).

Like SSA Countries in Ethiopia, access to grid line may not necessarily imply reliable electricity service connection. According to the Ministry of Water Irrigation and Electricity report of Ethiopia (2015), only about 25% of the households have connectivity with 100 kWh/annual per capita electricity consumption. This implies that a large percentage of population particularly in the rural areas still rely on non-renewable and unclean energy sources such as charcoal, wood, biomass, kerosene and other petroleum product gases to meet their basic needs (Dawit Diriba, 2018); (Mossie Zeru & Diriba Guta, 2020); (International Energy Agency, 2012). However, the heavy dependence and inefficient utilization of biomass resources for energy have resulted in high depletion of the forest resources creates land degrading, climatic change soil erosion (BDNM, 2019), Lack of modern energy is, in particularly immense in rural part of Ethiopia. Thus, energy poverty and enhancing livelihoods of it people through modern energy provision still challenge in rural area (Dawit Diriba, 2018).

Currently, Understand this problem the government and non-governmental Organization in Ethiopia providing a solar energy to households and enterprises across the country. Under the country's Growth and Transformation Plan (GTP II), the Government has set ambitious targets for expanding access to off-grid energy through solar technologies, including 3.6 million lanterns, 400,000 solar house systems and 3600 solar photovoltaic (PV) systems for rural health centers, schools and other government service centers by 2025 (Christian Anteneh, 2019); (Lemma Shallo et al.,); (Mossie Zeru & Diriba Guta, 2020). This plan can be feasible for Ethiopia as it has huge potentials for renewable electricity generation of up to 45,000 MW from hydro plants and 5.5 kwh/m²/day from solar energy (Asress et al., 2013); (Mossie Zeru & Diriba Guta, 2020). Accordingly, if utilized optimally, this can alleviate the current energy shortage in the country and thereby improve the process of rural electrification.

Many studies have conduct on determinants of solar energy adoption at the household level in world wide. For instance, Mossie Zeru & Diriba Guta (2020); Dil Lemma Shallo et al. (); Christian Anteneh (2019); Dawit Diriba (2018); Bahadur Rahut et al. (2017); Xingdong Wang et al. (2017); Warkaw Legesse Abate A.S. Chawla (2016). However, most study conduct particularly in urban area and also, the above research finding indicates socio-economic variable affect adoption of solar technology one area from another area. Thus, this study aimed to analyze factors that determine rural household's adoption solar technology in case of West Belesa and East Belesa districts of Ethiopia.

2. Review related literature review

In investigative factors that determine rural household's adoption solar technology through a logit model approach past studies used different econometrics model such as probit model,

multinomial logit and logit model. For example, De Groote et al. (2016) investigated the heterogeneity in the adoption of the PV system in the region of Flanders (Belgium). The author explained that important housing characteristics such as house size, roof insulation, and quality of the roof are positively correlated with the solar PV installation. He also showed that as the age of the house increase, the rate of adopting solar home system decrease.

Mossie Zeru & Diriba Guta (2020) examine factors influencing household adoption of solar home system in Baso Liben District; Amhara Regional State of Ethiopia. The result of the binary logistic regression model indicated that as income of household increase, their probability to adopt solar home system also increases. Likewise, participation in off-farm income activities, house type, educational status, training access, media access, and prior knowledge positively correlated with the adoption of SHS. On the other hand, gender and access to electricity are negatively associated with the adoption of SHS.

Kindeye. F (2019) applied inferential and descriptive statics to examine examined determinants of lighting Energy transitions in rural Ethiopia, who revealed that landholding size, level of education, house type, and modern communication technologies have a positive influence on the adoption of renewable energy resources including solar. But family size has a negative effect on solar home system adoption.

Mossie Zeru & Diriba Guta (2020) investigated the determinants of household adoption of solar home system. The finding showed that income of the household, landholding size, number of cattle, age of household head, family size, and education level of the head has a positive effect on solar home system adoption. The author also found that male-headed households are less likely to adopt solar home system compared to female-headed counterparts.

IRENA (2013) investigates the extent to which the level of income of households influences adoption, it also seeks to establish the extent Education of house hold head influence adoption of solar technology and finally to which extent the availability of substitute power source influence adoption of solar Technology in laikipia North constituency

In summary, the reviews on factors that determine rural household's adoption solar technology Indicated, that the effect of agro-ecological, demographic, and socio-economic factors were different indifferent areas (Figure 1). This indicates that, in order to identify factors that determine rural household's adoption solar technology different areas location and resource specific research should be conducted. Besides, the review shows that logit were more appropriate model.

Figure 1. Conceptual framework for determinants of solar technology adoption in rural households prepared by Ahmed ().

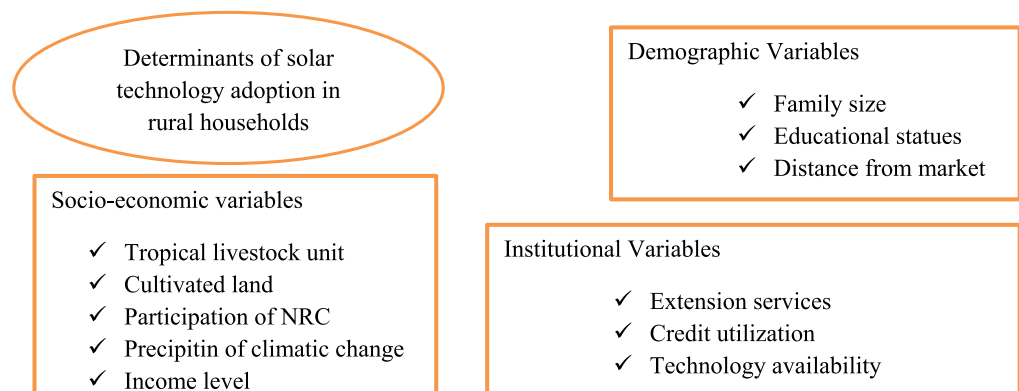


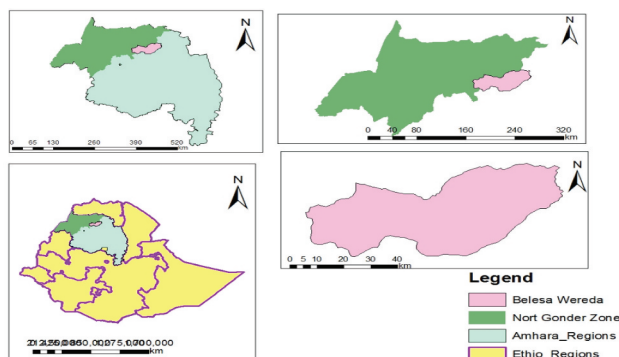
Table 1. Number of sample households from East and West Belesa

	East Belesa		West Belesa	Total
Chamakorach	126	Dikuana	132	
	46%		58.4%	
Dengora	148	Kalay	94	
	54%		41.6%	
Total	274		226	500
	54.9%		45.1%	100%

3. Material and methods

3.1. Description of study area

This study was conducted in the North West parts of Amhara region by selecting two sample *woredas* based on project intervention area. The study *woredas* are: West Belesa and East Belesa Districts in North Gondar Administrative Zone (see Table 1).



3.2. Data type, sample size and sampling procedure

The study used primary data collected through focus group discussion (FGD) and individual interview. Four FGDs were undertaken in the four CARE intervention kebeles by involving 8–12 farmers of different age, gender and social groups. Through the FGD, using a checklist, participants on the other hand, the primary data was obtained through demographical and socio-economic characteristics of the sample households. In this study, both qualitative and quantitative data was collected from primary and secondary sources. The main primary data was obtained from information on the demographical and socio-economic characteristics of the households and the secondary data collect form published, unpublished document and woreada Agricultural office.

The required sample size was calculated using the formula (Yemane, 1967) cited in (Israel, 1992), the formula is given as follow:-

$$n = N/1 + N(e)2$$

where, “n” is the sample size required “N” is the total number of households with in project interventions’ *kebeles* from the two district and “e” is the level of sampling precision which is assumed to be 5% in this study. According to (SWEET, 2019), the total population of the project interventions’ *kebeles* from the two districts has 43,715. Therefore, using the above formula the sample size required from the district is calculated as:-

$$n = 43,7151 + 43,715(0.05)^2 = 396 \text{ but use } 500.$$

To gain a higher efficiency in our estimates, we decided to push the sample size from 396 to 500 households for the study.

A multistage sampling technique was used to select the sample respondents. The sampling technique involves three stages. In the first stage, select the two districts by using purposive sampling because project interventions *woredas*. In the second stage 20 *kebeles* (ten from West Belesa and ten from East Belesa district) were obtained from project intervention *kebele's* then four sample *kebeles* (two from *West Belesa* and two from *East Belesa* district) were selected purposefully. The reason for the selection of these *kebeles* is based on their accessibility and long year's intervention area in energy sector. In the third stage, the numbers of all farm households from each selected sample *kebele's* were, listed. Finally, headed a total of 500-sample farm households of the study were, selected using simple random sampling technique from the four-sample *kebele's* in a proportional-to-size of each *kebele's* (Table 1).

3.3. Methods of data analysis

In this study were used both descriptive statics and econometric model. Using descriptive statics like T-test and χ^2 for continuous and categorical variables.

The empirical model is based on the logit model, as the dependent variable is a dichotomous take on a value of 1 if a household adopted solar energy technology and otherwise it has a value of 0. There are two standard dichotomous response models used: logit and probit models. The alternative model is based on an ordinary least squares (OLS) model known as the linear probability model (LPM), but this model suffers from major limitations.

The two standard binary models (i.e., the logit and probit models) are similar, and they generate predicted probabilities that are almost identical. However, the logit model is computationally easier to use and lends itself to a meaningful interpretation than the other types (Gujarati, 1995). For a similar study, Mossie Zeru & Diriba Guta (2020); Lemma Shallo et al. (); Dawit Diriba (2018) applied the logistic regression, while Christian Anteneh (2019); Bahadur Rahut et al. (2017) applied the probit model for a similar application.

Binary logistic regression model: Use of appropriate model is usually determined by the nature of the dependent variable or variables. Here in this study the dependent variable has dichotomous nature. Then ordinary linear regression is not appropriate because of the non-interval nature of the variable and the spacing of the outcome choices cannot be assumed to be uniform. Probit is similar to the logit model and in most application both model give quite similar result but logit uses logistic cumulative distribution function, whereas probit assume normal distribution.

In logistic regression, we would assume that the explanatory variables affect the response through suitable transformation of the probability of success, p_i (odds of success).

$$P_i = F(Z_i) = F\left(\sum_{i=1}^m \beta_i X_i\right) = \frac{1}{1 + e^{-Z_i}} \quad (1)$$

$$Z_i = \alpha + \sum_{i=1}^m \beta_i X_i$$

where P_i = the probability that farmers adoption

$$i = 1, 2, 3 \dots m$$

e = base of natural logarithms (2.718)

m = number of the explanatory variables

α = intercept

β_i = coefficient of explanatory variables.

4. Results and discussion

4.1. Samples' socio-demographics

Selected socio-economic and demographic characteristics of respondent households are reported in Table 2. The results show a statistically significant variation of a number of variables for the two groups. The results indicate that around 94.5% of households adopted solar energy technology. With regard to household demographics, the age of the household head showed a statistically significant variation. The household head of adopters of solar energy technology were relatively younger (on average 42.9 years) compared to non-adopters (about 50.6 years). Similarly, the household size showed a significant variation between the two groups, with the adopter households having about 8 family member on average compared to three family member for non-adopters (Table 2). The analysis shows that there was a statistically significant variation in the number of livestock holding was converted to tropical livestock unit (TLU) to standardize the analysis. The conversion factors used were based on the average tropical livestock unit for adopter was 2.94 and 1.34 units respectively compared to non-adopter TLU (Table 2). Similarly, cultivated land showed a significant variation between the two groups, with the average cultivated land size of non-adopter was 0.91 ha and the corresponding figure for the adopter solar technology household was 0.60 ha.

The analysis shows that there was a statistically significant variation in the education levels of household heads between the two groups. Households who adopted solar energy technology had more educated household heads. The comparison by adopter solar technology reveals that, 91.3% of non-adopter and 48% of adopter were illiterate whereas, 2% of non-adopter and 52% adopter were literate (Table 3). Likewise, there was a statistically significant variation in the Agricultural extension services of household heads between the two groups. Households who adopted technology more access of Agricultural extension services The comparison by adopter 87% of non-adopter and 16.4% of adopter were not get extension services whereas, 13% non-adopter and 83.6% of adopter were get Agricultural extension services (Table 3). Similarly, Participation in environmental conservation activity also shows a statistically significant variation in between the two groups. The comparison by adopter reveals that 39% of non- adopt and 47.8% of adopter was not participating in environmental conservation activity whereas, 61% of non- adopter and 52.8 % of adopter participate in environmental conservation activity (Table 3). Besides, Knowledge about

Table 2. Summary of descriptive statistics for continuous variables

Variable	Non adopter (n =23)	Adopter (n =477)	Difference	Combined	T-value
	Mean	Mean	Mean	Mean	
AgeHH	50.65	42.95	7.7	43.3	2.7**
HHsize	3.17	4.83	-1.66	4.75	-4.36***
TLU	1.43	2.94	-1.51	2.87	-3.44***
Nnfrminc	5617.39	7936	-2319.32	7830.02	-1.82
Caltland	0.608	0.910	-0.302	0.896	-2.22**
Dmkt	90.21	82.808	7.41	83.14	0.864

Source: Computed from own survey data, (2019)*, ** and *** represent significance at 0.1, 0.05 and 0.01 levels respectively

Table 3. Summary of descriptive statistics for discrete variables

Variables	Categories	Non Adopter (23)	Adopter (470)		X ² - value
		Freq. (%)	Freq. (%)	Freq. (%)	
EduL	0 = Illiterate	21 (91.3)	229 (48)	250 (50)	16.42***
	1 = Literate	2 (8.7)	248(52)	250 (50)	
CreditU	0 = Not-utilize	18 (78)	284 (59)	302 (60.4)	3.215
	1 = Utilize	5 (22)	193(41)	198(39.6)	
PECon	0 = no	9 (39)	11 (47.8)	20 (4)	77.48***
	1 = yes	14(61)	466(52.8)	480 (96)	
AgExtkASTPCC	0 = No	20(87)	78 (16.4)	98 (19.6)	

69.40***21.27***0.030

1 = Yes 0 = No 1 = Yes 0 = No 1 = Yes

3 (13)19(82.6)4(17.4)3(13)20(87)

399 (83.6)167(35)310(65)18(3.7)459(96.3)

402 (80.4)186(37.2)314(62.8)21(4.2)479(95.8)

Source: Computed from own survey data, (2019)

*, ** and *** represent significance at 0.1, 0.05 and 0.01 levels respectively.

solar technology shows a statistically significant variation in between the two groups. The comparison by adopter reveals that, 82.6% of non- adopter and 35% of adopter were not knowledge

Table 4. Logit regression result

Variables	Coef.	Std.Err.	Z	Od ratio
Age	-0.45	0.27	1.55	0.95
Education status (1 =literate)	3.09*	1.10	2.57	22.0
Family size	0.078*	0.28	2.93	2.16
TLU	0.35	0.28	1.39	1.42
Income	0.00	0.00	0.26	0.99
Cultivated land	0.28	0.891	0.41	1.32
Participation NRC (1 =yes)	2.91*	0.6	2.92	18.3
Extension service (1 =yes)	2.904*	0.86	3.52	8.2
Distance form MKT	000	0.00	0.09	1.0
Knowledge STeco (1 =yes)	3.82*	0.71	3.26	45
Credit Utilization (1 =yes)	1.3***	0.79	1.52	3.9
Perception on Ccha (1 =yes)	2.8**	1.242	1.85	17.4
Constant	-7.4*	1.71	2.89	0.0
Pseudo r-squared	0.65	Number of obs.	500	
Chi-square	122.37	Prob > chi2	0.000	

Own survey, 2019 Dependent variable is Adoption of solar technology; *, ** and *** are statistically significant at 1%, 5% and 10% level of significance, respectively.

about solar technology. Whereas, 17.4% of non-adopter and 65% of Knowledge about solar technology (Table 3).

Therefore, descriptive statistics confirm that there is a significant difference between solar energy technology adopter households and non-adopters in terms of their demographics, economic, and institutional factors. However, it is difficult to infer causality as the effect of other factors which are not controlled. Hence, the econometric analysis based on the logistic regression model is used to determine factors affecting the decision for household solar energy technology adoption while controlling for unobserved variables (Table 4).

4.2. Econometrics model results

This part of the study discusses the factors that affect rural households of solar technology. Farmers' and which factor that affect the decision farmer's to adopt solar energy technology briefly discussed.

4.2.1. Education level

Significantly and positively affects the adoption solar energy at 1% significant level. It implies that for every one unit increase in education level the probability of the adoption solar energy technology also increases by 22%. The odds ratio also revealed that educated households adopted the solar technology more chance by a factor of 22% than non-educated (illiterate) household farmers'. These results are supported by Mossie Zeru & Diriba Guta (2020); Lemma Shallo et al. (); Christian Anteneh (2019); Bahadur Rahut et al. (2017).

4.2.2. Family size

Significantly and positively affects the adoption solar energy at 1% significant level. It implies that for every one unit increase in family size the probability of the adoption solar energy technology also increases by 2.16%. This is due to large family size to meet family food consumption by using solar technology than small family size household. From the model result, other things being constant, the odds ratio in favor of the probability of adopt solar energy technology by 2.16 increases with a unit increase family size. This result contrast with Christian Anteneh (2019).

4.2.3. Participation in natural resource conservation activity

It was positively and significantly effects on adoption of solar energy at a 1% significant level. This indicates that a household that participates in environmental conservation activity better understands and gets more information about how to mitigate climatic change by adopting energy-conserving solar technology than a non-participant in environmental conserving activity. From the model result, other things being constant, the odds ratio in favor of the adoption of solar technology by a factor of 18.3 for a unit increase in the participation of environmental conservation.

4.2.4. Agriculture extension contact

In the study, area the dominant sources of extension services are: development agents (DAs) who visit farms and homes of individuals to provide agricultural extension education including environmental management. The variable showed significant and positive relation with the decision to adoption solar energy at less than 1% level of significance. Those household who have contact with extension worker to obtain extension services were found to be more adopt solar energy technology as compared to those who have no contact. From the model result, other things are being constant, the odd ratio in favor to adopt energy conserving technology increase by a factor of 18.2 for a unit increase in the frequency of extension services.

4.2.5. Knowledge about solar technology

It was a significant and positive effect on adoption solar technology. Household that better awareness about the benefit of the technology high probable to adopt than no awareness about energy conserving technology. From the model result, other things being constant, odds ratio in favor of to adopt energy conserving technology increase by a factor of 45 for a unit increase in the

awareness about energy conserving technology. This result support by Mossie Zeru & Diriba Guta (2020).

4.2.6. Access to credit

It is significantly at 10% and positively affects the adoption of solar energy technology. Thus, access to credit is a key factor in enhancing rural households' affordability of solar energy technology. From the model result, other things being constant, the odds ratio in favor of adopting solar technology increases by a factor of 3.96 for a unit increase than counterparts. This finding is supported by Shallo et al. ().

4.2.7. Perception about climate change

It had a significant and positive effect on adoption solar technology at 1% significance level. This probably because of the farmer that thinks the presence of climate change high interest to use energy solar technology than the household that no think that the presence of climate change. From the model result, other things being constant, odds ratio in favor of to adopt energy conserving technology increase by a factor of 17.4 for a unit increase in the awareness about climate change.

In contrast, variables such as age of household head, Tropical livestock unit, income level, land holding and distance to market had no significant effect on the adoption of solar technology.

5. Conclusion and police implication

For a country like Ethiopia where, electric network expansion is mostly limited to the urban side of the country, the vast majority of rural residents in a different part of rural areas have low electric grid connection and most of them have no chance of connecting to the grid in the near future. However, there are several factors which possibly affect the farmers' adoption of solar energy. Thus, study aimed to analyze factors that determine rural household's adoption of solar technology in case of West Belesa and East Belesa districts of Ethiopia. The findings of the study from the binary regression analysis indicated that seven independent variables were significant in explaining the factors affecting rural household's adoption of solar energy. These variables were education status, family size, participation on natural resource conservation activity, extension services, knowledge about solar technology, credit utilization and perception on climatic change which had positive influences. Since natural resource conservation activity, education status, and credit utilization were the positive determinants of the adoption of solar energy. Based on the finding, the study recommends that the Government and NGOs should give natural resource conservation training should incorporate practical knowledge of how solar technology adoption is important for the rehabilitation of degraded land. Stockholder institutions should arrange smoothly for the potential to enhance household decisions on solar technology adoption. Furthermore, efforts towards effort the education level of household's heads training exercise to motive to adopt solar technology.

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Disclosure statement

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