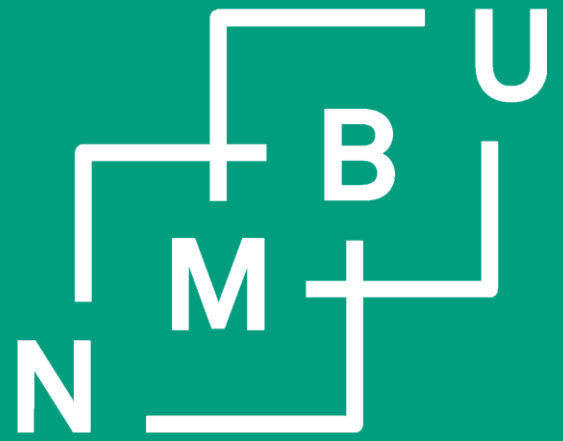
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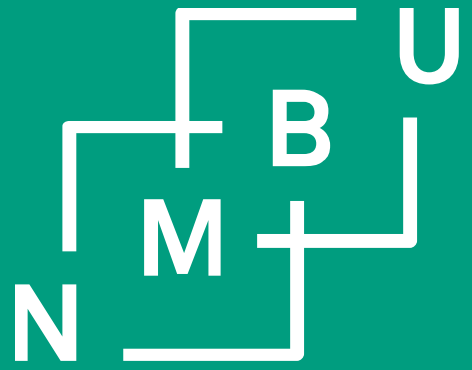

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Bringing Power to the People of Uganda: Determinants of solar Photovoltaics adoption in Uganda

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Introduction

- Electricity is critical to the household welfare and development process
- In Uganda, only 15% of the households had access to grid electricity in 2019, most of who live in the urbans (UBOS,2019), thus energy poverty.
- Solar energy use is expanding and (LSMS 2018/2019) reports that 36% of the households in the survey use solar energy

Background

- There critical constraints of grid electricity

- Grid electricity requires infrastructure which is costly to build and maintain
- Grid electricity is expensive right from connection fee to the grid to variable user fee
- The grid does not reach every part of the country
- Requires a modern roof

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Off-grid solar power is expanding: hence becoming a viable alternative to grid electricity in villages and towns across Uganda

- Endowed with sunshine thus high potential for solar energy production. About 200,000 km2 of Uganda's land area has solar radiation exceeding 2,000 kWh/m2 /year
- Cost of connecting solar is low and declining
- Solar is wireless (no need to connect to the grid)
- No requirement of a modern roof

Objectives and questions

- To asses and empirically examine the factors determining the sustainable use of solar PVs in Uganda

Research question:

- what are the major drivers to the adoption and use of solar PVs in Uganda?

Contribution of the study

- We aim at exploring ways to increase electrification among Ugandans since the long-serving system of hydro has failed.
- The paper will, therefore, contribute to the debate on energy poverty in Uganda.
- This study brings forth new evidence by utilizing the detailed Uganda 2018/2019 Living Standards Measurement Survey (LSMS) household data to analyze the household energy demand in the country. This study will be specific to Uganda to identify its uniqueness in terms of the drivers of solar PV adoption.

Methodological Framework

- **Data sources**
- We use the Living Standards Measurement Survey (LSMS) data for 2018/2019 Uganda. The data collected from the household survey included demographic and socioeconomic characteristics and energy sources.

- **Dependent variables:** solar use
- **Other energy sources:** Grid electricity, Kerosene use and Others

- **Independent variables:** Wealth, Education, Gender, age, Location, Household size, number of dependents, electricity prices, electricity hours, generator, grid connection.

continue

Model Specification

The binary regression is mathematically specified as:

- $y_i^* = X\beta + \epsilon$
- $y_i = \begin{cases} 1 & \text{if } y_i^* > 0 \\ 0 & \text{if } y_i^* \leq 0 \end{cases}$

Where y_i^* is a latent (unobserved) variable, y_i is the observed variable which takes on value of 1 if a household i has solar panel and zero otherwise. X is a vector of independent variables.

The multivariate probit model in this paper was formulated as:

- $y_{ij}^* = X_i\beta_j + u_{ij}$
- $y_{ij} = \begin{cases} 1 & \text{if } y_{ij}^* > 0 \\ 0 & \text{if } y_{ij}^* \leq 0 \end{cases}$
- y represents the four binary outcomes (lighting fuel choices), namely: Solar PVs, grid-electricity, kerosene, and others. X is a matrix of the explanatory variables and u_{ij} are assumed to be independent identically distributed across i but correlated across j for any i

Results

- Only a few (36%) households used solar PVs.
- 38% of the respondents had access to grid-electricity.
- 25.5 % of the households are located in urban areas.
- The average price of electricity per unit was shs 690
- The average electricity hours was 3 hours per day. .

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Solar use	3155	.361	.48	0	1
Grid	3170	.38	.486	0	1
Location	3170	.255	.436	0	1
Elec price	3170	690.272	78.717	572.4	771.1
Age hhhead	3170	47.373	15.728	18	98
Hhsize	3170	5.668	2.992	1	22
Gender	3170	.346	.476	0	1
Dependents	3170	2.49	1.942	0	11
Elec hrs	3170	3.076	7.666	0	24
Generator	3170	.001	.036	0	1
Saving	3128	.845	.362	0	1
Educ level	2950	5.957	4.481	0	16

Note: Grid is access to grid-electricity, elec_price is electricity prices, age_hhd is the age of the household head, Hhsize is the size of the household, elec_hrs is electricity hours, and edu_level is the education level of the household head, and Saving is a proxy for wealth.

- Grid connection, being in urban, electricity prices, being a male-headed household and electricity hours are negatively associated with the adoption of solar PVs.

- Age, household size, number of dependents, saving, education and generator are positively correlated with the adoption of solar PVs.

- Table 2: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11	(12)
(1) solar_use	1.000											
(2) grid	-0.177	1.000										
(3) location	-0.186	0.498	1.000									
(4) elec_pric	-0.038	0.150	0.103	1.000								
(5) age_hhd	0.018	-0.035	-0.043	0.026	1.000							
(6) hhsize	0.158	-0.088	-0.082	0.062	0.060	1.000						
(7) gender	-0.118	0.024	-0.006	0.008	0.160	-0.150	1.000					
(8) dependents	0.129	-0.106	-0.119	0.032	-0.166	0.781	-0.138	1.000				
(9) elec_hrs	-0.258	0.503	0.488	0.186	-0.055	-0.059	0.005	-0.105	1.000			
(10) generator	0.007	0.007	0.015	0.027	0.012	0.042	-0.018	-0.021	0.032	1.000		
(11) saving	0.093	0.053	0.058	-0.041	-0.108	0.041	-0.056	0.020	0.054	0.011	1.000	
(12) educ_level	0.051	0.246	0.259	0.090	-0.250	0.031	-0.277	0.019	0.296	0.036	0.141	1.000

Discussion

- Households in urban areas, households with access to grid-electricity, households with reliable grid-electricity supply and male-headed households are less likely to adopt solar PVs.
- Wealth, education, age of the household head and size of the household positively influences solar adoption
- Number of dependents, electricity prices and generator are insignificant

Determinants of Solar PVs – probit regression

	(1)	(2)	(3)
VARIABLES	dy/dx	dy/dx	dy/dx
Grid	-0.10	-0.18***	
	(0.06)	(0.06)	
Location	-0.28***		-0.32***
	(0.07)		(0.07)
elec_price	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
age_hhd	0.00**	0.00**	0.00**
	(0.00)	(0.00)	(0.00)
Hhsize	0.06***	0.06***	0.06***
	(0.01)	(0.01)	(0.01)
Gender	-0.20***	-0.20***	-0.20***
	(0.06)	(0.06)	(0.06)
Dependents	-0.01	-0.01	-0.01
	(0.02)	(0.02)	(0.02)
elec_hrs	-0.07***	-0.07***	-0.07***
	(0.01)	(0.01)	(0.01)
Generator	0.44	0.44	0.46
	(1.20)	(1.18)	(1.20)
Saving	0.37***	0.37***	0.37***
	(0.07)	(0.07)	(0.07)
educ_level	0.04***	0.04***	0.04***
	(0.01)	(0.01)	(0.01)
Constant	-1.20***	-1.23***	-1.19***
	(0.25)	(0.25)	(0.25)
Observations	2,898	2,898	2,898

- The correlation coefficients (-0.5297 to -0.9993) between solar use and the three energy sources are high and negative as expected.
- The negative sign indicates that the energy sources are potential substitutes.
- The high correlation between the various energy sources with solar use suggests that the Multivariate probit model is the most appropriate model for analyzing solar PVs adoption.

Correlation Matrix for the various energy sources

Variables	(1)	(2)	(3)	(4)
(1) solar_use	1.000			
(2) grid-electricity	-0.6066***	1.000		
	(0.0378)			
(3) Kerosene_use	-0.5297***	-0.1755***	1.000	
	(0.0284)	(0.047)		
(4) Others	-0.9993***	-0.9961***	-0.9991***	1.000
	(0.0530)	(0.3804)	(0.0734)	

Determinants of Solar PVs Adoption in Uganda – Multivariate probit Model

	(1)	(2)	(3)	(4)
VARIABLES	Solar	Grid-electricity	Kerosene	Others
Location	-0.6622***	1.4619***	-0.1266**	-0.2568***
	(0.0644)	(0.0690)	(0.0628)	(0.0634)
educ_level	0.0237***	0.0801***	-0.0030	-0.0607***
	(0.0060)	(0.0082)	(0.0062)	(0.0065)
age_hhd	0.0042**	-0.0048**	0.0043**	-0.0064***
	(0.0017)	(0.0024)	(0.0018)	(0.0018)
Hhsize	0.0520***	0.0384**	-0.0340***	-0.0256*
	(0.0136)	(0.0183)	(0.0147)	(0.0146)
Gender	-0.2371***	0.2391***	0.0848	-0.0416
	(0.0555)	(0.0738)	(0.0560)	(0.0543)
Dependents	0.0054	-0.1003***	0.0408*	-0.0061
	(0.021)	(0.029)	(0.0222)	(0.0223)
Saving	0.3584***	0.1193	0.0280	-0.3358***
	(0.0697)	(0.1055)	(0.0709)	(0.0654)
Constant	-1.0952***	-2.1276***	-0.7796***	-0.6319***
	(0.1210)	(0.1869)	(0.1281)	(0.1237)
Observations	2,898	2,898	2,898	2,898

- The coefficients for location are negative for solar, kerosene and others and positive for grid-electricity.
- This implies that urban households are more likely to adopt grid-electricity relative to other energy sources.
- This is because electricity is viewed as a better energy source or urban households are already connected to the grid, hence a lock-in effect.
- Education is positively associated with the adoption of clean energy sources (solar and grid-electricity) compared to other energy sources.
- Household size increases the likelihood of using solar and grid-electricity, decreasing the probability of using kerosene and other energy sources.
- Dependents increases the possibility of using kerosene and reduces the likelihood of using grid-electricity.

- A proxy for wealth, increases the probability of adopting solar PVs and reduces the likelihood of using other energy sources.
- Age increases the probability of adopting solar and reduces the likelihood of using other energy sources. This may indicate that older people are wealthier thus can afford clean energy like solar. However, the age of the household head also increases the probability of using kerosene and reduces the likelihood of adopting grid-electricity. The reasoning here is that older people are accustomed to using kerosene hence a lock-in effect, and they may lack awareness of modern energy technologies like solar and grid-electricity.
- Male-headed household reduces the probability of adopting solar but increases the likelihood of using grid-electricity. We argue that women may prefer solar energy clean energy relative to kerosene, and it's more affordable than grid-electricity. While males may choose grid-electricity since they can afford it, given that, on average, males are richer than females in Uganda.

Conclusion and Implications

- our results contribute to the debate on energy poverty in Uganda.
- We contribute on the attainment of Sustainable Development Goals (SDGs) focus on ensuring access to affordable, reliable, sustainable, and modern energy for all by 2030
- We explore ways to increase electrification among Ugandans through the adoption of solar PVs as an alternative energy source

Recommendations

- Embarking on projects and programmes that boost households' incomes and the country's economic growth, improving the quality of education and educate more people, especially rural household heads on solar energy, massive awareness campaigns for solar PVs, encouraging and supporting more research on solar PV technologies throughout the value chain to improve solar energy quality

Thank you