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

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Abstract
We examine the factors determining the adoption and use of solar PV technologies in Uganda using the detailed Uganda 2018/2019 Living Standards Measurement Survey (LSMS) household data. Data are analyzed with a Probit model and a Multivariate Probit model. We find that the major drivers of solar PVs use in Uganda are saving, education, age of household head, household size and wealth. 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. We provide recommendations on how to increase the uptake of solar PVs.
Keywords: Multivariate Probit, renewable energy, Lighting

1. Introduction

Access to electricity promotes economic activity, thus leading to human development and improved welfare. Therefore, the Sustainable Development Goals (SDGs) focus on ensuring access to affordable, reliable, sustainable, and modern energy for all by 2030. Even though Uganda has implemented several programs to increase electricity accessibility, most of its population is still not connected to the electricity grid. Only 15% of the households accessed electricity through the grid in 2019, most of which lived in urban areas (UBOS, 2019).
Additionally, many households find grid electricity costly, both in terms of connection fees and price of electricity (Blimpo & Cosgrove-Davies, 2019). There are critical constraints related to electricity transmission (grid) too. Many households, firms, and public agencies that would otherwise use electricity do not have access to supplies through the grid. Besides, grid extension and maintenance are costly. Moreover, the areas without grid access are usually characterized by widely dispersed households, hence it is costly to provide grid electricity to most of these areas.
However, off-grid solar energy is becoming a viable alternative to traditional electricity systems in villages and towns across Uganda. Off-grid solar power is expanding rapidly, and the LSMS 2018/2019 reports that 36% of the households surveyed used solar energy.
Moreover, households who have access to the grid, might desire to install solar PV as an alternative or supplement to electricity from the grid. Electricity supply from the grid is unreliable, and characterised with frequent blackouts – both planned and unplanned. Moreover, Uganda is well endowed with sunshine and the sun is available, therefore the risks of electricity failures from solar electricity are less than hydro.
However, the most important question that remains unaddressed concerning access to electricity is: what are the major drivers to the adoption and use of solar PVs in Uganda? Therefore, this study aims at assessing and empirically examining the factors determining the use of solar PV technologies in Uganda by employing binary probit and Multivariate probit models.
The aim is to explore of increasing electrification among Ugandans since the long-serving system of hydro has failed to solve the energy poverty problem in Uganda.

2. Methods

Model Specification and Econometric Methodology

Two econometric analyses were carried out using binary probit regression (binary probit) and multivariate probit (MVP) models to analyze the major factors influencing the adoption and purchase of solar PVs in Uganda. Binary probit regression models are used to examine the relationship between a binary dependent variable y and one or more explanatory variables X. The dependent variable ' y ' in this study represents the household's decision to purchase and use solar PV. (y = 1, adopt; y = 0, otherwise), Meanwhile, the explanatory variables can take any form (discrete, continuous).
The binary regression is mathematically specified as:

$$y_i^* = X\beta + \epsilon$$

$$y_i = \begin{cases} 1 & \text{if} \quad y_i^* > 0 \\ 0 & \text{if} \quad y_i^* \leq 0 \end{cases}$$

Where y_i^* is a latent (unobserved) variable, y_i is the observed variable that takes on the value of 1 if a household i has a solar panel and zero otherwise. X is a vector of independent variables.
We also employ a multivariate probit model to examine the major determinants of the adoption of solar PVs in Uganda. Multivariate probit models are used to estimate more than one correlated binary dependent variables jointly. The model is the most appropriate model for analyzing solar PVs adoption since we believe that solar PV adoption is

correlated with grid electricity, the use of kerosene and other lighting forms. Therefore, we estimate Multivariate Probit model analysis with four binary outcome choice variables namely: solar PVs, grid-electricity, kerosene, and others (none of the mentioned three). The multivariate probit model has also been used by researchers (Ali et al., 2019; Behera et al., 2015; Wassie & Adaramola, 2021) to analyze the determinants of household choices of alternative energy sources for lighting. Following (Mullahy, 2016), the multivariate probit model in this paper was formulated as:

$$y_{ij}^{*} = X_i\beta_j + u_{ij}$$

$$y_{ij} = \begin{cases} 1 & \text{if} \quad y_{ij}^{*} > 0 \\ 0 & \text{if} \quad y_{ij}^{*} \leq 0 \end{cases}$$

In this model, y represents the four binary outcomes (lighting fuel choices), namely: Solar PVs, grid-electricity, kerosene, and others. For each type of lighting fuel choice, the household is faced with a binary choice (1 = use of the energy type, or 0 = otherwise).

$i = 1,2,3 \ldots N$ indexes observations, $j = 1,2,3,4$ index outcome

where X is a matrix of the explanatory variables; $\beta_1, \beta_2, \beta_3 and \beta_4$ are parameter estimates and u_{ij} are assumed to be independent identically distributed across i but correlated across j for any i, and MVN denotes the multivariate normal distribution. (Henceforth, the i subscripts will be suppressed). The model is estimated using the maximum likelihood estimation.

3. Results

Estimates from the probit model revealed that that solar PVs' adoption in Uganda is driven by savings, education, age of the household head, size of the household and wealth. We argue that with increased savings households can afford to cover the up-front investment of solar PVs. Whereas education increases purchasing power and awareness hence the preference for cleaner and convenient energy sources like solar. In the case of a large household, the fixed cost of solar PVs can be spread among the household members. Also, older household heads may be richer and thus can afford to adopt solar PVs thus age positively affects solar adoption. Wealth positively affects solar adoption due to affordability reasons. However, age and wealth have minimal marginal effects on solar adoption. On the contrary, 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. We argue that households already connected to the grid may be reluctant to adopt solar PVs because they may perceive solar adoption as an additional cost, and there may be a lock-in effect to grid-electricity. Furthermore, urban households in Uganda are already connected to grid-electricity, hence perceiving solar adoption as an additional expenditure. Also, where grid-electricity supply is reliable, the probability of adopting solar PVs reduces, an indication that if reliable, grid-electricity is preferable compared to solar energy. Moreover, since women in Africa are more responsible for energy collection, they are more affected by lack of energy hence may be more willing to pay for cleaner and convenient energy technologies like solar PVs compared to the Male. Electricity prices do not influence the decision to adopt solar PVs in Uganda.

From the Multivariate Probit Model, the coefficients for location are negative and significant 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. Moreover, there is more access to grid-electricity in urban areas than in rural areas. The effect of all the variables on solar adoption as shown by the Multivariate Probit model is similar to that in the binary probit Model in terms of sign and significance.

Conclusions

The goal of this study was to empirically examine the factors affecting solar PVs adoption in Uganda. The findings from the probit and multivariate probit models showed that the uptake of solar PVs in Uganda is driven by savings, education, age of the household head, size of the household and wealth. Nevertheless, 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. Considering the various energy sources, households in urban areas prefer grid-electricity to solar, kerosene and other energy sources. This may imply that grid-electricity is of better quality e.g., in terms of voltage compared to other energy sources. Also, Solar PV units can be a bit costly to buy, whereas with grid there may be less of an up-front investment, but you pay monthly. For liquidity constrained households the difference in cost profile over time might be decisive.

We recommend that, since wealth drives solar PVs adoption in Uganda, the government should embark on projects and programmes to boost households' incomes. This will increase the purchasing power of the households, thus increased solar PVs adoption. Given that most households in Uganda live below and around the poverty line, it implies limited ability to pay for solar panels since the entire investment is up-front. More research is needed through market innovation of various solar panels for further large cost reduction for the end-user. Further, the government should educate people, especially rural household heads on the uses and benefits of clean solar energy. Education provides households with knowledge of clean energy such as solar energy thus households will prefer and adopt solar energy. Notably, the government should encourage and support more research on solar PV technologies throughout the value chain to improve solar energy quality.