www.jard.edu.pl http://dx.doi.org/10.17306/J.JARD.2023.01721

Journal of Agribusiness and Rural Development

pISSN 1899-5241
eISSN 1899-5772

4(70) 2023, 379–390
Accepted for print: 25.10.2023

POULTRY FARMERS' PREFERENCES FOR SOLAR PHOTOVOLTAICS AS A MAJOR SOURCE OF ENERGY IN OYO STATE, NIGERIA

Sheriff Kunmi Badmus✉[1,2], Olanike Olubunmi Alawode[1]

[1]University of Ibadan, Nigeria
[2]Centre for Econometrics and Applied Research, Ibadan, Nigeria

Abstract. Amidst rising food insecurity, Nigerians are confronted with the problem of an insufficient grid supply of electricity to support active development of the economy. The problem has lingered as fuel prices have surged following the Nigerian Government's declaration of the cessation of fuel import subsidies. However, solar photovoltaics remain a competitive alternative given their growing popularity; thus, having more insight into farmers' preferences for solar PV will allow suppliers and the government to develop products that can help stimulate business viability as well as energy policy. This study examined poultry farmers' preferences for solar photovoltaics as a major source of energy in Oyo State. Primary data were obtained from 150 poultry farmers using multistage sampling. Results from the choice models show that as the capacity of solar systems increases, the likelihood of choosing an alternative over the status quo also increases. The brand variable was also significant, indicating the relevance of certain brands to farmers' choices. The cost parameter was negative, which means there is an inverse relationship between price and the selection of an alternative. Also, farms with more birds (>1000), higher incomes and educated farmers were more likely to adopt solar PV than other current options. Further implications of the results are discussed.

Keywords: food security, sustainable energy, poultry, willingness to pay, marketing mix, choice modelling

INTRODUCTION

Global crises such as the pandemic have underscored the need for more resilient production systems (Bag et al., 2022). Geopolitical tensions such as the Russia-Ukraine war have also emphasized the need for supply chain flexibility and efficiency (Guenette et al., 2022). The indicators of a global economic recession are emphatic and pressing; thus, the global race to implement optimal and more efficient production systems that reduce various indices of economic failure remains relevant (Guardian, 2023). The need to combat climate change complicates various economic problems, as the exploitation of fossil fuels and production capacities continues (Liang et al., 2022; Liverpool-Tasie et al., 2019). It is imperative to address energy efficiency and energy consumption savings given the energy resource shortage, rising energy prices, and pressing environmental problems (Cui et al., 2021).

More than half of the 15% of the world's population that lacks access to electricity is situated in sub-Saharan Africa. They resort to using fuels for basic household and daily activities, leading to significant negative outcomes on health and safety, and contributing to the global greenhouse burden (Trotter et al., 2017; Trotter, 2016). Access to electricity is important for national development, with effects on the economy and the social and human capital base, and benefits such as improved healthcare services, education and productivity. Access

✉Sheriff Kunmi Badmus, Department of Agricultural Economics, University of Ibadan, Ibadan, Oyo State, Nigeria, e-mail: sbhadmus@gmail.com, https://orcid.org/0000-0002-0432-4024

to affordable and clean energy for all by 2030 stands as one of the United Nations' sustainable development goals (Emili et al., 2016).

Food security targets can rarely be met if food production is limited by poor access to energy, unreliable electricity supplies and unsustainable practices. Energy usage in poultry houses is significant, as it contributes to different phases of growth in birds through the provision of light (O'Connor et al., 2011). Energy is an essential part of producing, processing, marketing and distributing animal products. Most of these products must be refrigerated or processed to keep them from spoiling. Transportation is also a vital element in the animal products industry. Any restrictions on the availability of energy to the industry would have serious and immediate impacts on the production and marketing processes (Pishgar-Komleh et al., 2017; Atilgan and Koknaroglu, 2006).

In Africa, agriculture and agro-industries account for more than 20% of GDP in most countries, and they also make up a significant share of export revenues (Karekezi and Kithyoma, 2002). Nearly three quarters of the African population depends on agriculture to secure their livelihoods (Food and Agriculture Organization, 2022). Due to the increasing trend in population growth and income, the demand for eggs and poultry meat has significantly increased in recent years across large parts of the continent (Heise et al., 2015). According to estimates by the United States Agency for International Development, USAID, this trend is likely to continue over the next few years. The consumption of poultry, meat and eggs is estimated to rise in Nigeria due to an increase in population and improved purchasing power (Dutch Ministry of Foreign Affairs, 2020).

An unstable grid supply of electricity, the price of fossil fuels and associated energy pitfalls have led to energy crises which have undermined the productivity of several sectors and have contributed to the incidence of poverty (Okonkwo et al., 2020; Monyei et al., 2018; Uzoma et al., 2010). It has been reported that power outages lead to a loss of 126 billion naira yearly (Oyedepo, 2012). In addition to lost income, energy production has also yielded dangerous effluents which are actively involved in mediating poor living conditions and health hazards.

Seventy percent of Nigerians are engaged in agricultural production; despite this significant percentage, Nigeria is yet to attain self-sufficiency in food products owing to the inefficient combination of inputs for agricultural production and poor value addition to agricultural produce (Food and Agriculture Organization, 2022). It is estimated that Nigeria has 180 million poultry birds (FAO, 2018). Various studies have argued that the poultry sector contributes to the biological and socio-economic development of Nigerian society (Olanrewaju et al., 2020; FAO, 2018; Obike et al., 2018), and a study by Olanrewaju et al. (2020) has shown that unstable electricity limits the productivity of poultry farmers.

Off-grid electricity sources range from pico-solar solutions (for example, solar lamps and lanterns) to solar home systems and mini-grids, which can be powered by solar, biomass or even a hybrid form of energy (Adamu, 2020). The reliability of grid energy access can be improved by diversifying the source of energy away from government grids and fossil fuels. The reach of the sun is as wide as the sky, and this potentially places every household or farm at the centre of energy access, storage and sustained usage. Sustainable agriculture implies a production system that achieves an optimal yield from current usage while future interests are secured. The use of fossil fuels, pesticides, fertilizers and other farm inputs that deposit significant greenhouse gases is fundamentally unsustainable. The adoption of green alternatives could help increase access, reliability and sustainability.

It is expected that positive population and income growth will lead to increasing demand for poultry products in Nigeria. The poultry industry has emerged as the most commercialized and fastest expanding segment in the animal husbandry subsector, but it still faces many problems, such as poor production systems, low quality and high cost of feed inputs and the poor performance of the energy sector (Heise et al., 2015). Several waves of efforts have been deployed to revamp the agricultural sector of the country since the restoration of democratic government in 1999. On the policy side, the ban on the importation of poultry products has been among the major incentives for growth (Dutch Ministry of Foreign Affairs, 2020).

The relatively high energy input in intensive livestock systems has given rise to concerns regarding greenhouse gas emissions and climate change. The energy consumption of industrially produced poultry is relevant because of the production of carbon dioxide (CO_2) along the production chain. Carbon dioxide emissions are produced by the burning of fossil fuels during animal production and slaughter and the transport of processed and refrigerated products, but importantly also through land use and land-use change and the use of inputs for the production of feed. The energy used for heating, ventilation and air conditioning systems typically accounts for the largest quantity of energy used in intensive poultry operations (Gerber et al., 2007).

Changes in climatic conditions have had a ripple effect on poultry production. It has been shown that increased dry spells and temperatures in Africa can affect poultry production directly and indirectly. Increased temperature and heat stress have been linked to losses including death, low egg production (quantity and quality), and reduced growth rate in intensive poultry farming systems in Africa and Asia (Liverpool-Tasie et al., 2019; Bhadauria et al., 2014). Chickens reduce their feed intake to regulate their internal temperature, which affects their growth and productivity when they are faced with heat stress (Nyoni et al., 2019). Climate change affects poultry (and other livestock) production indirectly because of its effect on maize yields. Maize is a key ingredient in poultry feed; lower maize yields due to climate change affect the availability and price of feed and the profitability of poultry production.

In light of the effect of climate change on productivity, poultry farmers are left to consider climate adaptation strategies such as water or air ventilation, which are expected to require more energy usage. From this, we can conclude that the usage of non-renewable sources of energy for poultry production would add to the existing problem of climate change, which has come to affect all elements of life and industry around the globe. Generating non-polluting sources of energy and energy efficiency in poultry and other sectors therefore stand as potent tools for breaking the vicious circle of climate change around the globe.

It is vital to explore the clean and quiet benefits of solar photovoltaics, since farmers often resort to mechanical means such as power generators for ventilation and lighting and to provide energy for other basic farm needs. Studies have shown that low light intensity and continual high background noise have a detrimental effect on egg production in the early laying phase as well as influencing the time allocated to different behaviours (O'Connor et al., 2011). Campo et al. (2005) also found that noise stimuli cause stress and fear in laying hens, which can adversely affect their productivity and performance.

Agriculture can play a significant part in renewable energy production. Poultry operators in Ibadan could produce renewable energy through the use of solar photovoltaic (PV) panels, then use the electricity for bird production, running fans and lighting while reducing the demand on grid suppliers and reducing pollutants. A solar PV system is a module that converts sunlight into usable electricity. Agriculture, and specifically the poultry industry, could play a significant role in reducing environmental pollutants as well as lowering farm production costs. Since energy plays a crucial role in poultry production and there is sufficient roof space in poultry houses, the poultry industry is a feasible target for solar energy adoption (Byrne et al., 2009).

This study specifically addresses the preferences of farms that have adopted or are willing to adopt solar PV and how these preferences differ from one another. The main interest of this study lies in identifying the attributes of Solar PV that are important to poultry farmers. It has been argued that employing a user-centred design helps the overall outcome or effectiveness of products (Bao et al., 2020).

Statements of research questions

The following research questions were raised to guide this study:

- What is the level of adoption of solar energy by poultry farmers in Oyo State?
- What are the constraints on farmers' adoption of solar energy?
- What are the determinants of farmers' adoption of solar energy?

Objectives of the study

The main aim of this research is to assess poultry farmers' preferences for solar PV as the major source of energy in Oyo State, Nigeria. Its specific objectives are to:

- assess t inhe level of adoption of solar energy by poultry farmers;
- determine the constraints on farmers' adoption of solar energy;
- examine the determinants of farmers' adoption of solar energy.

METHODOLOGY

Type and source of data

Located in the South-West geopolitical zone of Nigeria, Oyo State consists of 33 Local Government Areas and 29 Local Council Development Areas.

The study used a quantitative approach to gather data. Insights were gathered from interviews with farmers and solar experts and from a literature review to identify key attributes to focus on in the subsequent quantitative survey. Data for the study were obtained from primary sources using a well-structured questionnaire. Data were collected on farmers' socio-economic characteristics, such as sex, age, marital status and other factors that may influence their willingness to adopt solar photovoltaics. Data on awareness, such as how the farmers got to know about solar PV and how long they've been using the technology, were also collected. Further data were collected on willingness to pay and preferences for solar PV to determine the willingness to pay for solar PV systems and the factors influencing this. The R statistical software was used to convert the choice dataset to a standard choice dataset following the specifications on the usage of the support.CES package by Aizaki et al. (2014).

The following attributes were selected for use in the choice experiment: price, capacity, solar only or solar plus inverter, and country of manufacture. The price of off-grid solar electricity is a concern in Nigeria as it is elsewhere (Salisu, et al., 2019; Ohunakin et al., 2014). Though the price has dropped over the years, compared to other energy sources, the cost of off-grid solar electricity is generally higher (Elegbede et al., 2021). The price range used for solar panels and batteries in the experiment was determined by market experts and online prices in Nigeria (JUMIA Nigeria, 2021).

The price coefficient in the analysis of choice experiment data tends to be negative given the relationship between the demand and price of a commodity. However, literature in psychology shows that this is not always the case—people often assume that a higher price means higher quality, so they choose the more expensive product in the absence of other information (Elegbede et al., 2021; Sagebiel, 2017; Rommel et al., 2016).

The attribute of capacity demonstrates the wattage farms can achieve from rooftop solar PVs and batteries. Since it may be difficult for farmers to understand the power in wattage terms, the number of birds that can be reared using a product was used as a proxy for capacity (see Table 2.1). The ability to rear more birds implies a system with more capacity.

The attribute of "solar and inverter" indicates the preference of farmers for solar panels only or combined solar and inverter systems. Solar panels cannot provide wattage at night when there is no sunshine. However, the price of an inverter battery is significant, and this may affect farmers' choices. Higher prices will be associated with solar and inverter systems, as is the case in reality.

The final attribute of the experiment was the country in which the products were manufactured. From the previous energy survey, respondents expressed a lack of trust in solar technology, and the country variable is intended to address the importance of trust (Elegbede et al., 2021). Nigerians perceive products manufactured in China as of relatively low quality and products made in the United States as of higher quality. However, certain US products are also manufactured in China given the structure of the market for products of particular grades. Against this backdrop, the country attribute serves to evaluate the effect of certain brands on farmers' choices and not trust.

Table 1. Attributes and their levels

Categorical attributes	Levels
Backup	Solar only
	Solar and Inverter
Brand	USA
	China
Continuous attributes	
Capacity (birds)	1200
	1500
	5000
	7000
Price (Naira)	220,000
	300,000
	900,000
	1,700,000

This table contains the attributes of solar PV considered in the study and their levels. ₦ is the symbol for the Nigerian currency, Naira (₦).
Source: own elaboration.

For the experimental design, a set of profiles was constructed and the R statistical software was used to create a design with attributes and levels (Aizaki et al., 2014; Lancsar et al., 2017). For each product, the design considered attributes and their various levels. For solar products, four attributes were considered, each with varying levels. This gave 2*2*4*4 (= 64) possible profiles. A total of 16 choice tasks were generated in a single block, with three choice tasks (two choice tasks and an opt-out option) per choice set. Respondents were presented with 9 choice tasks (four choice sets) instead of 16 to avoid fatigue and to collect more reliable data. The attributes and levels in this example are presented in Table 1. Options A and B (the first and second choice tasks respectively) represent the various attributes of solar photovoltaics (PV). This was necessary to present the respondents with different scenarios. The opt-out option (Option C) was for respondents who were not interested in green alternatives and stands for the respondents' current choice of energy; it is also referred to as the status quo.

The choice tasks were demonstrated and presented to farmers. A trial run was conducted to ensure the tasks were understood and applicable to the respondents.

Modelling farmers' preferences for solar PV using choice experiments

Choice modelling is based on the extension of the utility theory, which holds that individuals are rational and confined by their budgets when making decisions. The seminal papers of McFadden and Train (2000) introduced the random parameters logit model (RPL), also known as the mixed multinomial logit model (MNL). This model helps in relaxing the assumption of independent and irrelevant alternatives. Subsequent developments were made by Fiebig et al. (2010), who nested the MNL/RPL model to give the generalized multinomial logit model (GMNL), which allows for the estimation of choices that were not originally captured in the experimental process by allowing for individual scale and preference heterogeneity.

Model specification

The analysis of the choice data relies on a random utility model where the utility that a farmer i derives from choosing alternative j in choice scenario s is given by

$$U_{isj} = X'_{isj}\beta + \varepsilon_{isj} \qquad (1)$$

$i = 1, \ldots$
$j = 1, \ldots, J$
$s = 1, \ldots, S$

where X_{isj} is a $K \times 1$ vector of explanatory variables and β is a conformable vector of coefficients. The disturbance term ε_{isj} is assumed to be identically and independently distributed as extreme value, the standard multinomial logit (MNL) specification results. The simplicity of estimation and interpretation are among the main advantages of this model, but it features some restrictive assumptions that are unrealistic in certain choice contexts.

The specification of scale heterogeneity and preference heterogenity gives the GMNL model in equation (2):

$$U_{isj} = (\beta_{0j} + Z'_i Y'_j + \eta_{0ij}) + X'_{isj}\,(\beta_{\sigma i}) + \varepsilon_{isj} \qquad (2)$$

$$i = 1, \ldots.. n, j = 1, \ldots.., J, s = 1, \ldots\ldots, S$$

where:
U_{isj} – dependent variable,
X_i – independent variables or attributes,
ε – error term,
β_i – regression coefficient.

This thesis specifies three models: the Multinomial Logit (MN), the Panel Mixed Logit Model (MXL) and the Generalized Multinomial Logit Model (GMNL).

Willingness to pay values

The willingness to pay (WTP) values for each of the attributes are calculated as the ratio between each of the attribute estimates and the cost or price estimate. This idea is consistent with those of Arora et al., 2020 and Lancsar et al., 2017 and is estimated using the formula below

$$E(WTP^k) = -\frac{E(\beta^k)}{\beta^{price}}$$

RESULTS

Tables 2 and 3 show the socioeconomic characteristics of the respondents. Six persons lived in a household on average, with a range of 2–10 persons. More than half of the sampled farmers were male. The population of married and single farmers in the sample was fairly balanced and masked other categories of marital status. The mean age of farmers was 35.86, with a ±10 range indicating that most of the sampled farmers were of an active economic age. The farming experience of respondents was 7.17 ±5.22 years. It is expected that farmers

Table 2. Socioeconomic characteristics of respondents

Variable	Description (n = 150)	Frequency (%)
Age	0–29	47 (31.33)
Mean = 35.86 ±10.21	30–49	83 (55.33)
Min 21	50–59	15 (10.00)
Max 67	>60	5 (3.33)
Sex	Male	98 (65.33)
	Female	52 (34.67)
Marital status	Married	72 (48.32)
	Never married	68 (45.64)
	Other categories	9 (6.03)
Education of the farm head	No formal education	8 (5.33)
	Secondary or primary	13 (8.67)
	Tertiary	129 (86)
Farming experience (years)	0–5	71 (47.33)
Mean = 7.17 ±5.22	>5–15	71 (47.33)
Min 0.4	>15–30	7 (4.67)
Max 40	>30	1 (0.67)
Household size	0–3	31 (21.23)
Mean = 5.76 ±4.08	>3–6	77 (52.74)
Min 1	>6–10	30 (20.55)
Max 36	>10	8 (5.48)
HH members assist in the production	Yes	118 (79.73)
	No	30 (20.27)

Source: field survey, 2021.

Table 3. Socioeconomic characteristics of respondents (continued)

Variable	Description (n = 150)	Frequency (%)
Scale of practice	Full-time	53.00 (34.9)
	Part-time	97.00 (65.1)
Bird size	0–1000 birds	107.00 (71.33)
Mean = 10 234.4 ±74 904	1001–5000 birds	31.00 (20.67)
Min = 12	5001–10000 birds	8.00 (5.33)
Max = 70 000	100 001>birds	4.00 (2.66)
Access to credit	Yes	41.00 (27.52)
	No	108.00 (72.48)
Farm head monthly income (N)	Mean income (interval data)	
	Less than N50,000	43.00 (29.05)
	N50,000 to less than N100,000	51.00 (34.36)
	N100,000 to less than N250,000	31.00 (20.95)
	N250,000 to less than N500,000	10.00 (6.76)
	Others	2.00 (1.36)
	Prefer not to say	11.00 (7.43)

Source: field survey, 2021.

become better in their management of inputs and birds as their farming experience increases, and this is truer for the poultry industry given the effect of knowledge and input choice on productivity. This is illustrated by the distribution of the educational level of the respondents, with 86% of the farmers having had tertiary education or training.

The bulk (63.41%) of the sampled poultry farmers earned less than N100,000 monthly. The results show that most of the farmers practiced poultry farming on a part-time (65.1%) basis. The majority (79.73%) of the respondents reported that household members assisted them in production; this may be possible because most (73.1%) of the sampled farmers reared fewer birds (less than 1,000 units), which may not require extended manpower and management. Most (72.48%) of the respondents had access to credit should they plan to expand their production base or adopt new technology.

Table 2 shows that the majority (86.67%) of the farmers were aware of Solar PV, less than 40% used it, and 71.49% of the farmers would be willing to pay for it. It is expected that access to installers would lead to access to more information about the technology and hence an improved adoption rate. The majority (56.85%) of the sampled farmers did not have access to installers. Interestingly, more than half of the respondents were not connected to the national grid. The reason behind this trend may be the unreliable nature of the grid supply, which may be counterproductive for some poultry systems.

Most of the farmers ranked petrol generators (45.14%) as their major source of energy, followed by the national grid (34.72%), diesel generators (17.81%) and solar systems (6.94%). This is similar to the distribution of backup energy choices, with solar systems overtaking diesel energy. This section highlights the overreliance of poultry farmers on petrol generators as their major backup source of energy (see Table 4). Table 5 ranks the severity of certain constraints on the adoption choice of respondents. High initial investment cost (1) is the most severe constraint, followed by the insecurity of solar plant infrastructure (2), poor quality control of solar panels (3), lack of awareness and information (4), lack of access to installers (5); and variability and intermittency of solar radiation (6).

Table 4. Awareness and adoption of solar PV

Variable	Description	Frequency (%)
Aware of solar energy	Yes	130.00 (86.67)
	No	20.00 (13.33)
Existing usage	Yes	47 (31.33)
	No	103 (68.67)
Willingness to purchase solar panels	Yes	84.00 (71.79)
	No	33.00 (28.21)
Access to installers	Yes	63.00 (43.15)
	No	83.00 (56.85)
Grid connection	Yes	70.00 (47.95)
	No	76.00 (52.05)
Major source of energy	National grid	50.00 (34.72)
	Petrol	65.00 (45.14)
	Diesel	11.00 (17.81)
	Solar, batteries and inverters	10.00 (6.94)
	Others	2.00 (1.39)
Backup source	National grid	25.00 (17.24)
	Petrol	77.00 (53.10)
	Diesel	13.00 (8.97)
	Solar, batteries and inverters	22.00 (15.17)
	Others	8.00 (5.52)

Source: field survey, 2021.

Table 5. Constraints on the adoption of solar PV

Constraints	Not a constraint	Moderate	Severe	Mean ±SD	Rank
High initial investment cost	19.00 (12.67%)	76.00 (50.67%)	55.00 (36.67%)	1.24 ±0.66	1
No access to Installers	86.00 (58.11%)	46.00 (31.08%)	16.00 (10.81%)	0.52 ±0.62	5
Insecurity of solar plant infrastructure	58.00 (39.19%)	72.00 (48.65%)	18.00 (12.16%)	0.73 ±0.66	2
Lack of awareness and information	75.00 (50.34%)	60.00 (40.27%)	14.00 (9.4%)	0.59 ±0.66	4
Variability and intermittency of radiation in your location	85.00 (57.05%)	57.00 (38.26%)	7.00 (4.70%)	0.47 ±0.59	6
Ineffective quality control of solar panels	59.00 (39.33%)	72.00 (48%)	19.00 (12.67%)	0.73 ±0.67	3

Source: field survey, 2021.

Following the distribution in Table 6, grid and solar systems were perceived to be free of noise pollution while petrol and diesel generators ranked highest. Petrol generators and solar systems were perceived as the most

Table 6. Features of energy sources

Features	Grid	Petrol generator	Diesel generator	Solar system
No noise pollution	–	103.00 (69.13%)	46.00 (30.87%)	–
Reliability	20.00 (13.61%)	47.00 (31.97%)	20.00 (13.61%)	60.00 (40.82%)
Ease of operation or use	46.00 (30.87%)	46.00 (30.87%)	11.00 (7.38%)	46.00 (30.87%)
Air pollution/ smoke	3.00 (2%)	59.00 (39.33%)	46.00 (30.67%)	2.00 (1.33%)

Source: field survey, 2021.

reliable sources while the grid, petrol generators and solar systems were considered easy to operate. As for noise pollution, petrol and diesel generators were perceived as the biggest polluters.

Table 7 shows the distribution of selected choices. Both Options A and B are green, with the attributes being price, capacity, solar (or solar and inverter) and brand. Option C is the opt-out or base option, which corresponds to the respondents' status quo. Option A is the most preferred option followed by B and C respectively.

Table 7. Distribution of respondents' preferred choice scenarios

CHOICE SET	Option A	Option B	Option C	Total
C-1	79	33	36	148
C-2	63	44	41	148
C-3	51	61	36	148
C-4	58	48	41	147
Average	42.47	31.47	26.06	100

Source: field survey, 2021.

Consistent with other papers on choice analysis (see Sagebiel, 2017; Ghijben et al., 2014; Sagebiel and Rommel, 2014), this thesis starts with the traditional multinomial logit model and then proceeds to more sophisticated models such as the panel mixed logit (MXL) and generalized multinomial logit (GMNL). The advantages of the models have been mentioned in the methods section. The adoption of different models also serves as a check on the consistency of the results and the robustness of the analysis.

Table 8 below shows that the MNL and MXL models mirror each other concerning the sign and significance of the variables. The GMNL model, which nests the MNL and MXL models, looks similar to the other models, although it characterizes the effect of brand on farmers' choices as insignificant. As the capacity of a solar system increases, the likelihood of choosing an alternative over the status quo also increases. The brand variable is also significant, indicating the relevance of certain green brands on farmers' choices. The cost parameter is negative, which means there is an inverse relationship between price and choosing an alternative.

Table 8. Relationship between respondents' choice and attributes, case variables and choice alternatives using the Multinomial Logit, Mixed Logit and Generalized-Multinomial Logit Models

Attribute	MNL	MXL	GMNL
Inverter	0.2398 (0.1979)	–0.1923 (0.2993)	0.2923 (0.2309)
Capacity	0.0005*** (0.0002)	0.0030*** (0.0004)	0.0030*** (0.0008)
Brand	–0.3396*** (0.1169)	–0.2898* (0.1602)	–0.0291 (0.0024)
Price	–0.0142*** (0.0008)	–0.0107*** (0.0018)	–0.0098*** (0.0024)
Option A			
Female	0.0254 (0.3803)	0.0176 (0.5097)	
Age	–0.0110 (0.0181)	0.0397 (0.0253)	
Marital status	–0.01187 (0.4057)	–0.5212 (0.5377)	
Bird size	0.8604* (0.4498)	0.5671 (0.6623)	
Income	–0.5645 (0.4161)	–1.2095** (0.5485)	
Education	1.6973*** (0.5298)	1.9203*** (0.7012)	
Option B			
Female	–0.2306 (0.3766)	–0.5036 (0.4519)	
Age	–0.0110 (0.0181)	0.0038 (0.0225)	
Marital status	–0.0649 (0.3743)	–0.4166 (0.380)	
Bird size	1.0342** (0.4373)	0.7794 (0.5922)	
Income	–0.1031 (0.4316)	–0.4965 (0.4643)	
Education	0.9501* (0.5164)	1.1749** (0.5617)	
Option C – Base Alternative			
No. of obs.	1,737	1,737	1,773
Wald Chi2	42.26	73.6	52.52
Prob>Chi2	0.0004	0.0000	0.0004
Log-likelihood	–586.586	–510.216	–542.581

Source: field survey, 2021.

This relationship is valid based on the theories of demand and empirical findings (Yao and Sui, 2020).

The case-specific variables are interpreted according to the dominating sign and significance across models. Though insignificant, younger, single and female farmers are more likely to choose "green" alternatives over the "brown" status quo. Also, farmers with more birds and higher educational attainment prefer green choices over the status quo. Farmers earning below ₦50,000 monthly prefer the status quo over the green alternatives

Willingness to pay values

Table 9 below shows the willingness to pay values for attributes across models. The willingness to pay for inverter systems over solar-only systems is mixed and insignificant, indicating that respondents were not willing to pay for this attribute. Despite the advantages of an inverter system, its higher price compared to a solar-only system may put farmers off. However, it may not be possible for farmers to operate efficiently without an inverter system; hence, this result in the context of the research means that farmers would only purchase solar inverter systems if the prices were significantly lower.

Table 9. Willingness to pay values

	MNL	MXL	GMNL
Inverter	106.5133 (100.7965)	–18.0057 (27.3317)	29.7099 (25.1689)
Capacity	0.2216*** (0.0178)	0.2836 *** (0.0260)	0.3059*** (0.0437)
Brand	–150.8552*** (51.8942)	–27.1421* (14.5288)	–2.9613 (14.7588)

Source: field survey, 2021.

The surveyed farmers were willing to pay significantly for the ability of a solar system to cater for an extra bird, suggesting the relevance of capacity to their preferences. The evidence on the effect of brand on farmers' choice is mixed; overall, farmers significantly respond to branding when deciding how much to pay for solar systems.

CONCLUSIONS

Summary of major findings

The study evaluated poultry farmers' preferences for solar PV as a major source of energy in Oyo State. It also assessed the determinants of farmers' willingness to pay for solar PV. Using data from a choice experiment, the study was able to profile farmers' preferences for solar PV given the included attributes and their willingness to pay values. Data on 150 farms were sourced using questionnaires. The data were analyzed using descriptive statistics and random utility models. The results revealed that the majority (65.33%) of the respondents were males, implying that the majority of the farms were headed by males. The mean age was 35.86±10.21. This means that the average farmer was within his or her economically active period. The results also revealed that (48.32%) of the respondents were married while 45.64% had never been married. Most of the farmers rank petrol generators (45.14%) as their major source of energy, followed by the national grid (34.72%), diesel generators (17.81%) and solar systems (6.94%).

The distribution of the choice set shows that Option A (43.47%) was the most preferred option followed by options B and C (31.08% and 25.45% respectively).

The results from the choice models show that as the capacity of a solar system increases, the likelihood of choosing an alternative also increases. The brand variable is also significant, indicating the relevance of certain brands to farmers' choices. The cost parameter is negative, which means there is an inverse relationship between price and choosing an alternative. The significance of their standard deviations connotes the presence of preference heterogeneity among farmers for solar PV. Based on the MXL model, young, female and single farmers are more likely to adopt solar PV over the "brown" status quo. Also, farmers with more birds and higher educational attainment prefer green choices over the status quo. Farmers earning below ₦50,000 per month prefer the status quo to the green alternatives

RECOMMENDATIONS

Price of solar products

The models show that the price variable is negative, which means that people are more likely to go for cheaper products. This is in line with demand theory. Thus, it is recommended that producers pay attention to the price of the solar systems they design for farmers given the researched preferences and socioeconomic mix.

Willingness to pay for solar panels

The majority of the farmers (86.87%) were aware of and willing to pay (71.79%) for solar panels, which shows that there is a potential market for farm-based solar systems among the sampled population. This study thus recommends that this potential market should be explored by firms and government using the right mix of market stimulation, designs and prices as elucidated in the current study.

Effect of the brand

The study shows that the concept of national branding exists and influences consumer choices, as surveyed respondents were not willing to pay for Chinese products over American products. Brand failure as expressed in this study may be due to the poor quality of Chinese products, and this is consistent with the conclusions from Elegbede et al. (2021). The implication of this discovery is that national governments, especially the Nigerian government, should place more emphasis on product standardization and grade. Correspondingly, bodies like the Standard Organization of Nigeria (SON) should work harder to ensure the quality of Nigerian-made products and other imports.

The cost of inverter systems and the trade-offs

The research found that despite the advantages of an inverter system, its prices compared to a solar-only system may distract farmers from the innovation. However, it may not be possible for farmers to operate efficiently without inverter systems; hence, this result in the context of the research means that farmers would only purchase solar inverter systems when the prices are significantly low. This submission is relatable given the costs of batteries and inverters which may drive up the initial investment cost of a solar package.

REFERENCES

Adamu, F. (2020). Using Data to Drive Strategy: A Framework for Clean Technology.

Aizaki, H., Nakatani, T., Sato, K. (2014). Stated preference methods using R (1st Ed.). Chapman and Hall/CRC. Retrieved from: https://www.crcpress.com/Stated-Preference-Methods-Using-R/Aizaki-Nakatani-Sato/p/book/9781439890479

Arora, R.S., Brent, D.A., Jaenicke, E.C. (2020). Is india ready for alt-meat? Preferences and willingness to pay for meat alternatives. Sustainability, 12(11), 4377. https://doi.org/10.3390/su12114377

Atilgan, A., Koknaroglu, H. (2006). Cultural energy analysis on broilers reared in different capacity poultry houses. Italian J. Animal Sci., 5, 393–400. https://doi.org/10.4081/ijas.2006.393

Bag, S., Rahman, M.S., Srivastava, G., Chan, H.L., Bryde, D.J. (2022). The role of big data and predictive analytics in developing a resilient supply chain network in the South African mining industry against extreme weather events. Int. J. Prod. Econ., 251, 108541. https://doi.org/10.1016/j.ijpe.2022.108541

Bao, Q., Sinitskaya, E., Gomez, K.J., MacDonald, E.F., Yang, M.C. (2020). A human-centered design approach to evaluating factors in residential solar PV adoption: A survey of homeowners in California and Massachusetts. Renew. Energy, 151, 503–513. https://doi.org/10.1016/j.renene.2019.11.047

Bhadauria, P., Kataria, J.M., Majumdar, S., Bhanja, S.K., Kolluri, G. (2014). Impact of hot climate on poultry production system-a review thermoregulatory mechanism of poultry. J. Poult. Sci. Technol., 2(4), 56–63. Retrieved from: https://www.academia.edu/10044750/Impact_of_Hot_Climate_on_Poultry_Production_System-A_Review

Byrne, J., Kurdegelashvili, L., Hegedus, S., Zhang, X., Walker, R., Salisbury, M., Hromiko, R., Schreiber, J. (2009). Creating A Solar City. Determining the potential of solar rooftop systems in the City of Newark (Issue August). Retrieved from: http://ceep.udel.edu

Campo, J.L., Gil, M.G., Dávila, S.G. (2005). Effects of specific noise and music stimuli on stress and fear levels of laying hens of several breeds. Appl. Anim. Beh. Sci., 91(1–2), 75–84. https://doi.org/10.1016/j.applanim.2004.08.028

Cui, Y., Xue, X., Riffat, S. (2021). Cost Effectiveness of Poultry Production by Sustainable and Renewable Energy Source. Meat Nutr. https://doi.org/10.5772/INTECHOPEN.97543

Dutch Ministry of Foreign Affairs (2020). Poultry Sector Study Nigeria. Netherlands Enterprise Agency.

Elegbede, O., Kerr, J., Richardson, R., Sanou, A. (2021). Using a choice experiment to understand preferences in off-grid solar electricity attributes: The case of Nigerian households. Energy Sustain. Dev., 60, 33–39. https://doi.org/10.1016/j.esd.2020.12.001

Emili, S., Ceschin, F., Harrison, D. (2016). Product–Service System applied to Distributed Renewable Energy:

A classification system, 15 archetypal models and a strategic design tool. Energy Sustain. Dev., 32, 71–98. https://doi.org/10.1016/J.ESD.2016.03.004

FAO (2018). Livestock and livelihoods spotlight NIGERIA: cattle and poutry sectors. Food and Agriculture Organization of the United Nations, 1–12. Retrieved from: http://www.fao.org/3/CA2149EN/ca2149en.pdf

FAO (2022). FAO in Nigeria. Food and Agriculture Organization of the United Nations. Retrieved from: https://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/

Fiebig, D.G., Keane, M.P., Louviere, J., Wasi, N. (2010). The generalized multinomial logit model: Accounting for scale and coefficient heterogeneity. Market. Sci., 29(3), 393–421. https://doi.org/10.1287/mksc.1090.0508

Gerber, P., Opio, C., Steinfeld, H. (2007). Poultry production and the environment-A review. FAO, January, 1–27. Retrieved from: http://www.fao.org/ag/againfo/home/events/bangkok2007/docs/part2/2_2.pdf

Ghijben, P., Lancsar, E., Zavarsek, S. (2014). Preferences for Oral Anticoagulants in Atrial Fibrillation: a Best–Best Discrete Choice Experiment. PharmacoEconomics, 32(11), 1115–1127. https://doi.org/10.1007/s40273-014-0188-0

Guardian, T. (2023). Third of world economy to hit recession in 2023, IMF head warns. International Monetary Fund (IMF). The Guardian. Retrieved from: https://www.theguardian.com/business/2023/jan/02/third-of-world-economy-to-hit-recession-in-2023-imf-head-warns

Guenette, J.D., Kenworthy, P.G., Wheeler, C.M. (2022). Implications of the war in Ukraine for the global economy. https://doi.org/10.1596/37372

Heise, H., Crisan, A., Theuvsen, L. (2015). The poultry market in Nigeria: Market structures and potential for investment in the market. Int. Food Agribus. Manag. Rev., 18(SpecialIssueA), 197–222.

JUMIA Nigeria. (2022). Shop All Products - TVs, Laptops, Fashion Items | Jumia Nigeria. Retrieved from: https://www.jumia.com.ng/catalog/?q=solar+generators

Karekezi, S., Kithyoma, W. (2002). Renewable energy strategies for rural Africa: Is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor to sub-Saharan Africa? Energ. Pol., 30(11–12), 1071–1086. https://doi.org/10.1016/S0301-4215(02)00059-9

Lancsar, E., Fiebig, D.G., Hole, A.R. (2017). Discrete choice experiments: A guide to model specification, estimation and software. PharmacoEconomics, 35(7), 697–716. https://doi.org/10.1007/s40273-017-0506-4

Liang, C., Umar, M., Ma, F., Huynh, T.L.D. (2022). Climate policy uncertainty and world renewable energy index volatility forecasting. Technol. Forecast. Soc. Change, 182, 121810. https://doi.org/10.1016/J.TECHFORE.2022.121810

Liverpool-Tasie, L.S.O., Sanou, A., Tambo, J.A. (2019). Climate change adaptation among poultry farmers: evidence from Nigeria. Clim. Change, 157(3–4), 527–544. https://doi.org/10.1007/s10584-019-02574-8

McFadden, D., Train, K. (2000). Mixed MNL models for discrete response. J. Appl. Econ., 15(5), 447–470. https://doi.org/10.1002/1099-1255(200009/10)15:5<447::aid-jae570>3.0.co;2-1

Monyei, C., Adewumi, A., Obolo, M.O., Sajou, B. (2018). Nigeria's energy poverty: Insights and implications for smart policies and framework towards a smart Nigeria electricity network. Renew. Sustain. Energy Rev., 81, 1, 1582–1601 https://doi.org/10.1016/J.RSER.2017.05.237

Nigeria at a glance | FAO in Nigeria | Food and Agriculture Organization of the United Nations. (n.d.). Retrieved Jan 4rd 2022 from: https://www.fao.org/nigeria/fao-in-nigeria/nigeria-at-a-glance/en/

Nyoni, N.M.B., Grab, S., Archer, E.R.M. (2019). Heat stress and chickens: climate risk effects on rural poultry farming in low-income countries. In: Clim. Dev., 11, 1, 83–90. https://doi.org/10.1080/17565529.2018.1442792

O'Connor, E.A., Parker, M.O., Davey, E.L., Grist, H., Owen, R.C., Szladovits, B., Demmers, T. G.M., Wathes, C.M., Abeyesinghe, S.M. (2011). Effect of low light and high noise on behavioural activity, physiological indicators of stress and production in laying hens. Brit. Poult. Sci., 52(6), 666–674. https://doi.org/10.1080/00071668.2011.639342

Obike, K.C., Amusa, T.A., Olowolafe, H.B. (2018). Risk management and determinants of farm output among small scale poultry farmers in Ekiti State, Nigeria. Agro-Science, 16(2), 9. https://doi.org/10.4314/as.v16i2.2

Ohunakin, O.S., Adaramola, M.S., Oyewola, O.M., Fagbenle, R.O. (2014). Solar energy applications and development in Nigeria: Drivers and barriers. Renew. Sustain. Energy Rev., 32, 294–301. https://doi.org/10.1016/j.rser.2014.01.014

Olanrewaju, A., Animashaun, O., Nabinta, R. (2020). Analysis of the Factors Militating Against Broiler Production in Abeokuta North Local Goverment Area of Ogun State, Nigeria. FUDMA J. Agric. Agricult. Technol. Retrieved from: https://www.researchgate.net/publication/341354254_ANALYSIS_OF_THE_FACTORS_MILITATING_AGAINST_BROILER_PRODUCTION_IN_ABEOKUTA_NORTH_LOCAL_GOVERNMENT_AREA_OF_OGUN_STATE_NIGERIA

Oyedepo, S.O. (2012). Energy and sustainable development in Nigeria: the way forward. Energy Sustain. Soc., 1–17. https://energsustainsoc.biomedcentral.com/articles/10.1186/2192-0567-2-15

Pishgar-Komleh, S.H., Akram, A., Keyhani, A., van Zelm, R. (2017). Life cycle energy use, costs, and greenhouse gas emission of broiler farms in different production systems in Iran—a case study of Alborz province. Env. Sci. Poll. Res., 24, 16041–16049. https://doi.org/10.1007/s11356-017-9255-3

Renerworld (2022). Renerworld Products | Solar Energy system, Renerlite, Solar Panels, Inverter, Lithium-Ion Battery. Retrieved from: https://www.renerworld.com/products

Rommel, J., Sagebiel, J., Müller, J.R. (2016). Quality uncertainty and the market for renewable energy: Evidence from German consumers. Renew. Energy, 94, 106–113. https://doi.org/10.1016/J.RENENE.2016.03.049

Sagebiel, J. (2017). Preference heterogeneity in energy discrete choice experiments: A review on methods for model selection. Renew. Sustain. Energy Rev., 69, 804–811. https://doi.org/10.1016/j.rser.2016.11.138

Sagebiel, J., Rommel, K. (2014). Preferences for electricity supply attributes in emerging megacities – Policy implications from a discrete choice experiment of private households in Hyderabad, India. Energy Sustain. Dev., 21, 89–99. https://doi.org/10.1016/j.esd.2014.06.002

Salisu, S., Salisu, S., Mustafa, M., Olatomiwa, L., Mohammed, O. (2019). Assessment of technical and economic feasibility for a hybrid PV-wind-diesel-battery energy system in a remote community of north central Nigeria. https://doi.org/10.1016/j.aej.2019.09.013

Štreimikienė, D. (2021). Developmen. United Nations. https://data.worldbank.org/indicator/SP.POP.GROW?locations=NG

Trotter, P.A. (2016). Rural electrification, electrification inequality and democratic institutions in sub-Saharan Africa. Energy Sustain. Dev., 34, 111–129. https://doi.org/10.1016/j.esd.2016.07.008

Trotter, P.A., McManus, M.C., Maconachie, R. (2017). Electricity planning and implementation in sub-Saharan Africa: A systematic review. „Renewable and Sustainable Energy Reviews", 74(March), 1189–1209. https://doi.org/10.1016/j.rser.2017.03.001

Uzoma, C.C., Ibeto, C.N., Nnaji, C., Okala, N.O. (2010). The role of renewable energy resources in poverty alleviation in Nigeria. Contin. J. Soc. Sci., 3, 31–37. Retrieved from: https://www.researchgate.net/publication/232282799_The_Role_of_Renewable_Energy_Resources_in_Poverty_Alleviation_and_Sustainable_Development_in_Nigeria

Yao, L., Sui, B. (2020). Heterogeneous preferences for shale water management: Evidence from a choice experiment in Fuling shale gas field, southwest China. Energy Policy, 147, 111831. https://doi.org/10.1016/j.enpol.2020.111831