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The Endogeneity Effects of Conservation Agriculture Adoption on Smallholder Farmers' Food Security Status in Osun State, Nigeria

Olawuyi Seyi Olalekan[1*], [2]Balogun Taofeek Ayodeji
[1]Department of Agricultural Economics and Extention, University of Fort Hare, Eastern Cape, South Africa
[2]Cooperative Information Network, Obafemi Awolowo University, Ile-Ife, Nigeria
201704974@ufh.ac.za*, btaofeekayodeji@yahoo.com

Abstract: Goal two of the Sustainable Development Goals stipulates that, individuals at all strata are food secure. This is a major social problem with far reaching economic and development consequences. Growing population has exacerbated the pressure on land base agriculture to supply energy requirements, and traditional agricultural practices have complicated the topical issue. Thus, efforts to simultaneously improve agricultural productivity and keep the system sustainable calls for appropriate sustainable agricultural practice such as conservation agriculture. This study investigates the links between CA adoption and household food security in Nigeria. Two hundred and twenty-one respondents in the study area were sampled. Multisampling technique was used to select the required sample and a questionnaire was administered. Descriptive statistics result revealed farmers' and farm-based characteristics while food security index divulged the food security status of the respondents. The Double hurdle model was employed to investigate factors driving the adoption of CA and extent of adoption while two-stage least square (2SLS) estimated bi-causal links between CA adoption and food security status. The age of respondents, gender, education, access to credit, farm size cultivated and access to extension services contributed significantly to the adoption of CA and so to the extent of adoption. The two-stage least square confirms the exogeneity of CA adoption with food security status. By implication, the adoption of CA practices in Nigeria is a viable option to increase food production and by extension to attain sustainable food security status.

Keywords: *Endogeneity, conservation agriculture, food security, double hurdle model, 2-SLS*

1. Introduction

There are more noticeable consequences of farming systems today relative to the previous experience because of the growing call for agricultural practices that are sustainable and preserve the environment (Shrestha & Clements, 2003). To supply the needs of today without compromising the potentials of tomorrow, agricultural practices that aim to increase per capita productivity trend needs to be done sustainably. Sustainable agricultural practices have assumed a challenging dimension owing to hike in food prices and energy, changing climate, water shortage, degraded biodiversity including budgetary exigency (Kassam, Friedrich, Shaxson & Pretty, 2009). Moreover, population growth has risen with the demand for nutritious diet, water and other agricultural harvests thereby mounting more pressure on agricultural resources. Government and other proponents of development in advanced economies have advocated for food security by using practices that are sustainable (Kassam et al., 2009). Attaining food security in Nigeria is crucial, but has encountered economic and developmental challenges like deteriorating eating pattern, distress sales of assets to provide daily nutrition among the average families (Ajani, Adebukola & Oyindamola, 2006). Moreover, one of the Sustainable Development Goals (SDG) demands that no individual should go hungry regardless of their status. Programmes such as Special Program for Food Security (SPFS), Root and Tuber Expansion program, Fadama development projects, community oriented agriculture and rural development projects and providing infrastructures have been established to ensure that Nigerians are food secure (Ojo & Adebayo, 2012). In spite of government's efforts to attain food security, the impact remains largely unfelt especially among the rural population who are primary producers. Then, efforts to simultaneously improve agricultural productivity and keep the system sustainable demands appropriate methods of land stewardship such as agricultural conservation.

Conservation agriculture (CA) supports the resourceful utilization of available natural resources through a unified soil, water and biological resources management, effectively combined with other inputs (FAO, 2008). CA helps to maintain a safe environment and promotes sustainable agricultural production. It gives the opportunity to harvest higher crop yields at minimum production costs without degrading soil fertility and water (FAO, 2008). CA also adopts pragmatic approaches to minimise soil erosion, reconstitute the organic matter, maintain soil moistness and fertility (African Conservation Tillage (ACT), 2005). Mazvimavi, Ndlovu, Nyathi & Minde (2010) opined that keeping soil unexposed is among the primary principle of CA. As such, cover crops aid CA system, not only to better soil characteristics but also to enhance the capacity for a prolific biodiversity. With this, farmers are more well-informed about mulching, though argument persist that mulching is only achieved using crop residues. Nonetheless, small farms produce small biomass which hinders them from the 30 percent recommended mulch cover to practice CA, other reports have suggested leaf litters and grasses as equally good materials (Giller, Witter, Corbeels & Tittonell, 2009). Global assessments of agricultural land show some 106 million hectares under CA cultivation or in part no-till systems (Derpsch & Friedrich, 2009; FAO, 2008). The potential and the actual level of CA adoption by smallholder farmers has also been questioned (Bolliger et al., 2006; Erenstein, 2003; Affholder et al., 2009; Giller et al., 2009). Limited access to land, informal land tenure systems , insufficient technical know-how , irregular extension services, difficult access to agricultural inputs and markets, and smallholders' impatient desire to quickly reap returns on the resources invested, are factors that deter the adoption of CA. Giller et al. (2009), argued that CA maybe profitable to farmers cultivating medium to large-scale automated farms, it is simply not cost effective for resource-poor farmers and their farming systems.

Empirical studies establishing the nexus between CA adoption and household food security in Nigeria are scanty with the notable exception of Babatunde & Setiloane (2006); Omotesho & Muhammad-Lawal (2010); Kuku & Liverpool (2010); Ojo & Adebayo (2012). Moreover, there is dearth of study on this topical issue particularly in Nigeria. Aina (2011) averred that the Nigeria agricultural system is characterized by peasant production system and by extension low productivity as a result of poor response to agricultural technology adoption. This is further buttressed by Kassam, Friedrich, Derpsch & Kienzle (2015) who reported that there is no substantial evidence to show for the investment allocated to agricultural research in Africa because the adoption of this technology by farmers in many parts of Africa is (0.8%), with no record or documentation for Nigeria. To justify the investment made in Nigerian Agricultural research, there is need to investigate farmers' adoption (consciously or unconsciously) of CA practices in Nigeria; this will assist to formulate relevant policy to enhance food productivity and subsequently reduce the persistent food insecurity menace through proper awareness about the need to consolidate on the current trend and success of CA adoption in other sub-Saharan Africa countries as well as the developed world.

In fact, not having sufficient information about the adoption of conservation practices and food security and how they relate theoretically has led to the low level of enlightenment and empowerment of farmers with the requisite skills in Nigeria. The policy directions are mainly influenced by what is known. More viable policies directions would have been adopted if more is known, hence, the need for the study. Basically, this study identified the CA technologies commonly practiced by smallholder farmers in Osun state, Nigeria; established the Food security status (FSS) of respondents, investigated factors driving use of CA technologies and the extent of CA technologies adoption; and examined the existence of bi-causal relationship between CA adoption and FSS.

2. Literature Review

Conservation tillage is viewed as a combination practice that covers soil surface with crop residues for the purpose of facilitating the infiltration rate of water, reduces erosion and at the same time enhances soil quality for better productivity. According to African Conservation Tillage (2005), conservation tillage is a conventional agriculture practice which reduces soil erosion and runoff. Furthermore, zero tillage is regarded as an integral part in achieving conservative agricultural practice. In the same vein, report from FAO in 2011 stated that when tillage is adopted in the process of land preparation there is a reduction in soil erosion and the rate at which land and water is being polluted. Also, there is a noticeable decline in the heavy reliance on external input to better the quality and efficient use of water and reduction in green-house gases emission by cutting down on fossil fuel utilization (FAO 2011; Also, Mazvimavi et al. (2010) and Shetto & Owenya (2007) in their separate reports revealed that tillage saves resources that farmers would have hitherto committed to agricultural production. Furthermore, the foregoing authors opined that when crops are rotated and intercropped with nitrogen fixating crops (legumes), top-dressing fertilizer that restores soil fertility is added and at the same time aids effective utilization of soil nutrient and weed control. Doing this can end the life cycle of a particular disease or pest capable of causing total economic loss (African Conservation Tillage (ACT) 2008).

In addition, Langyintuo (2005) observed that scientists who come up with innovative technologies such as CA to boost food production are often challenged with the accurate identification of factors that limit their adoption rate among farmers especially the smallholders. According to FAO (2008), smallholder farmers only cultivate area of land varying between less than a hectare to ten hectares of land with the primary aim of sustaining the family using family labour. With about 500 million smallholder farms distributed across the world, FAO (2008) reiterated their importance in securing food for over 2 billion people mainly in Asia and Sub-Saharan Africa. In the past decade, the number of reported cases of malnutrition have risen, majority of these cases have been traced to reduced purchasing power and soaring rate of unemployment (Low External Input and Sustainable Agriculture (LEISA), 2009). Strategies to improve households' well-being according to Roslan, Nor-Azam & Russayani (2010) are fundamentally macro policies such as food security. Moreover, the rationale behind most of the support systems that aim to better the lot of the poor people is that, physical and human capital development makes farmers reorganize themselves to invoke positive changes in their various economic activities. Today, food insecurity is considered a global menace, so complex that people who are directly confronted with the situation have to device a means to be food secure while paying attention to their economic and social limits (Farooq and Azam, 2002).

According to Olagunju, Oke, Babatunde & Ajiboye (2012), household food insecurity mainly stems from lack of wealth (asset and income). In the authors' explanation, wealthier households are less vulnerable to food shortages compared with low-income household with meagre resources, and, the impact of food price inflation is relatively severe on poor household as food accounts for a large part of their spending. As reported, the link between the food security status and the purchasing power of a household is dynamic and it changes in time (Romer-Lovendal and Knowles, 2006; Aliber, 2009). However, with other factors such as prices of other products, availability of close substitutes, taste left unchanged, the quantity and quality of items consumed is likely to change when there is variation in income. Equally, changes in the price of consumable and non-consumable items also dictate individuals' purchasing power (Olagunju et al., 2012).

3. Methodology

The Study Area: The study area is Osun State, Nigeria. Osun state is located in the South West of Nigeria, with the Capital city being Osogbo. The state shares boundary with Kwara State in the north, Ekiti State and Ondo State in the east, in the south by Ogun State and Oyo State in the west. The area is homogeneous and agrarian in nature which supports the cultivation of food and tree crops; food processing, marketing and trading are other livelihood activities in the area. Social interaction among the inhabitants of the state is moderate alongside other minority ethnic groups.

Sampling Procedure and Sample Size: Osun state was stratified into 3 Agricultural Development Programme (ADPs) Zones namely Osogbo, Iwo and Ife-Ijesha. A Multistage sampling method was adopted to select the sample for the study. The first stage begun with the purposive selection of Iwo and Ife-Ijesha ADP Zones owing to its rurality and prevalent agricultural activities. The second stage involved random sampling of 2 Local Government Areas (LGAs) from each of these zones (that is, Olaoluwa and Ejigbo LGAs as well as Ede North, and Ife East LGAs from Iwo ADP zone and Ife-Ijesha ADP zone respectively). In the third stage, 3 villages were randomly chosen from the villages identified across 4 LGAs selected in the second stage. Thus, a total of 12 villages were selected. Considering the population variation of the selected villages across the chosen L.G.As, proportionality factor and random sampling techniques were used to select 230 respondents at the fourth stage. The figure was arrived at using the formula stated as follow:

$$S = \frac{n}{N} \times 230 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$ where:

S = sampled respondents from the selected villages, in each of the L.G.As
n = population of registered farming households in each of the villages.
N = total population of registered farming households in the 12 villages across the 4 L.G.As chosen.
230 = number of respondents sampled.

Only 221 copies of the questionnaire were used in the final analyses. Others were either not returned or contained inadequate information. This indicates that a response rate of 96.08 percent was coded and used for the final analyses. It is important to stress that only 230 samples were selected across the enumerated LGAs because of fund and time. Based on the information collected from the 2 ADP zonal offices in question, this sample size also represents about 22% of the total population across the 12 villages used in this study.

Data Collection: The data was sourced primarily by administering questionnaire to respondents (household heads) in a scheduled interview process due to perceived low literacy level of the respondents. The information collected includes: age, gender, household size, years spent in school, primary and secondary occupation, marital status, size of the farmland, access to extension agent and frequency of extension agent visit etc. Furthermore, information was gathered on the awareness of CA practices, CA techniques commonly practiced and methods of operations, challenges involved, land availability and use, labour use and institutional factor among others. Information on respondents' household monthly expenditure on food and non-food items was also collected.

Data Analytical Techniques*:* Frequency counts, percentages, mean values and standard deviation are descriptive statistics that describe farmers and farm-based characteristics. Food security index was used to establish the FSS of the respondents. The double hurdle model was also used to investigate factors driving adoption of CA and so the extent (rate) of CA adoption while two-stage least square (2SLS) technique was used to examine the endogeneity effect of CA adoption on FSS (that is, to establish the existence of bi-causal relationship between CA adoption and FSS). The choice of 2SLS technique with the use of instrumental variables (IV) is found appropriate for this study because it estimates causal interactions and at the same time permits the estimation of consistency where independent variable correlates with the error terms (to guard against the existence of endogeneity issue) (Stock, Wright and Yogo, 2002). Such correlation is usually observed where there is reverse causation between dependent variable and at least one of the covariates, and when there are relevant explanatory variables which are omitted from the model, or when the covariates are subject to measurement error. To use the ordinary linear regression at this point will only yield result that is inconsistent, biased and spurious (Stock et al. 2002). Only a good instrument will yield an estimate that is consistent. And, to obtain good instrument(s), test of endogeneity (using ivendog command in STATA) was carried out after the estimation of 2SLS model which produced the Wu-Hausman F test and Durbin-Wu-Hausman chi-square test. In the same vein, Humphreys (2013) stressed that Wu-Hausman test is appropriate to ascertain the reliability, appropriateness and to control for self-selection bias especially when it has to do with the choice of instruments in 2SLS and IV estimation. Adepoju (2013) also confirmed that IV estimation can be used to handle endogeneity in models with linear parameters.

Model Specification*:* This study benefited from the analytical framework stated by Omonona & Agoi (2007); Adepoju & Salman (2011); Cragg (1971) and He, Fletcher, Chinnan & Shi (2009).

Approach to Measurement of Food Security-Households' Food Expenditure Approach (HFE) (Omonona & Agoi 2007; Arene & Anyaeji 2010): This involves getting per capita food expenditure of i^{th} household divided by 2/3 mean per capita food expenditure of all households. This was used to construct food security index and subsequently, FSS of the smallholder farmer households. The HFE approach was found appropriate therefore, used to measure food security for this study after a literature review of different approaches. It solves the problem of getting the actual total income of farming households which respondents find difficult to divulge and also solves the difficulties in getting daily calories intake especially, in Nigeria. Hence, following Omonona & Agoi (2007), a distinction was made on household food security status by separating them into those that are food secured and those that are not food secured by means of food expenditure approach to construct food security index. Arene & Anyaeji (2010) also adopted this approach to establish the FSS of various smallholder farmers.

This is given by:

$$F_i = \frac{Per\ capita\ \ food\ \exp enditure\ \ for\ the\ ith\ household}{2/3 mean\ per\ capita\ \ food\ \exp enditure\ of\ \ all\ household} \text{...}(2)$$

Where:

Fi = food security index

When:

$Fi \geq 1$ = food secure i[th] household and

$Fi < 1$ = food insecure i[th] household.

Therefore, any household with a per capita monthly food expenditure exceeding or equal to two-third of the mean per capita food expenditure is considered to be food secure. Otherwise is considered to be food insecure.

Double-Hurdle Model (D-H Model): The D-H model introduced in 1971 by Cragg is more popular in estimating two-stage decision processes. The merit of D-H model relative to the Tobit model lies in its framework that can be conditioned to estimate observed consumer's behavior as a joint choice of two decisions as an alternative to a single decision. For this study, the D-H econometric model methodology is considered appropriate because it estimates a probit model in the first stage in order to determine the factors affecting the smallholders' decision to adopt CA practices while the second hurdle confirms the actual or observed level (extent) of CA adoption. This makes it possible to separate the initial decision to adopt ($y > 0$ vs $y = 0$) from the decision of how much to adopt (extent); y given $y > 0$ (Olwande & Mathenge, 2012). The D-H model analyses the determinants of incidences (awareness) and intensity (extent) of adoption of CA practices; that is, drivers of CA practices adoption. The choice of this model stems from the assumption that households make two sequential decisions concerning the adoption of innovative technology. Each hurdle is conditioned by the farmer's socio-economic attributes along with the adopted CA practices. To estimate the D-H model, a Probit regression model (fitting all the observations) is stated after a truncated regression of non-zero observations (Cragg, 1971). The D-H model is designed to analyse the probability of an event occurring or otherwise. So that if it occurs, assumes a continuous value. . In relation to this study, the decision to adopt each practice comes first, followed by the extent of use (i.e. the level of adoption).

Thus, the first hurdle is stated as;

$d_i^* = Z_i'\alpha + u_i$ (decision to adopt a CA practice) ……………………..(3)

$y^* = X_i'\beta + v$(intensity/extent of use) …………………………………..(4)

$di = 1$ if $d^*>0$ ………………………………………………..(5)

$di = 0$ if $d^*\leq 0$

Then, the second hurdle which has the semblance of a Tobit model, is stated as:

$y^* = \max(y_i^{**}, 0)$ …………………………………………………………..(6)

Finally, the observed variable, y_i, is determined by the interaction of both hurdles as follows:

$y = d_i y_i^*$ ……………………………………………………………………………..(7)

$u_i \sim N(0, 1)$ $v_i \sim N(0, \sigma^2)$

If both decisions are made jointly (the Dependent Double Hurdle), under a condition where the error term is assumed to have a bi-variate normal distribution, it follows that the two decisions have been made together. Then, it is stated as:

$(ui, vi) \sim BVN(0, \psi)$

The composition of the two-stage decision suggests that participation and use be estimated together in order to yield efficient estimate (He *et al.,* 2009)

Economic and Behavioral relation of FSS and CA: In order to relate conservation agriculture (CA) to FSS of farming household, the farming household economic behaviour under constraint utility maximization gives a useful theoretical underpinning. The model establishes a direct link between the asset endowments of farming households, variables explaining the economic and social conditions under which household make decisions on farming household FSS. Thus, the independent variables fitted in the model below is hypothesized to affect the farming household FSS.

$$Y_i = \alpha + \beta CA_i + \lambda SC_i + \gamma HC_i + \in X_i + \mu_i \text{...} (8)$$

Y_i = FSS of *i*[th] households (proxied by food security index).

α = Intercept,

CA_i = Farmers endowment of CA technologies adoption (index)

SC_i = Farmers endowment of social capital/other institutional factors

HC_i = Farmers endowment of human capital (proxied by years of formal education)

X_i = Vector of farmer's characteristics, and
μ_i = error term (unobserved disturbances and potential measurement errors).
Explicitly,

Farming household Characteristics:
H_1 = Age of farming respondent (years)
H_2 = Age squared captures life cycle of respondent (years)
H_3 = Gender of respondent (dummy: 1 for male, 0 if otherwise)
H_4 = Household size (actual number of people in the household)
H_5 = Primary occupation (dummy: 1 if farming, 0 if otherwise).
H_6 = Years spent in school (years).

Farm-based Characteristics:
F_1 = Farm size under cultivation (ha)

Social capital/Institutional factors:
I_1 = Membership of social group (dummy: 1 for member, 0 if otherwise)
I_2 = Frequency of extension visit (actual: continuous)
β, λ, γ and $\in$ are parameters to be estimated.

4. Results and Discussion

This section presents the summarized statistics of the respondents' socio-economic characteristics. The conservation practices adopted by the respondents were examined, coupled with the distribution of households by their FSS, factors driving adoption and extent of CA technologies adoption. The endogeneity effect of CA adoption on households' FSS was investigated and reliability of the instruments used was also tested.

Socio-economic characteristics of the sampled respondents*:* The summarized statistics of some socio-economic attributes of the household heads are reported in Table 1.

Table 1: Summary Statistics of selected Respondents' socio-economic variables

Socio-economic variables	Mean	Standard Dev.	Min	Max
Age (years)	53.96	12.31	24	76
Years spent in School (actual)	6.85	4.07	0	18
Household size (actual)	6.80	2.71	1	15
Farm size under cultivation	1.90	1.07	1	6
Food expenditure (₦)	18235.43	7371.58	4700	49000
Per capita food expenditure (₦)	3257.56	2379.24	662.5	18300
Number of CA technology adopted	1.48	1.39	0	4

Source: Data Analysis, 2016

The mean age of respondents in the study area is 53.96 years. The minimum and maximum ages of the enumerated respondents are 24 and 76 years, respectively. The maximum years spent in school was 18 years. Also, the maximum household size is 15 persons with an estimated mean of 70 individuals in every 10 homes. Besides, the estimated monthly mean food expenditure and per capita mean food expenditure were ₦18,235.43K and ₦3,257.56K, respectively. This suggests that the monthly food expenditure is relatively high in the study area despite being a rural setting. Furthermore, this outcome suggests that food production in the area is at subsistence level. Equally, an average household in the study area adopted at least one CA practice/technology.

Distribution of Households by FSS: Available information (FAO, WFP, IFAD, 2012; Cook & Frank, 2008) agrees that human and economic development have a close and important link with food security. Food security is among the Sustainable Development Goals (SDGs) that attracts global attention (United Nations

Department of Economic and Social Affairs (UNDESA), 2015). Given the importance of food security, household's FSS of respondents in the study area is presented in Table 2.

Table 2: FSS Distribution of Households

FSS	Frequency	Percentage
Food Insecure	74	33.48
Food Secure	147	66.52
Total	**221**	**100.0**

Source: Data Analysis, 2016

The distribution revealed that 66.52% of the sampled households are food secured while 33.48% are food insecure; this suggests that more than half of the respondents are food secured. This result indicated that more households in the study area are food secured.

Factors Driving Adoption and Extent of CA Technologies Adoption*:* The processes through which farmers develop attitude, make decisions and use or not use innovative technology (Talukder, 2012) are sequential, and they determine the rate and extent of adoption. The D-H model was estimated to understand the position of respondents concerning adoption of conservative agriculture. The independent D-H model assumes a normal distribution and uncorrelated error terms from the first and second hurdles. . This implies that respondents make the two-stage decision to adoption CA and extent of CA adoption independently. Testing the independence of the two decisions, the relationship between the error term in the first hurdle (Tier1) and second hurdle (Tier2) in the models was investigated. The result revealed uncorrelated error terms. This suggests that factors influencing smallholder farmer's decision to adopt CA in the first hurdle (selection equation) were unassociated with the decision variables in the second hurdle (outcome equation) involving extent of CA adoption. This affirms the relevance of estimating D-H model relative to Probit and/or Tobit models. Table 3 presents the maximum likelihood estimates (MLE) of the independent D-H model.

Table 3: Maximum Likelihood Estimates (MLE) of the Independent Double-Hurdle Model.

	Coefficient	Std. error	Z	p>/z/
Tier1 (CA Adoption Decision)				
Constant	15.228	228.7654	0.07	0.947
Age	-0.2464	0.1008	-2.44**	0.015
Age-squared	0.0018	0.0009	2.03**	0.042
Gender	-1.8175	0.3956	-4.59***	0.000
Marital status	0.8691	0.7717	1.13	0.260
Years spent in school	-0.0580	0.0256	-2.26**	0.024
Household size	0.0575	0.0434	1.32	0.185
Access to credit	0.4484	0.2425	1.85*	0.064
Primary occupation	-6.5685	228.7475	-0.03	0.977
Mode of land acquisition	-0.2784	0.2609	-1.07	0.286
Farm size under cultivation	0.1746	0.1008	1.73*	0.083
Social organization membership	-0.1378	0.3079	-0.45	0.654
Access to extension services	-0.4965	0.2967	-1.67*	0.094
Tier2 (Extent of CA Adoption)				
Constant	1.2693	0.2411	5.26	0.000
Age	-0.0231	0.0095	-2.42**	0.015
Age-squared	0.0001977	0.0000968	2.04**	0.041
Marital status	-0.0861	0.0536	-1.60	0.108
Years spent in school	0.0150	0.0060	2.46**	0.014
Household size	-0.0017	0.0062	-0.28	0.782
Access to credit	-0.0736	0.0321	-2.29**	0.022
Primary occupation	0.0395	0.0391	1.01	0.312
Mode of land acquisition	-0.0302	0.0360	-0.84	0.401
Access to extension services	0.0188	0.0202	0.93	0.352

Sigma Constant	0.1748609	0.0110305	15.85	0.000

Wald chi2 (12) = 43.43, Log likelihood = -41.750046, Prob> chi^2 = 0.0000
***, **and * - significance level at 1%, 5% and 10% probability respectively.
Source: Data Analysis, 2016

The log-likelihood ratio (LR) and Pr > chi^2 corroborate the reliability of the model. This means that factors influencing the two-stage decision relating to adoption and extent of adoption of CA practices could be expressed in the independent D-H model. Coefficients in the first hurdle indicate how a given decision variable affects the likelihood to adopt CA practices while those in the second hurdle indicate how decision variables influence the extent of CA adoption. The result of the first hurdle (Probit model) indicates that age (P<0.05), quadratic age (P<0.05), gender (P<0.01), years spent in school (P<0.05), access to credit (P<0.1), farm size under cultivation (P<0.1) and access to extension services (P<0.1) are statistically significant decision variables that influenced the likelihood of CA adoption among the respondents. In line with this, the likelihood of CA adoption decreases by 24.64% for every increase in age; the result is in line with *a-priori* expectations, because increase in age is expected to discourage adoption of CA in the sense that older farmers tend to be rigid in adopting new practices; hence, prefer their traditional farming practices. Also, the likelihood of CA adoption decreases by 181.75% for being a female gender because female headed households tend to focus on children and household chores. And, as expected, increase in years spent in school decreases the likelihood of CA adoption by 5.8% because educated individuals prefer white collar jobs in cities relative to farming, let alone adopting innovative technology. In the same vein, more access to extension services decreases the likelihood of CA adoption by 49.65%. This result negates *a-priori* expectations and the reason could be linked to inadequate extension services in the study area. *Ceteris paribus*, extension services are expected to teach modern farming techniques to smallholder farmers to improve their crop productivity and FSS.

On the other hand, an increase in quadratic age, access to credit and farm size under cultivation increase the likelihood of CA adoption by 0.18%, 44.84% and 17.46%, respectively. This means that, increase in quadratic age increases CA adoption; this contravenes the earlier findings. Quadratic age, being a measure of life cycle hypothesis, stipulates a declined productivity, since ageing affects capability to work on the farm. Similarly, access to credit facilities and farm size under cultivation, potentially boost adoption of CA practices. Access to more credit facilities can translate to adoption of innovative practices and improved farming operations on larger land; hence, result to increased productivity and improved FSS. This finding refutes *a-priori* expectations. In the same vein, the truncated model in the second hurdle revealed that age (P<0.05), quadratic age (P<0.05), years spent in school (P<0.05), and access to credit (P<0.05) are statistically significant decision variables that influence respondent's extent of CA adoption. The result of the second hurdle revealed that: age and years spent in school are positive determinants of extent of CA adoption (that is, intensity of CA technologies adoption) in the study area. This finding suggests that an increase in quadratic age increases the chances of adopting CA by 0.01%; this contradicts *a-priori* expectations. Quadratic age, being a measure of life cycle hypothesis affects farm proficiency; thus, ageing ordinarily reduces farm productivity and adoption of new technologies. Also, as expected, additional years spent in school increases the probability of CA adoption by 1.5%; this negates *a-priori* expectations. Educated individuals search for white collar jobs in the cities, therefore, unwilling to take farming as a profession. Similarly, the coefficients of age and access to credit have negative relationship with the extent of CA adoption. This suggests an inverse relationship with extent of CA adoption. It implies that, a unit increase in age reduces extent of CA adoption by 2.31%; this is expected because ageing affects the farmer's capability to work; hence, discouraging adoption of CA. Equally, access to credit reduced the probability of extent of CA adoption by 7.36%. This negates *a-priori* expectation, and could be traced to non-utilization of credit facilities for which it was allocated. Summarily, the truncated model (Tier2) revealed that specific socio-economic variables are important and significant factors driving the adoption of CA and the extent of CA adoption among respondents.

Endogeneity Effect of CA Adoption on Households' Food Security Status (2-SLS Estimation): According to Ashley & Parmeter (2015), an estimated model will be spurious if the dependent variable correlates with the error term (ε). Therefore, eliminating endogeneity in models estimating food security will help formulated development policy that tackles food security issues head-on. The endogeneity estimation as shown in Tables

10a and 10b reveals factors influencing CA adoption decision in the first-stage regressions and Instrumental variables (2SLS) regression estimates in the second-stage respectively.

Table 4a: Factors Influencing CA Adoption Decision

CA adoption decision	Coefficient	Std. error	t	P>|t|
First-stage regressions				
Constant	2.017695	0.1862875	10.83	0.000
Age	-0.0113341	0.0022864	-4.96***	0.000
Gender	-0.3387644	0.0706346	-4.80***	0.000
Years spent in school	-0.0141459	0.0067107	-2.11**	0.036
Household size	0.0170044	0.0100218	1.70*	0.091
Primary occupation	-0.4797596	0.0697852	-6.87***	0.000
Farm size under cultivation	0.0340149	0.0249853	1.36	0.175
Social organization membership	-0.1222154	0.075947	-1.61	0.109
Frequency of extension visit	-0.0557906	0.0310822	-1.79*	0.074
Mode of land acquisition	-0.0801178	0.0628212	-1.28	0.204

F-statistics = 15.71, Prob> F= 0.0000, R-squared = 0.4013

***, **and * - significance level at P<0.01, P<0.05 and P<0.1 probability level respectively.

Source: Data Analysis, 2016

The first-stage regression estimation in Table 4a showed that age (P<0.01), gender (P<0.01), years spent in school (P<0.05), primary occupation (P<0.01) and frequency of extension visit (P<0.1) are statistically significant decision variables which influence and have an inverse relationship with the adoption of CA technologies among smallholder farmers in the study area. Conversely, as expected, household size (P<0.1) is statistically significant and has a positive influence on the adoption of CA technologies as household members are expected to provide family labor needed on the farm. This has influence on CA adoption and potentially cut down the overall running expenses. In the same vein, the instrumental variables (2SLS) regression estimates are shown in Table 4b.

Table 4b: Factors Driving FSS

FSS	Coefficient	Std. error	t	P>|t|
Instrumental variables (2SLS) regression				
Constant	6.4843	1.8520	3.50	0.001
CA adoption decision	-1.7073	0.9757	-1.75*	0.082
Age	-0.0207	0.0138	-1.50	0.135
Gender	-0.6992	0.3903	-1.79*	0.075
Years spent in school	-0.0096	0.0251	-0.38	0.702
Household size	-0.2157	0.0322	-6.69***	0.000
Primary occupation	-0.9841	0.4630	-2.13**	0.035
Farm size under cultivation	0.0190	0.0789	0.24	0.809

Instrumented: CA adoption decision

Instruments: age, gender, years spent in school, household size, primary occupation, farm size under cultivation, social organization membership, frequency of extension visit, mode of land acquisition

F-statistics = 12.61, Prob> F= 0.0000, R-squared = 0.0277

***, **and * - significance level at P<0.01, P<0.05 and P<0.1 probability respectively.

Source: Data Analysis, 2016

It is evident from Table 4b that CA adoption decision (P<0.1), gender (P<0.1), household size (P<0.01) and primary occupation (P<0.05) are statistically significant decision variables which drive FSS. These variables have inverse relationship with FSS among the respondents. The implication of this result is that, increase in adoption of CA technologies potentially reduces FSS. This result negates *a-priori* expectation, but, the reason for this is attributable to the earlier finding which shows low level of CA adoption (see Table 1) where the average number of CA technologies adopted was 1.48; this obviously will affect the productivity and FSS; and by extension, total income and household welfare. Also, as expected, effect of female headed households on

FSS is hypothesized to be negative because, female headed households focus more on the children and other household chores and may not be fully involved in farming activities let alone, adopting new technologies to boost food security. Then, increase in household size was found to reduce FSS; there is a mixed feeling on those findings as it partially agrees and at the same time negates *a-priori* expectations. In the first instance, youth have no interest in farming; rather, they prefer to take up salaried jobs in major cities. This affects the productivity and by extension FSS. Secondly, an increase in household size is anticipated to boost productivity and FSS as family members are expected to provide the farm labor required. In this case, it is not so and the reason for this illuminates the reason earlier stated. In the same vein, an increase in primary occupation (farming, in this case) reduces FSS. This is against the *a-priori* expectations and this might be linked to households' low level of CA adoption. Furthermore, this may be the reason for cultivating small inherited farmland (being the prevalent mode of land acquisition) where production is low in accordance with farm size and by extension discourages achieving better FSS.

Since CA adoption decision is statistically significant and inversely related with FSS as shown in Table 4b, there is exogeneity of CA adoption decision with FSS. It means that the assumed instrumental variables-frequency of extension visit and social organization membership are not endogenous to the dependent variable (FSS). Put differently, the frequency of extension visit and social organization membership do not determine FSS and vice versa. The Wu-Hausman F test and Durbin-Wu-Hausman chi-square test estimated to affirm endogeneity effect (reverse causality) of CA adoption on smallholders' FSS revealed a significant effect with P-values of 0.02559 and 0.02329, respectively. This is an indication no reverse causality which suggests exogeneity of CA adoption with smallholders' FSS. Similarly, following endogeneity test, each instruments used against the instrumented in the instrumental variable estimation (IV estimation) was tested for their reliability.

Test of Endogeneity of: CA-adoption

Ho: Regressor is exogenous
Wu-Hausman F test: 5.05456 F (1,212) P-value = 0.02559
Durbin-Wu-Hausman chi-sq test: 5.14644 Chi-sq (1) P-value = 0.02329

Testing the Reliability of the Instruments used in 2SLS

. test (landacq=0) (freqextvst=0)
(1) landacq = 0
(2) freqextvst = 0
F(2, 211) = 2.63
Prob> F = 0.0742

. test (freqextvst=0) (socorgmem= 0)
(1) freqextvst = 0
(2) socorgmem = 0
F(2, 211) = 3.07
Prob> F = 0.0483

. test (pryocc=0) (frmszculv= 0)
(1) pryocc = 0
(2) frmszculv = 0
F(2, 211) = 25.58
Prob> F = 0.0000

. test (hhldsz = 0) (yrssptschl = 0)
(1) hhldsz = 0
(2) yrssptschl = 0
F(2, 211) = 3.90
Prob> F = 0.0217

. test (age = 0) (gender = 0)

(1) age = 0
(2) gender = 0
F(2, 211) = 24.63
Prob> F = 0.0000

The reliability test results show that the instruments specified in the model are good; hence, the estimation eliminated possible bias.

5. Summary, Conclusion and Recommendations

The test of reverse causality between CA adoption decision and households' FSS using instrumental variable estimation technique indicated that the direct effect of CA adoption decision on households' FSS outweighs the reverse effect in the explanation of the correlation between the two variables. This is evident by examining the significance level of the instrumented-CA adoption decision. Notwithstanding, this analysis sets a decisive context for the path of causality between CA adoption decision and FSS as stated in Table 4b. The low R-squared in the estimated OLS and 2SLS models is attributable to the nature (binary) of the regress and in the analysis. More so, the reverse causality (endogeneity) could have been accepted if the instrumented variable (CA adoption decision) is not statistically significant. Since the IV-variable is significant, by implication, the study concludes that, there is absence of reverse causality (bi-causal relationship) which further confirms the exogeneity of CA adoption with smallholders' FSS. Hence, the crux of the findings in this study is the need to adopt CA practices in Nigeria as a viable option to increase food production and achieve sustainable food security status which is in line with the sustainable development goals.

Consequent on the findings of this study, the following are recommended:

- There is need for Youths reorientation/encouragement to take up farming as an income generating activity regardless of their educational achievement. Though, education significantly affected the use of CA, it had a negative influence on the adoption rate of CA. It is essential to promote human capital development in the study area by increasing funding to schools to lessen the financial burden on parents in educating posterity. This calls for evolution of adult education policy complimented with Universal Basic Education to ensure qualitative education that can effect positive changes among respondents. By so doing, farmers will appreciate the value of education which invariably helps them to internalize and adopt new agricultural technologies such as CA.
- Invention should not be gender biased so that females can take active role in farming and adopt CA technologies to achieve better FSS. Their roles should not be limited to household chores alone.
- Access to credit had a positive and significant association with CA technology adoption. Thus, credit facilities should be made available to active/registered farmers to expand their scale of operations and adopt CA technologies.
- Extension services are vital to transferring agricultural innovations to farmers. Efforts concerning visits by extension agents should be doubled in the study area to enlighten smallholder farmers on the need to adopt CA practices coupled with adequate trainings on the technical know-how.
- High dependency ratio in terms of large household size has significantly shown over time to negatively affect FSS than those with fewer members, especially in the rural settings where meagre income is prevalent. As the outcome of the study confirms that majority of the respondents perceive large family size as a way to access family labour, labor-saving devices should be promoted along with birth control strategies.
- Farming on a medium/large scale as a means of livelihood should be promoted because primary occupation was significant but affected FSS negatively. This is traceable to the subsistence scale of production resulting from the small land holding farmers cultivate.
- There is need to substantiate investment in Nigeria Agricultural sector. As a short-term intervention plan to facilitate CA adoption, provision of incentives that will motivate households to engage in farming is required. This could be achieved through effective and sincere institutional framework devoid of political interference.

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