Women's Empowerment and Technical Efficiency: What Role for Technology Adoption in Nigeria?

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Introduction

The significant contributions of rural women to agriculture in Nigeria cannot be overlooked. They participate tirelessly in all aspect of the value chain. Despite the significant contributions of women in agriculture production system in Nigeria, they remain marginalized in participating in decision making especially on issues that affect their productivity and profitability. In addition, they encounter different social and economic problems which limit their participation in equitable agricultural system (Mgbakor and Nwamba, 2013).

Several factors have been documented to be very important to improving women's farmers' productivity. Closing the gender gap in agriculture has been recognized as a critical strategy for boosting agricultural productivity, achieving food security and empowerment (Food and Agricultural Organisation [FAO], 2011). This is particularly important for women in rural areas especially in developing countries, where about 79 percent of them have agriculture as their primary form of occupation (Doss, 2010). The extent to which women have control over resources therefore affect their livelihood status (Ellis, 1999), and is manifested in their living conditions in areas such as productivity, nutrition, housing, sanitation, food access, among others. Women's productivity can be enhanced when they have secure ownership of, or access to, resources and income earning activities, including reserves and assets, to offset risks, ease shocks and meet contingencies (Chambers, 1989). A very important strategy in closing the gender gap in agriculture is women's empowerment. This is very important for improving agriculture productivity. For instance, a woman who is empowered to make decisions regarding what to plant and what inputs to apply on her plot will be more productive in agriculture. An empowered woman will also be better able to ensure her children's health and nutrition, in no small part because she is able to take care of her own physical and mental well-being (Smith *et al,* 2003). The empowerment approach is thus a strategic solution to closing the gender gap in agriculture, especially in a country like Nigeria where agriculture is the mainstay of majority of households in rural areas. In addition, access to and ownership of useful technologies play positive roles in influencing agriculture outputs. Several researchers have established the importance of technology use and adoption in improving the empowerment and livelihood outcomes of rural farmers. For example, the studies of Asfaw e*t al* (2012); Gitonga *et al* (2013); Mendola (2007) and Tefera *et al* (2011) examined the impact of technology adoption on empowerment and livelihood outcomes of smallholders in developing countries. These studies found positive correlation between technology adoption and women's empowerment.

There has been an increasing deployment of new technologies, especially Information and Communication technologies (ICTs) by different actors in the agriculture value chain in recent times. The booming mobile, wireless, and internet technologies have opened new frontiers for smallholders by increasing market opportunities, lowering transaction costs, minimizing risks, enhancing information sharing, and real time collaboration (Greijv et al, 2013; Miller and Jones, 2010). These technologies and their innovative applications have supported and spurred the development of new service delivery approaches. A key example in Nigeria is the electronic wallet (e-wallet) system which is an electronic distribution channel providing an efficient and transparent system for the purchase and distribution of agricultural inputs based on a voucher system. However, men and women especially in developing countries do not enjoy equal control over assets that they can use to improve livelihoods, well-being, and bargaining power within their households and communities. This affects their empowerment, ultimately limiting their efficiency and productivity. Several researchers for instance have established the importance of technical efficiency in agriculture productivity (Wu, (1995); Seyoum, Battese, & Fleming (1998); Binam, et al, (2004). A technically efficient production unit is defined as the one that gives the maximum level of output using the available inputs and technology. A firm that produces at the technological frontier is said to be technically efficient. However, if the output of a firm falls short of what it is expected to produce with a given input that means the firm is operating below the frontier and such is categorized as technically inefficient. Several studies have been conducted to compare the technical efficiency of men and women (Doss, 2015; Seymour, 2017;). These studies have come up with diverse results. For instance, some of the studies found that women are as productive as men others found that women are less productive than men. Considering the importance of women's empowerment in closing the gender gap in agriculture and its importance to achieving other development outcomes, it is important to examine the influence of women's empowerment on technical efficiency and also to assess the joint effects of technology adoption and women empowerment on technical efficiency.

However, there is a general weakness associated with most of the current indices and methodology used in measuring empowerment. They are aggregated and indirect measure of individual empowerment outcomes. These challenges constitute great limitations to assessing the empowerment and establishing the linkages between women empowerment in agriculture and other outcomes such as technical efficiency of smallholders, especially women. In order to address this, this study uses the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) developed by the International Food Policy Research Institute (IFPRI) and Oxford Poverty and Human Development Institute (OPHI), Oxford University (Alkire *et al.*, 2013). The index measures the empowerment, agency and inclusion of women in the agricultural sector. Specifically, the paper seeks answers to the following questions:

1. What is the influence of women's empowerment (aggregate) on technical efficiency of women farmers?

2. How women's empowerment in each indicator does influence technical efficiency?

3. How does the joint effect of empowerment and technology adoption on technical efficiency of women farmers?

The paper assesses the influence of the aggregate women's empowerment derived from the A-WEAI on technical efficiency of rural women farmers. It examines how the empowerment in the different indicators influences women's empowerment and how the joint interaction of women's empowerment and technology influence the technical efficiency of rural women farmers. This study is very important because it addressed the issues about women in Northern Nigeria. The project specifically targets the Northern part of Nigeria because though the region has huge arable land mass and conducive soil and conditions which support different forms of agricultural production ranging from crop farming, animal production and fishery, the region still lag behind in terms of growth and development in different areas of education, health, sanitation and food security. Notably, the prevailing security crisis prominent in many states of the region especially with the terrorism insurgence of the international terrorist group Boko Haram, has exacerbated the living condition of many people in the region. This coupled with poor governance, gender-inequalities and bias culture that promote discrimination and injustice against women and girls, is limiting the ability of people in the region to fully participate and benefit from different development efforts. This study is expected to provide information that can be used in designing and developing targeted policies and intervention for improving agricultural productivity and profitability.

The study proceeds as follows: the next section provides a review on the Women's Empowerment in Agriculture Index (WEAI) and its Abbreviated version (A-WEAI). This was followed by a review on 'Technical Efficiency'. The next section provides on health seeking behavior, perceived health status, time poverty and the intersection of gender on these. The next section provides the methodology which comprises of conceptual model and estimation methods, the study area and sampling methods. This was followed by the section on results and discussion. The paper rounded off with conclusions and recommendations for practice and policy.

The Women's Empowerment in Agriculture Index (WEAI)

The Women's Empowerment in Agriculture Index (WEAI) measures the empowerment, agency and inclusion of women in the agricultural sector. The WEAI can be adapted to measure empowerment of women in rural areas at large either as farmers, agricultural or non-agricultural wage workers. It can be used to assess the state of empowerment and gender parity in agriculture, detect key areas in which empowerment can be enhanced and monitor progress over time (Alkire *et al,* 2013). The Index was commissioned in 2012 by the US government as a tool to monitor women's empowerment from the Feed the Future Initiative. However, the WEAI has also been used extensively since 2012 by a variety of organizations to assess the state of empowerment and gender parity in agriculture, track changes in women's empowerment due to direct or indirect result of development initiatives and also identify key areas in which empowerment needs to be strengthened. (Malapit *et al,* 2015). Using the data collected through individual or household surveys, the WEAI uses indicators based on research work on empowerment, agency, among others. It holds advantage over other aggregated indices because the data used in developing the index is based on the household-level data collected by interviewing men and women within the same households.

The WEAI is an aggregate index that shows the degree to which women are empowered in their households and communities and the inequality between spouses in the household (Alkire *et al,* 2012). It comprises two sub-indices. The first assesses empowerment of women in five domains, including:

1) decisions about agricultural production;

2) access to and decision-making power about productive resources;

3) control of use of income;

4) leadership in the community; and

5) time allocation.

The second sub-index, the Gender Parity Index (GPI) measures the percentage of women whose achievements are at least as high as men in their households and, for women lacking parity, the relative empowerment gap with respect to the male in their household.

As the name is, the A-WEAI is the abridged version of the WEAI. While the original WEAI has ten indicators in five domains of empowerment. A-WEAI evolve based on feedback from stakeholders such as USAID implementing partners, field teams, researchers, and representatives from organizations that had used the WEAI. It was reported that the WEAI is very resource-intensive especially in regard of time to administer and field costs. Also, few key modules in the WEAI were identified to be problematic specifically the sections on time use, autonomy in production, and speaking up in public. These were observed to be time consuming, sensitive in nature and difficult to understand (Malapit *et al*, 2015). The A-WEAI reduces the indicators from ten to six while retaining the five domains (Table 2). This according to Malapit (2014) takes about 30 percent less time to administer than the original WEAI. It also includes the new autonomy vignettes, a simplified 24-hour recall time module that collects only primary activities, and streamlined sections on production decisions and resources.

Table 1: Comparison of WEAI and A-WEAI

	WEAI	**Weights**	**A-WEAI**	**Weights**
Domains	**Indicators**		**Indicators**	
Production	• Input in productive decisions • Autonomy in production	• 1/10 • 1/10	• Input in productive decisions	• 1/5
Resources	• Ownership of assets • Purchase, sale, or transfer of assets • Access to and decisions on Credit	• 1/15 • 1/15 • • 1/15	• Ownership of assets • Access to and decisions on Credit	• 2/15 • 1/15

Income	• Control over use of income	• 1/5	• Control over use of income	• 1/5
Leadership	• Group membership • Speaking in public	• 1/10 • 1/10	• Group membership	• 1/5
Time	• Workload • Leisure	• 1/10 • 1/10	• Workload	• 1/5

Source: Alkire *et al* (2012) and Malapit *et al* (2015)

Technical Efficiency

A technically efficient production unit is defined as the one that gives the maximum level of output using the available inputs and technology. This study applies the stochastic production function model to measure technical efficiency of rural women smallholder farmers in North Central and North West Nigeria. Battesse and Corra, Meeusen and Van den Broeck and Aigner et al. have applied the stochastic frontier model to farm level analysis data as early as 1977. Since then, several researchers have applied the stochastic frontier model in their estimation model. For instance, Kalirajan (1981) in his study among rice farmers estimated a stochastic frontier Cobb-Douglas production function using cross-sectional data. For Nigeria, several studies have applied the stochastic frontier model in estimation of farm level analysis. Such include the studies of Ajibefun and Abdul Kadri (1999), Ojo and Ajibefun (2000) and Ojo (2003). Technical efficiency is just one of the two measures of economic efficiency. The other measure, allocative efficiency assesses the probability of the firm to produce profit-maximising output through the use of the right mix of given inputs with specific prices. On the other hand, firms will face different prices of inputs, and, therefore, different combination of inputs, depending on the environment in which they operate. This study therefore assumes that all farms are allocatively efficient and various input they combined are justified since different farms face different input prices since they operate in diverse markets.

The stochastic frontier production function model represented as:

$Y1 = f(Xa, ß) + Vi - Ui$ (1)

Where Yi = quantity of agricultural output in a specified unit

Xa = the vector of input quantities

B = the vector of production function parameters

f (Xa, b) (the frontier production function) is a measure of maximum potential output for any specific input vector Xa.

Vi and Ui cause actual production to deviate from this frontier.

Vi = the systematic component, this captures the random variation in output, which

results from factors that are not within the control of the farmers (e.g. natural disaster, rainfall).

The Vi assumed to be independently, identically distributed with zero mean and

constant variance {i.e. N (O, ó v^2)}, it is independent of Ui .

The Ui, a non-negative term represents the deviations from the frontier production function, this is ascribed to controllable factors – technical inefficiency. This is attributed to be half normal, identically and independently distributed with zero mean and constant variance {/N(O, $ó^2$).

The stochastic frontier production function model is estimated by using the maximum likelihood estimation procedure (MLE), and for an individual farm, the technical efficiency is defined based on the observed output (Yi) and the corresponding frontier output (Yi) taking into consideration the available technology.

Therefore,

TE = Yi

Yi*

= exp (Xib + Vi - Ui)

exp (Xib+ Vi)

= exp (-Ui) (2)

Thus, O ≤TE ≤1 (Seyoum et al., 1998)

Researchers, Aigner et al. (1977) and Meeusen and van den Broeck (1977) proposed a single-equation cross-sectional stochastic production frontier model which assumes that farmer uses the input vector X_i to produce a single output Y_i based on the following equation:

$Y_i = f(X_i, \beta) \exp(V_i - U_i)$ i = 1,2,………,N (1)

The error term in the model consists of two components, the traditional symmetric random noise component (V_i) and a new one-sided inefficiency component (U_i). The V_i's takes into consideration measurement error and other random factors that are not within the control of farms such as weather, political instability, price variations etc. in addition, the V_i's are independently and identically distributed with mean zero and constant variance, σ_v^2. The U_i that depicts technical inefficiency combines the outcome of non-price and farm factors which prevents a farm from achieving their maximum possible output from the given set of inputs and technology. Also, U_is are non-negative and they are presumably independent and identical distribution. As a result, when the farm is fully technically efficient (TE=1), U takes the value of 0 and when the farm faces constraints (0<TE<1) U takes a value less than 0. The magnitude of U indicates the 'efficiency gap''. The 'efficiency gap' describes the extent to which farm's given output emanate from its potential output. The V_i's together with U_i's are assumed to be independent of the regressors. With this, a farm faces its stochastic frontier (f ($X_{i,}$ β) exp (V_i); a deterministic part (f ($X_{i,}$ β)) common to all farms and a farm-specific part (exp(V_i).

Therefore, farm-specific Technical Efficiency (TE_i) is measured as the ratio of the observed output of the farm to the potential output derived by the frontier function and is outlined as:

$$TE_i = \frac{f(Xi,\beta)\exp(Vi - Ui)}{f(Xi,\beta)\exp(Vi)} = \exp(-Ui) \qquad (2)$$

TE_i measures how close the farm gets to its maximum achievable output, immediately external shocks (i.e., noise) are removed. Y_i achieves its maximum value of $f(Xi,\beta)\exp(Vi)$ and TE_i=1 if U_i = 0). In another way, $U_i \neq 0$ describes the shortfall of observed output from the maximum potential output. Therefore, to calculate TE_i, there is the need to estimate equation (1), after which the residuals is will then be decomposed into estimates of and then decompose the residuals into estimates of noise (Vi) and technical inefficiency ($-U_i$).

The estimation of equation (1) requires assumptions about the functional form of the production function and the distribution function for Vi and Ui. The random fluctuations are assumed to be drawn from a symmetric distribution while the inefficiencies are assumed to be drawn from an asymmetric distribution due to the fact that they can only decrease the production below frontier levels. For Vi's, we used the standard hypothesis based on existing literature and assume V~N(0; σ_v^2.). However, selecting an appropriate distributional form for the $U_{i'}$s is challenging since the researchers need to assume a high level of knowledge about the unknown phenomenon been investigated. The most commonly used one-sided distributions are the half-normal, truncated normal and exponential distributions. This is usually based on the assumption that U_i is independently and identically distributed and truncated at zero of the normal distribution with mean μ and variance σ_u^2 (i.e., |U ~ (μ, σ_u^2|)

Conceptual Model and Estimation Methods

Model Specification

In order to examine the influence of women empowerment and its joint effects with technology adoption on technical efficiency, the study used the stochastic frontier production model proposed by Battese and Coelli (1995). Two common forms of production forms are often used in the literature to estimate technical efficiency using stochastic frontier production function. These are the Cobb-Douglas and general translog functional forms. The Cobb-Douglas specification is nested in the translog model, therefore, this study used the translog functional specification. The log linear translog production frontier with three inputs land (X_1), labour (X_2) and fertilizer (X_3) for farm is given by:

$$\text{Ln Qi} = \beta o + \beta_1 \text{Ln}X_1 + \beta_2 \text{Ln}X_2 + \beta_3 \text{Ln}X_3 + 0.5\beta_4 LnX_1^2 + 0.5\beta_5 LnX_2^2 \beta + 0.5\beta_6 LnX_3^2 + \beta_7 \text{Ln}X_1 \text{Ln } X_2 + \beta_8 \text{Ln}X_1 \text{Ln } X_3 + \beta_9 \text{Ln}X_2 \text{Ln } X_3 + \text{Vi} - \text{Ui} \quad (3)$$

Where Ln Q is the log of total income, LnX_1 is the log of land, LnX_2 is the log of labour (value); LnX_3 is the log of fertilizer (value) and βs are the parameters to be estimated.

To assess the influence of women's empowerment on the technical efficiency, we used the A-WEAI to measure individual women's empowerment derived from each women's score in the 5DE.

The study uses the women empowerment score derived by calculating the woman's achievement of empowerment in the 6 weighted indicators measured in the A-WEAI (Table 2). Each indicator is assigned a value of one if a woman achieves adequacy according to cutoffs defined by Alkire et al. (2013) or zero otherwise. In addition, the study assessed the empowerment in each of the six indicators. Each of the 6 indicators of the A-WEAI is assigned a value of 1 if the individual's achievement is adequate, i.e., it exceeds the defined inadequacy cut-off for the specific indicator (Malapit et al., 2015), and a value of 0, if otherwise.

The six indicators of the five domains of empowerment (5DE) which are decisions about agricultural production; access to and control over productive resources; control over the use of income; leadership in the community and time allocation. The conditions for empowerment in each of the indicators are spelt out in Table 2 while the description of the empowerment variables is presented in Table 3. A person is said to be empowered if she reached a certain threshold (has "adequate" achievement) in that area. These are computed as six different dummy variables with an individual woman allotted the value '1' if the person is adequate in the particular indicator, or 0, if otherwise. Taking a step further, the study interacts technology adoption in terms of mobile phone with women's empowerment and examines its influence on technical efficiency.

Table 2: The domains, inadequacy cut-off, and weights A-WEAI Indicators

Domain	Indicator Name	Inadequacy-cut off	Weight
Production	Input in Productive Decisions	Inadequate if individual participates in agriculture activities BUT does not has at least some input in decisions; or she does not make the decisions nor feels she could.	1/5
Resources	Ownership of Assets	Inadequate if household does not own any asset or if household owns the type of asset BUT she/he does not own most of it alone	2/15

	Access to And decisions on credit	Inadequate if household has no credit OR used a source of credit BUT she/he did not participate in ANY decisions about it	1/15
Income	Control over use of income	Inadequate if participates in activity productive activities BUT has no input or little input in decisions about the use of income generated, or does not feels she/he can make decisions regarding wage, employment and major household expenditures	1/15
Leadership	Group Membership	Inadequate if he/she is not part of AT LEAST ONE group; inadequate if no groups reported in community	1/5
Time	Workload	Inadequate if works more than 10.5 hours a day	1/5

Source: Adapted from Malapit *et al.*, (2015)

Table 3: Description of empowerment variables

	Definition	Type
Empowerment (aggregate)	Aggregate empowerment in all the five domains (six indicators) with threshold of 0.8 (1 = Yes; 0 = No)	Dummy
Empowerment*ICT	Aggregate empowerment interacted with mobile phone adoption (1 = Yes; 0 = No)	Dummy
Empowered in production activities	Assesses if the respondent is empowered in input in productive decisions (1 = Yes; 0 = No)	Dummy
Empowered in asset ownership	Assesses if the respondent is empowered in ownership of assets (1 = Yes; 0 = No)	Dummy
Empowered in decision-making on income	Assesses if the respondent is empowered in Control over use of income (1 = Yes; 0 = No)	Dummy
Empowered in credit	Assesses if the respondent is empowered in access to and decisions on Credit (1 = Yes; 0 = No)	Dummy
Empowered in group	Assesses if the respondent is empowered in group membership (1 = Yes; 0 = No)	Dummy
Empowered in workload sharing	Assesses if the respondent is empowered in workload sharing (1 = Yes; 0 = No)	Dummy
Household members	Number of people in the household (number)	Continuous
Household type	The type of household (1 = dual adult only; 2 = female	Dummy

	adult only)	
Age	Age of household head (years)	Continuous
Literacy	Household head can read and write (1 = Yes; 0 = No)	Dummy
Married	Household head is married (1 = Yes; 0 = No)	Dummy
Occupation	Household head primary occupation is agriculture (1 = Yes; 0 = No)	Dummy

Estimation Methods

In order to effectively achieve our objectives, we estimate two models using the ordinary least square (OLS) approach. The reason behind the use of the OLS is because the outcome variable, technical efficiency is continuous. The independent variables are the individual total empowerment score in the 6 weighted indicators of the A-WEAI and also the individual women's empowerment in each of the 6 indicators.

Description of the study area, data and sample household characteristics

To build the evidence base for effective agricultural policy design, the study uses data from Nigeria Baseline Study (NIBAS) gathers information on the livelihoods and agricultural behaviors and outcomes of farming households in Nigeria. The study was conducted by Obafemi Awolowo University (OAU) in collaboration with the International Institute of Tropical Agriculture (IITA) and the Nigerian Institute of Social and Economic Research (NISER). The study was sponsored by the Bill and Melinda Gates Foundation. The NIBAS project covers six states Northern states extending over three agro-ecological zones (Southern Guinea Savanna, Northern Guinea Savanna and Sudan Savanna) and two political zones (North Central and North Western) in Nigeria. The six states are: Benue, Kaduna, Kano, Katsina, Nasarawa, and Niger (Figure 1).

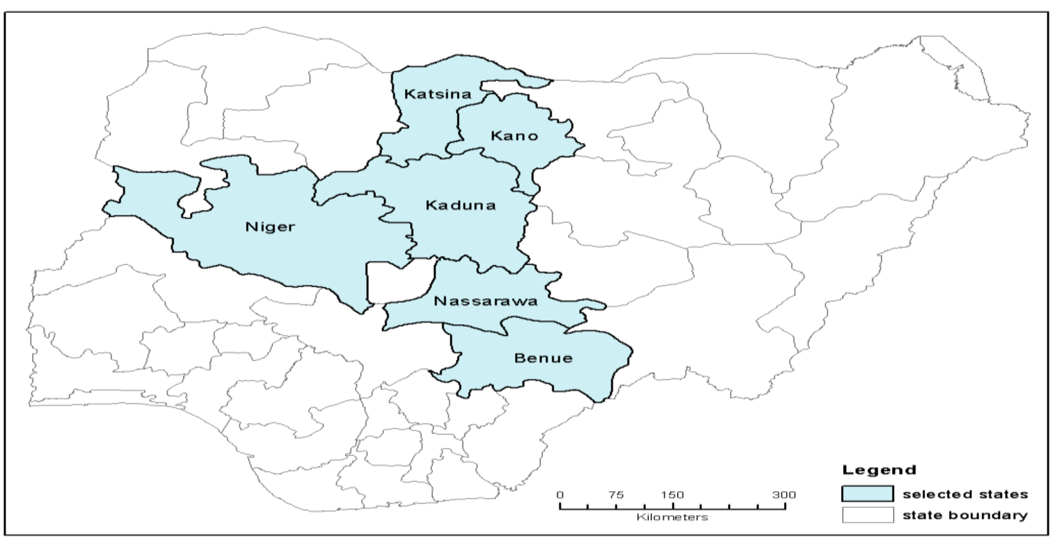

Figure 1: Map of Nigeria showing the six states included in NIBAS Project

The broad objective of NIBAS is to capture the current state of agriculture and build an understanding of farmers' livelihoods in the study sites. Specifically, it documents levels of production and rates of technology usage among farming households, giving particular attention to seven key crops. The survey also captures detailed information on gendered patterns within the farming enterprise. This information will be used as a benchmark by relevant decision-makers as they set adoption and productivity targets so that performance and progress can be monitored over time. This study additionally serves as a good opportunity to build local capacity within the implementing institutions, with an expectation that the government will design and conduct similar agricultural studies in the future. Information was collected in the household survey on the following topics: landholdings, input use, farm management, levels of production, household demographics, household income-generating activities, household food security, women's empowerment and women's dietary diversity. Throughout the agricultural modules, the survey gives special attention to seven primary crops: maize, cassava, sorghum, rice, groundnuts, cowpeas, and yams.

A multistage sampling procedure was used to select 600 households in each state. This sample size was determined with the use of power calculations and with the intent to capture variation in agricultural productivity, production of the seven primary crops, and other indicators within and across the six states. The household survey adopted the existing master sampling frame developed by the National Bureau of Statistics (NBS) in a nationwide survey conducted jointly with the World Bank Living Standards Measurement Study (LSMS) team in 2008 for the selection of Enumeration Areas (EAs) for the household listing exercise. The master sampling frame was updated by NBS in 2011/2012 and 2012/2013. The EAs were systematically selected using probability proportional to size (PPS) sampling in the first stage. The sample includes 360 EAs across all six states. Based on household listings, simple random sampling (SRS) of households within EAs was used at the second stage, and approximately 10 households were selected to be surveyed in each EA. It should be noted that we did not exclude households that were non-agricultural. We did not sample with replacement (i.e., replacing a household that was selected but was unavailable at survey time) during implementation of the survey.

Results and Discussion

Description of the women's empowerment and sample household characteristics

The summary statistics of the respondents' empowerment in the 6 indicators of the A-WEAI is presented in Table 4. The result shows that 'control over the use of income' is the area where most of the women (99.3%) have achieved empowerment. This indicates that most of the women in the study area have control over the use of income that accrued from their activities including agriculture, non-farm economic activities, and wage and salary employment. On the other hand, access to and decision about credit is the area where only few (16.9%) of the women have achieved empowerment. This result shows that access to credit and or contributing to decisions on the use of credit is a main constraint for women in the study area. The result also shows that participation is an issue among the women as just slightly above half (57.3%) indicated been empowered in the indicator. In terms of household characteristics, the result shows that majority of the household head (96.6%) are married and belong to the dual adult households (100%) and have farming as their main occupation (77.5%).

Table 4: Summary statistics of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Empowered in production activities	3209	.822	.383	0	1
Empowered in asset ownership	3209	.985	.12	0	1
Empowered in decision-making on income	3209	.993	.086	0	1
Empowered in credit	3203	.169	.375	0	1
Empowered in group	3209	.573	.495	0	1
Empowered in workload sharing	3209	.688	.463	0	1
Household type	3209	1.029	.167	1	2
Household members	2877	8.24	4.129	1	43
Age of household head	2877	46.221	13.647	20	110
Household head is married	2877	0.966	0.181	0	1
Household head is literate	2877	0.497	0.500	0	1
Household head main occupation is agriculture	2877	0.775	0.417	0	1

In terms of the outputs and inputs, the result is presented in Table 5. The result shows that the farmers are smallholder farmers since they reported working with an average farm size of 6.89 acres. Based on the international standard, a farm that is less than 10 hectares is categorized as small scale (Mgbenka, Mbah, & Ezeano, 2015). Result shows that the average total income is extremely high. This shows a higher proportion when compared with similar outcomes from studies in Nigeria. Most studies in Nigeria have observed low productivity and income flow among rural farmers especially women. For example the studies of Oseni, McGee, & Dabalen 2014; Adams and Idisi, 2014; Yusuf, Balogun and Tiamiyu (2016) all reveal that rural farmers especially women have constraints with agricultural productivity which result in low income among the women smallholder farmers.

Table 5: Descriptive statistics of output and inputs used to measure technical efficiency

Variable	Obs	Mean	Std. Dev.	Min	Max
Total income (₦)	2877	6070000	2.51e+08	-3.60e+09	1.20e+10
Hired labour (₦)	2877	8754.645	53279.01	-84000	1500000
Land size (acre)	2877	6.894	15.833	0	618
Fertilizer (₦)	2877	257000	1790000	0	4.75e+07

Influence of women's empowerment on technical efficiency with and without interaction

Several studies have established the linkage between women's empowerment and other development outcomes. The studies of Malapit et al., 2015; Malapit and Quisumbing, 2015; Sraboni et al., 2014, all established a positive relationship between women's empowerment and food security and nutritional health in rural households. The effects of women's empowerment on technical efficiency without interaction and with interaction were examined in this study. This is derived by using the OLS estimation methods. The results are presented in Table 6 and 7 respectively. The result shows that women's empowerment have positive and significant relationship with technical efficiency (with or without interaction with ICT). This confirms previous studies for example the study of Seymour (2017) that examined the implications of women's empowerment in agriculture on technical efficiency in rural Bangladesh found that women's empowerment is positively associated with technical efficiency.

Also, the result reveals that women empowerment indicators such as input in productive decision, group membership, and ownership of assets have positive influence on technical efficiency while the relationship with workload sharing is negative. The study of Sell et al. (2018) also found that time constraint experienced by women through the efforts put on household work has negative influence on their technical efficiency. Ownership of assets in terms of inputs necessary for agricultural production is very important to closing the gender gap in efficiency among men and women farmers. For instance, among men and women rice farmers in Cote d'Ivoire, Adesina and Djato (1997) observed that the technical and allocative efficiency of men and women farmers is not different with fixed input and the prices of variable inputs are correlated with profit. There is no significant relationship between access to and decisions on credit and control over use of income and technical efficiency. When interacted with ICT adoption, input in productive decision and group membership's relationship change to negative, ownership of assets remains positive while workload sharing's becomes negative. Control over use of income now has positive relationship while access to and decisions on credit remain insignificant.

This implies that women who are empowered are more efficient with resources utilization irrespective of mobile phone adoption. Also, if women contribute to decision-making on their production activities, if they own assets, participate in group activities they have higher probability of producing the maximum level of output achievable with the inputs applied. The joint interaction of mobile phone adoption and empowerment in input in productive decisions or group membership leads to less efficiency in resource utilization in agriculture. This implies that as women own mobile phones and participates in decision-making in production decisions and group activities; it may mean investment in other productive activities other than agriculture which makes them to pay less attention to agricultural activities.

The joint interaction of mobile phone adoption and empowerment in asset ownership leads to higher technical efficiency. This is probably due to the fact that control and ownership of resources and assets are very important to agricultural production. Poor access to land and other resources pertinent to agriculture can limit the extent to which women participate in profitable and productive agricultural activities. Therefore, if women who own mobile phones also have ownership and control of major assets vital for agriculture activities, they would have higher tendency of using resources for efficiently.

The joint interaction of mobile phone adoption and empowerment in workload sharing leads to higher efficiency in resource utilization. Time use issues have strong gender dimensions in Africa, Therefore, if women have access to technology, empowered in workload, i.e. work less than 10.5 hours in a day and have access to leisure time, they will be more efficient with the use of resources.

The joint interaction of mobile phone adoption and empowerment in control over use of income leads to efficiency in utilisation of resources. This implies that when women have access to mobile phones and they exhibit some control over the use of income that accrued from their productive activities, they will be able to acquire and use resources more efficiently.

Table 6: influence of empowerment on technical efficiency without interaction

	Coef.	St. Err.	Coef.	St. Err
Empowerment (aggregate)	1.574***	0.158		
Empowered in production activities			0.153***	0.032
Empowered in asset ownership			0.256**	0.123
Empowered in decision-making on income			- 0.111	0.135
Empowered in credit			- 0.045	0.033
Empowered in group			0.122***	0.026
Empowered in workload sharing			-0.049*	0.026
Household type	-0.193*	0.100	-0.134	0.103
Household members	0.036***	0.003	0.040***	0.003
Age of household head	0.001***	0.001	0.000	0.001

	Coef.	St. Err.	Coef.	St. Err
Household head is married	0.000	0.001	0.000	0.001
Household head is literate	0.000	0.000	0.000	0.000
Household head main occupation is agriculture	0.002***	0.000	0.002***	0.000
Constant	12.569***	0.209	13.493***	0.247
R-squared	0.161		0.147	
Number of obs	1932.000		1928.000	
Prob > F	0.000		0.000	

*** p<0.01, ** p<0.05, * p<0.1*

Table 7: influence of empowerment (interacted with ICT adoption) on technical efficiency

	Coef.	St. Err.	Coef.	St. Err
Empowerment (aggregate)	0.100***	0.032		
Empowered in production activities			-0.200***	0.051
Empowered in asset ownership			0.120***	0.032
Empowered in decision-making on income			- 0.492**	0.199
Empowered in credit			-0.329	0.313
Empowered in group			-0.130***	0.038
Empowered in workload sharing			0.129***	0.038
Household type	-0.145	0.102	-0.095	0.104
Household members	0.041***	0.003	0.040***	0.003
Age of household head	0.000	0.001	0.000	0.001
Household head is married	0.000	0.001	0.000	0.001
Household head is literate	0.000	0.000	0.000	0.000
Household head main occupation is agriculture	0.002***	0.000	0.002***	0.000
Constant	13.739***	0.175	13.705***	0.175
R-squared	0.122		0.145	
Number of obs	1932		1928	
Prob > F	0.000		0.000	

*** p<0.01, ** p<0.05, * p<0.1*

Conclusion and Recommendation

Closing the gender gap in agriculture has been recognized as a strategic approach for achieving development outcomes. In closing the gap, studies have argued for a multi-dimensional approach to measuring empowerment focusing on different domains and pathways. This is because empowerment is domain-specific and the causal pathways through which resources are translated into agency also vary. This study contributes to literature on the relationship between household gender inequalities and technical efficiency on the use of agricultural resources. The study uses the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) to assess women's empowerment in agriculture among rural women farmers in Northern Nigeria. The study then establishes the linkage between women's empowerment with and without technology interaction and technical efficiency.

This study has confirmed the importance of women's empowerment in agriculture in the efficient use of resources for agricultural activities. The study further establishes the importance of technology adoption in reinforcing women's empowerment to improve technical efficiency in agriculture. This is especially important in pertinent areas like ownership and control of resources and workload. These areas have been established in many literatures to have strong gender dimensions to agricultural productivity and profitability especially in the rural African setting. This study therefore suggests continuous efforts by governmental, non-governmental and donor agencies in developing transformative program and policies that would close the gender gap in empowerment in agriculture. Empowerment is context specific, therefore, more research should be conducted to search and identify areas contextually peculiar to African women. Appropriate programs and interventions aimed at closing such gaps to improve agricultural productivity should be developed.

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