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Can digital technology promote market participation among smallholder farmers?

RESEARCH ARTICLE

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Abstract

Digital technology holds significant potential for enhancing business efficiency in agricultural marketing. However, empirical research on the use of digital technology among smallholder farmers engaged in staple crop marketing in Sub-Saharan Africa remains limited. Recognizing the pivotal role of digital technology in agriculture, this study aims to analyse and synthesize existing knowledge regarding the impact of mobile phones on market participation among smallholder farmers. Through a comprehensive analysis, we seek to provide a robust understanding that can inform policies and programs aimed at enhancing smallholder market integration. To achieve this objective, we collected cross-sectional data from 360 farmers in southeast Nigeria and implemented a double hurdle model to analyse market participation decisions and the extent of farmers' involvement in staple crop markets. In addition to traditional econometric methods, we employed propensity score matching to further investigate the impact of mobile phone ownership on market participation. Our analysis revealed that ICT tools, particularly mobile phones and radios, significantly influence both the decision and intensity of market participation among smallholder farmers. Specifically, mobile phones were found to play a crucial role in facilitating access to market pricing information and disseminating knowledge on improved production methods. Given the volatility of farm prices, the timely dissemination of market information through mobile phones is essential for farmers to make informed decisions. With a high percentage of mobile phone ownership and substantial investments in mobile networks in Nigeria, the digitalization of extension services and marketing information delivery systems could catalyse rapid improvements in agribusiness and marketing. This shift towards digital platforms has the potential to address information asymmetry, particularly among smallholder farmers, thereby fostering greater market integration and economic empowerment within rural communities.

Keywords: digital technology, double-hurdle model, market participation, staple crop
JEL codes: Q13, Q16, Q18

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1. Introduction

Due to the growing population in developing economies, mobile and internet service companies have invested extensively in many countries in sub-Saharan Africa. In Nigeria for instance, approximately 67% of the population is subscribed to one or more mobile network providers (Dulli *et al.*, 2020) a figure that has increased to about 87% as of January 2021 (Mediascape, 2021). Studies in other sub-Saharan countries report similar upward trajectories in mobile phone ownership (See: Karakara and Osabuohien, 2019; Doyle *et al.*, 2021; Kreniske *et al.*, 2021). The application of digital technology for the promotion of agribusiness among farmers in this region, therefore, appears set for a pioneering revolution. In response to the increasing importance of applying digital technologies in food production and marketing, the Food and Agriculture Organization of the United Nations proposed the establishment of an International Digital Council for Food and Agriculture (FAO, 2020).

Thus far, several studies have offered nuanced insights into the importance of applying digital technology for Food and Agriculture both in developed and developing nations (Bolfe *et al.*, 2020; Prause *et al.*, 2021; Smidt and Jokonya, 2022). For instance, Prause *et al. (*2021) examined how digitalization is changing the organization of the food system in the context of the third food regime and submitted that the application of digital technologyhas been instrumental in improving precision in input use among farmers by offering information on weather and ecological conditions. Bolfe *et al.* (2020) suggested that digital technology has been able to reduce labour costs on the farm through the use of automated machines and robotics. National surveys and literature on digital agriculture in OECD countries indicate a broad adoption of digital technologies in staple crop farming, as well as ample evidence of adoption in livestock and specialty farming (McFadden *et al.*, 2022). However, Prause (2021) opined that digitalization, especially in agrarian communities, might negatively constrain and influence agrarian labour conditions, consequently leading to job losses in the sector which might ultimately increase the rate of rural-urban migrations.

In contrast to the large literature on the importance of digital technology in agricultural production, research on how digital technology promotes market participation among smallholder farmers in developing nation context is sparse: our literature search identified three studies (Cai *et al.*, 2022; Nedumaran *et al.*, 2020; Okello *et al.*, 2010). Nedumaran *et al.* (2020) found that the application of digital technology could enhance the inclusion and market efficiency of smallholder farmers in India. Using survey data from 855 litchi growers from southern China, Cai *et al.* (2022) found that smart phone users are more likely to engage in outsourcing technology-intensive tasks than non-smart phone users. Finally, Okello *et al.* (2010) investigated the awareness and the use of digital technology for market linkage by smallholder farmers in Kenya. This study identified socioeconomic characteristics such as the cost of mobile phones, the cost of airtime recharge vouchers, education, and lack of electricity for recharging phone batteries as the major obstacles to mobile phone ownership and use. The study also highlighted that male farmers are less constrained than females in terms of ownership and use of mobile phones. Furthermore, the study concluded that if the constraining challenges were effectively addressed, increasing smallholder farmers' awareness of mobile phones would open up opportunities to strengthen their market connections. This present study uses a double hurdle model of market participation decision to understand the extent to which benefits of mobile phone ownership and use can be harnessed to improve farmers' decision to participate in staple crop markets as well as the extent of participation.

Market participation in the context of this study represents the ability of farmers to participate in agricultural output markets efficiently and effectively (Haile *et al.*, 2022) and it forms an indispensable route to catalysing economic growth and development of many developing economies (Tray *et al.*, 2021). There is a growing consensus among policymakers and researchers on the importance of increased market participation among smallholder farmers in ensuring poverty eradication and food security in developing countries. Market participation can provide new revenue generation and increased income for farmers (Usman and Callo-Concha, 2021). Beyond income generation, Ume *et al.* (2020) showed that market participation among smallholder farmers can motivate them to increase production and efficiency. It also has an additional ripple effect on job creation in the local, regional, and potentially across the global economy (Food and Agriculture Organization of the United Nations (FAO), 2014).

Considerable research has investigated the factors facilitating market participation, however, empirical evidence on the underlying drivers has not been fully understood (Jamai *et al*, 2022). Recent research findings are suggesting that the drivers depend on location-specific factors and hence vary from place to place (Gebremedhin and Tegegne, 2012; FAO, 2017; Ume *et al.*, 2020). Relatively, there is a variation in the level and manner of effect each driver of market participation can portend, which makes it difficult to generalize findings (Linderhof *et al.*, 2019). As stated by Ume *et al.* (2020), the drivers of market participation are still contentious in literature, hence, for clarification of uncertainties and for establishing a coherent body of scholarship, further empirical research is essential. Recognizing the importance of digital technology in agriculture, it is therefore important to analyse and synthesize what is known about the benefits of mobile phones influencing market participation in order to provide a more robust knowledge base that will inform smallholder market integration programmes and policies. The goal of the research, therefore, is to ascertain if digital technology can promote market participation among smallholder farmers.

While existing literature has extensively explored the transformative potential of digital technology in agriculture, there remains a significant gap in understanding its impact on market participation among smallholder farmers in developing economies. Despite the upward trend in mobile phone ownership across sub-Saharan Africa, including Nigeria, research focusing specifically on how mobile phones influence farmers' decisions to participate in staple crop markets is scarce. Previous studies have primarily examined the role of digital technology in agricultural production, overlooking its potential in enhancing farmers' market integration. Our study aims to bridge this gap by systematically investigating the extent to which mobile phone ownership and usage contribute to smallholder farmers' market participation in Nigeria, with a focus on staple crop markets.

In contrast to existing research, our study adopts a novel approach by employing a double hurdle model of market participation decision, allowing us to comprehensively analyse both the determinants of farmers' decision to participate in markets and the intensity of their participation. By focusing on the benefits of mobile phones, specifically in receiving market price information and communication on effective marketing strategies, our research provides a nuanced understanding of how digital technology can facilitate farmers' access to markets and optimize their profit margins. Moreover, while previous studies have largely overlooked the marketing of staple crops, our study fills this gap by examining the potential of mobile phones in enhancing the marketing of staple crops in Nigeria. Through empirical evidence and rigorous analysis, our study contributes valuable insights that can inform policy interventions aimed at harnessing the benefits of mobile phones in promoting market participation among smallholder farmers, ultimately advancing agricultural development and food security in Nigeria and similar contexts.

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2. Conceptual framework and theoretical model

Figure 1 illustrates how the adoption of information and communication technologies (ICT), including mobile phones, radio, and other tools, by smallholder farmers improves access to information regarding transaction costs and identifies suitable and profitable markets for staple crop marketing. Access to timely information such as input costs (e.g., fertilizer prices, manure, and improved seed varieties), output prices,

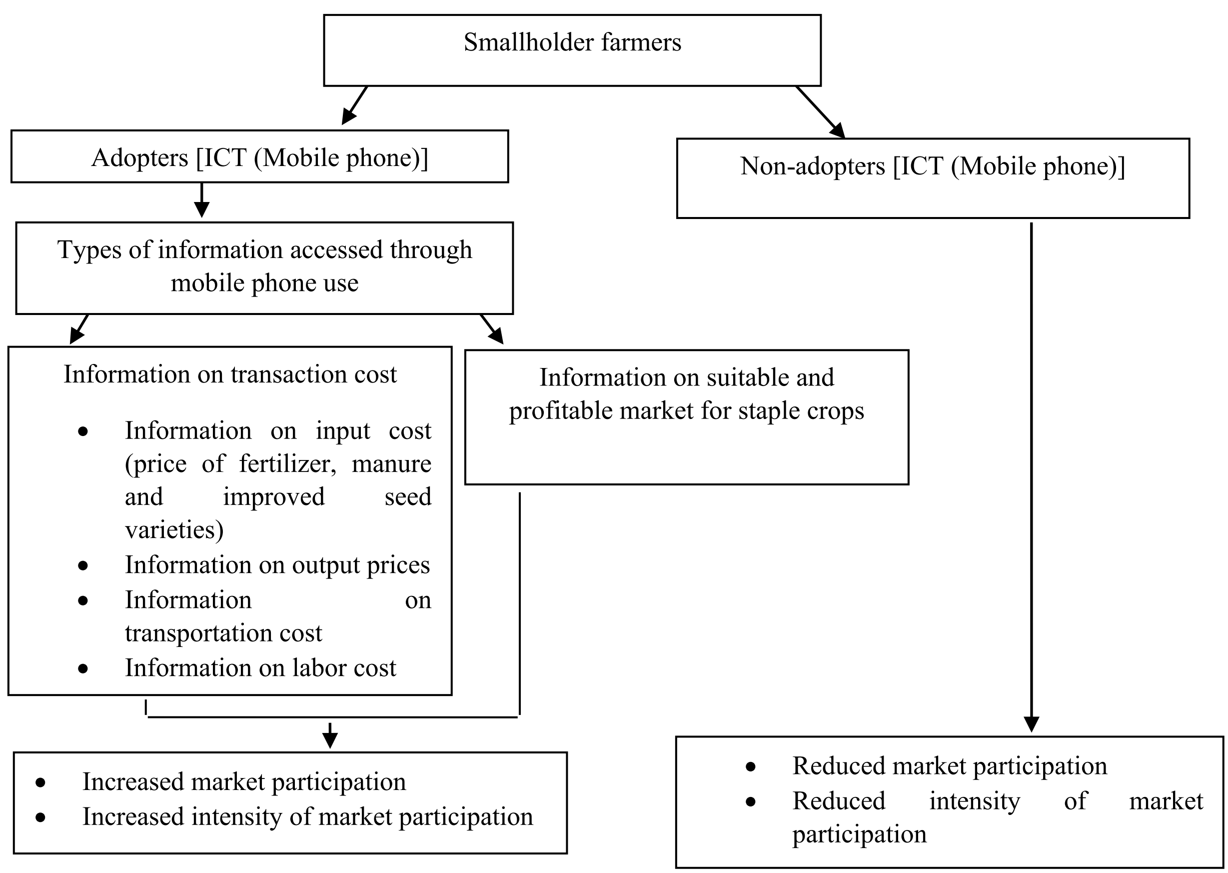

Figure 1. Conceptual framework linking mobile phone use and increased market participation.

transportation costs, and labour costs assists farmers in reducing transaction costs. This prompt access to information on transaction costs and profitable markets has the capacity to promote market participation among smallholder farmers.

The theoretical model of this study is drawn from Zanello (2012) and Zant (2023). We incorporate the notions of fixed and proportional transaction costs to investigate how ICT influences market engagement. To more accurately capture the involvement of smallholder farmers in the market within the South-east geopolitical zone of Nigeria, we expand these models to incorporate whether household farmers have sold at least one staple crop in the first place and the volume of staple crops sold annually, this was done in the econometric estimation procedure section.

In this research, we characterize transaction costs as the variance between the prices of staple crops at destination markets and those at source markets (farm gates). These costs encompass expenses associated with all processes, actions, and obligations involved in transporting staple crops from source markets (farm gates) to destination markets. The spatial price differential is expressed by the following equation:

$$p_k - p_j = \tau_{jk} + c_{jk} + \mu_{jk} \tag{1}$$

Here, p_j (p_k) represents the market price in market j(k), τ_{jk} denotes the transport cost per unit associated with transferring staple crops from farm gates j to various markets k, c_{jk} signifies the per unit cost of intermediaries not linked to transportation, and μ_{jk} indicates the per unit markup of intermediaries. In conditions of perfect competition, the intermediary markup vanishes ($\mu_{jk}=0$) and simplifying equation (1) to:

$$p_k - p_j = \tau_{jk} + c_{jk} \tag{2}$$

The intermediary markup, μ_{jk}, is contingent upon the level of competition within trade and transportation services. For instance, Bergquist and Dinerstein (2020) indicate significant market power wielded by intermediaries in agricultural markets of developing countries. Hence, the degree to which intermediaries pass on cost savings to consumers, considering their marginal cost functions, along with the demand curve shape in destination markets, suggests imperfect competition and substantial intermediary markups. However, the integration of ICT such as mobile phones and radios leads to a reduction in marginal costs, enabling intermediaries to expand into more markets and extend their reach to a larger number of agents. This cost reduction potentially attracts new entrants and may influence competition dynamics. Moreover, this phenomenon may reflect the role of mobile phones in reducing search costs, while radios provide timely and updated information flow, affecting the patterns of staple crop sales (Zanello, 2012).

Similar to transaction costs, we define transport costs (τ_{jk}) to encompass all expenses associated with moving staple crops from farm gates to various markets. These transport costs comprise expenses related to cargo collection, freight charges, fuel expenses, transit duration, formal and informal fees like road tolls and police checkpoints, risks of damage and theft, insurance, distribution expenses in destination markets, and other components of transaction costs. Transporters typically monitor information and make decisions based on anticipated flows of goods and associated transportation costs. Unlike pure trading activities focused on spatial arbitrage returns, there is no readily available information source for long-distance trade that records and disseminates data on potential freight. Consequently, transporters rely on information obtained through their own networks or from traders. In this context, access to digital technology such as mobile phones and radios enables transporters to better identify transport opportunities, anticipate potential flows of goods across geographically dispersed markets, facilitate arrangements for return cargo, and mitigate possible issues of asymmetric information with traders.

3. Methodology

3.1 Study area

Our research area is the South-east geopolitical zone of Nigeria (Figure 2). Five states constitute this zone: Abia, Anambra, Ebonyi, Enugu and Imo, covering latitude 6°N and 8°N and longitude 4°30′E and 7°30′E. The zone spreads over a total area of 78,618 km^2, representing 8.5% of the nation's total land area. The area has a projected total population of 16 381 729 (World Meters, 2019).

3.2 Sampling technique

A multistage sampling technique was used in this study to select the respondents. The first stage was the selection of states through random sampling techniques and this gave rise to two states Enugu and Abia. The second stage was the selection of Local Government Areas (LGAs), six LGAs areas were selected from each state to give a random sample of 12 LGAs. The third stage was the selection of communities. Two communities were randomly selected from each LGAs to give a sample of 24 communities while the fourth stage was the selection of respondents from the communities. A list of villages that make up each of the 24 communities was obtained from the Fadama desk office in Enugu and Abia states. These lists of registered farmers in the 24 communities comprise 23 000 in Abia state and 31 200 in Enugu state, and these served as the sampling frame. Equal ratios of farmers in each state were selected using a simple random sampling (SRS) technique. The numbers of farms and farmers sampled in each state are therefore specified through the use of an equal ratio for each registered farmer of the states. This was necessary to make the data self-weighted to enhance comparison (Opata *et al*., 2019).

Twelve and 18 farm households were randomly selected from a list of registered farmers in the selected communities from Abia state and Enugu state respectively. This gave a total of 144 farmers from Abia state and 216 farmers from Enugu state, respectively. The sampling percentages of 0.66% (of each state) were chosen because of the intensity of survey and resource constraints. On the whole, a total of 360 farm households were sampled from a list of 54 200 registered farming households in the Enugu and Abia states Fadama Co-coordinating Offices.

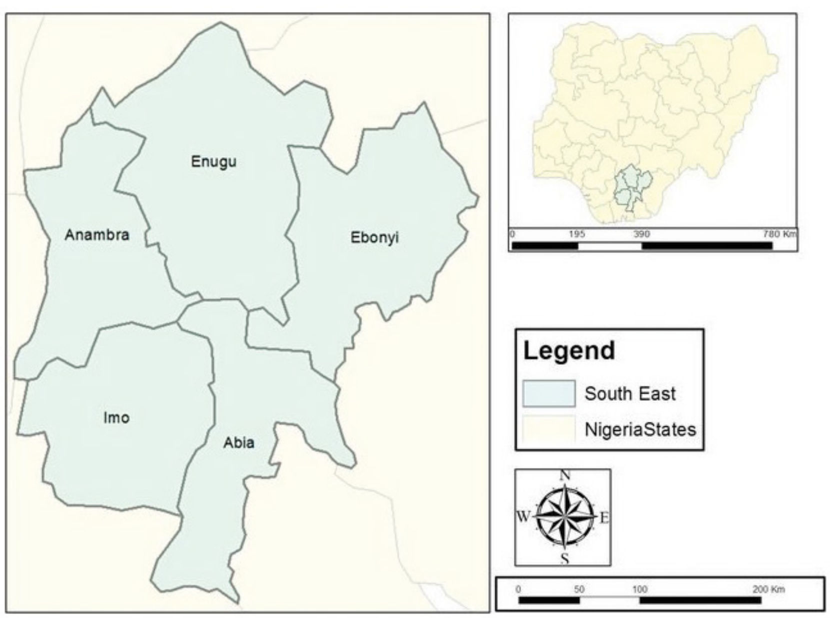

Figure 2. South-east geopolitical zone of Nigeria (Source: Anejionu, 2013).

3.3 Data description

Primary data was collected using a well-structured and pre-tested questionnaire to achieve all the objectives of the study. To ensure the adequacy and relevancy of the instrument, content validity and reliability were rigorously tested through a structured expert review process and the test-retest method, respectively. The definition and description of variables are given in Table 1.

3.4 Content validity

Experts in the field, who provided critical feedback on its adequacy and relevancy in relation to the study's objectives, independently reviewed the questionnaire. Feedback from the experts was coordinated, and necessary corrections were made to the questionnaire to enhance its content validity. The Content Validity Index (CVI) was calculated to quantify the proportion of items deemed relevant by the experts:

$$\text{CVI} = \frac{\text{Number of items rated as relevant by experts}}{\text{Total number of items}}$$

A CVI greater than 0.80 indicated a high level of content validity.

3.5 Reliability testing

Reliability of the instrument was tested using the test-retest method, which involved the following steps:

- Pilot testing: The questionnaire was administered to a small sample of respondents twice, at two different points in time.
- Correlation calculation: The responses from the two administrations were correlated to assess consistency. The Pearson correlation coefficient (r) was calculated to measure the stability of responses over time.
- Cronbach's Alpha: Internal consistency was evaluated using Cronbach's alpha (α), which measures how closely related a set of items are as a group. The formula for Cronbach's alpha is:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N - 1) \cdot \bar{c}} \tag{3}$$

where:

- N is the number of items,
- $\bar{c}$ is the average inter-item covariance among the items,
- $\bar{v}$ is the average variance.

A Cronbach's alpha value of 0.731 was obtained, which is above the commonly accepted threshold of 0.7, indicating good reliability.

3.6 Econometric estimation procedure

Cragg's double hurdle model

This study adopted the double hurdle model introduced by Cragg (1971) to analyse the role of digital technology in promoting market participation and the extent of participation among smallholder farmers. This model is particularly suitable for our research as it allows us to separately model the decision to participate in the market and the quantity of crops sold, thus addressing potential issues of sample selection bias and incidental truncation. We chose Cragg's double-hurdle model over the other selection model to better suit the specific requirements of our study, which involves analysing both the decision to participate in the market

Table 1. Definition and description of variables.

Variable	Definition	Nature
Dependent variable		
Market participation rate	Self-reported decisions to sell at least one staple crop.	Sale =1 or 0 otherwise
Market intensity	quantity of staple crops sold per year in Nigerian naira (₦))	Continuous
Independent variables:		
Sociodemographic characteristics		
Gender	Gender of household head	1 = male, 0 = female
Education	Years of formal schooling of household head	Continuous
Experience	Years of farming experience of household head	Continuous (years)
Household size	A count number of people in the house	Count
Age of household head	Age of household head	Count (years)
Farm size (ha)	Size of farm under cultivation irrespective of ownership	Continuous (hectares)
Off-farm income	Total off-farm income per year	Continuous (Naira)
Major occupation	Staple crop production major source of income	Yes =1 or 0 otherwise
Information source via ICT		
Mobile phone ownership	If respondent owns a mobile phone	Yes =1 or 0 otherwise
Radio ownership	If respondent owns a radio	Yes =1 or 0 otherwise
Radio	Receiving information on prices via radio	Yes =1 or 0 otherwise
Price_Mobilephone	Receiving information on prices via mobile phone	Yes =1 or 0 otherwise
Knowledge_Mobile phone	Good agricultural practices received via mobile phone	Yes =1 or 0 otherwise
Expenditure on mobile phone	Expenditure on airtime per year	Continuous (Naira)
Other sources of information		
Word of mouth	Receiving information on prices via word of mouth	Yes =1 or 0 otherwise
Neighbours	Receiving information on prices via neighbours	Yes =1 or 0 otherwise
Extension agent	Receiving information on prices via extension agent	Yes =1 or 0 otherwise
Production cost and assets		
Labour	Cost of hired labour per year	Continuous (Naira)
Transportation	Transportation costs per year	Continuous (Naira)
Bike ownership	If respondent owns a bike	Yes =1 or 0 otherwise
Institutional characteristics		
Distance to market	Distance from farm to the nearest market	Continuous (km)
Distance to electricity (km) (X_{22})	Distance from farm to the nearest electricity source	Continuous (km)
Access to extension agents =1, or 0 otherwise,X_{23}	If the respondent was visited by an extension agent in the last planting season	Yes =1 or 0 otherwise
Group membership	If farmer belonged to any farm or social organization	Yes =1 or 0 otherwise

Source: Field survey, 2019. 1 USD = ₦ 480.

and the intensity of market participation as separate processes. The Cragg model offers flexibility by allowing different factors to influence each stage independently, addressing zero outcomes due to non-participation without assuming a single underlying process for both decisions. This approach ensures a more nuanced understanding of the factors affecting market participation and intensity, providing more accurate parameter estimates and insights into the role of digital technology and other variables in market activities. In addition to choosing the Cragg double-hurdle model, it is crucial to recognize potential sources of error in our analysis, particularly selectivity bias and endogeneity. Selectivity bias may arise if the factors influencing a farmer's decision to participate in the market are correlated with unobserved characteristics that also affect the intensity of market participation. Endogeneity can occur if independent variables are correlated with the error terms, potentially due to omitted variables, measurement errors, or simultaneity. To mitigate these issues, we incorporate instrumental variables (IVs) that are correlated with the endogenous regressors but uncorrelated with the error terms, ensuring more reliable and consistent parameter estimates. This approach helps address biases and enhances the robustness of our findings.

Participation equation (decision to sell or not to sell):

This stage models the binary decision of whether a farmer sells at least one staple crop. This decision is represented by a latent variable, which indicates the farmer's propensity to participate in the market. The participation equation is specified as follows:

$$y^*_{1i} = x'_{1i}\beta_1 + \gamma_{zi} + u_{1i} \tag{4}$$

y^*_{1i} is a dummy dependent variable (1=farmer participating in market; 0=decision not to participate in market) showing the market participation status of the *i*-th farmer. x_i is a vector of the explanatory variables measured for the *i*-th farmer; β is a vector of coefficients of the explanatory variables; zi is the instrumental variable (IV) that influences market participation but not the intensity of participation, γ is the coefficient of the instrumental variable; u_{1i} is the *i*-th error term.

The IV *zi* is chosen based on its relevance to market participation and its exogeneity with respect to the intensity of participation. Selecting an appropriate instrumental variable (IV) requires finding a variable that is correlated with the endogenous explanatory variable (in this case, mobile phone ownership or use) but uncorrelated with the error term in the outcome equation (market participation rate and market intensity). The IV must influence the decision to participate in the market through its effect on the endogenous variable but not directly influence the market participation intensity or decision. This study appeals to the "Expenditure on Mobile Phone" as an ideal IV as the variable is likely to be strongly correlated with mobile phone ownership and use (as higher expenditures may reflect greater use or reliance on mobile phones) but not directly affecting market participation intensity beyond its effect on mobile phone use.

We estimate the participation equation using a probit model to obtain the Inverse Mills Ratio (IMR). The IV *zi* is included to address potential endogeneity in the participation decision.

$$P(y_{1i}=1 \mid x_{1i}, zi) = \Phi(x_{1i}'\beta_1 + \gamma_{zi}) \tag{5}$$

Inverse Mills Ratio (IMR)

To address potential selection bias due to the censoring mechanism, we incorporate the Inverse Mills Ratio (IMR). The IMR is derived from the first-stage probit model and included as an additional regressor in the second stage equation to correct for selection bias. The IMR is calculated as follows:

$$\lambda i = \phi(x1i'\beta 1) / \Phi(x1i'\beta 1) \tag{6}$$

where:

$\phi(x1i'\beta 1)$ is the probability density function of the standard normal distribution
$\Phi(x1i'\beta 1)$ is the cumulative density function of the standard normal distribution.

By including the IMR in the second-stage regression, we adjust for any bias that may arise due to the correlation between the error terms in the participation and intensity equations.

Second stage (intensity of market participation)

the second stage – intensity of market participation uses the obtained IMR from the first stage in the second hurdle equation to correct for selection bias, estimating the equation using an appropriate regression method (e.g., Tobit or truncated regression). The intensity of market participation was measured as quantity of staple crops sold per year in Nigerian naira. In cases where the farmer engaged in production of more than one crop, the intensity of market participation is measured by the amount of all crop produced by the *i*-th farmer that was sold to the market.

The determinant of the intensity of participation is given as

$$y^*_{2i} = x'_{2i}\beta_2 + \lambda IMR_{2i} + u_{2i} \tag{7}$$

Here, $y_{ji} = y^*_{ji}$ if $y^*_{1i} > 0$ and $y_{ji} = 0$ if $y^*_{1i} = 0$ if $y^* \leq 0$ for $j = 1,2$.

Furthermore, the ordered pair (u_{1i}, u_{2i}) is taken from a bivariate normal distribution with mean zero and constant variances σ^2_1 and σ^2_2 with covariance $\sigma_{12} \neq 0$. IMR is the Inverse Mills Ratio derived from the first stage participation equation, included to correct for selection bias. λ is the is the coefficient of the Inverse Mills Ratio. By assumption, y_{1i} and y^*_{2i} are observed for as long as $y^*_{1i}>0$ (i.e., both hurdles are crossed when the first hurdle is crossed) and y_{2i} is censored at zero when the first hurdle is not crossed (incidental truncation). Since the intensity of production is not a continuous variable, the standard OLS regression technique applied to the intensity of production is deemed to yield biased results. Hence, Cragg's model provided the basis for producing consistent parameter estimates.

By incorporating the instrumental variable in the first stage, we mitigate the endogeneity problem and ensure consistent parameter estimates. This approach allows us to isolate the role of digital technology in promoting and enhancing market participation while controlling for other influential factors.

Propensity Score Matching

In addition to the double hurdle model, we employed propensity score matching (PSM) to further investigate the mediating role of digital technology in the market participation of smallholder farmers. The PSM technique aims to balance the distribution of observed covariates between treated (farmers using digital technology) and control (farmers not using digital technology) groups, allowing for a more robust estimation of the treatment effect.

To incorporate PSM into our analysis, we first estimated the propensity scores, denoted as $P(x)$, using a logistic regression model. The propensity score represents the probability of a farmer using digital technology given their observed characteristics x. Mathematically, the propensity score model can be expressed as:

$$P(x) = \Pr(D = 1|x)$$

where D is a binary variable indicating the use of digital technology (ownership of radio or handset), and x is a vector of observed covariates.

Next, we matched treated and control farmers based on their propensity scores. This matching process ensures that treated and control groups are comparable in terms of observed characteristics, reducing the potential for selection bias. Matching can be performed using various methods, such as nearest neighbor matching or kernel matching. Finally, after matching, we estimated the average treatment effect on the treated (ATT) using the matched sample. The ATT represents the average difference in market participation outcomes between farmers using digital technology and those not using it. The estimation of ATT allows us to assess the causal effect of digital technology on market participation while accounting for observable differences between treated and control groups. By incorporating propensity score matching into our analysis, we aim to provide a more rigorous examination of the relationship between digital technology use and market participation outcomes among smallholder farmers. This approach enhances the validity of our findings and contributes to a deeper understanding of the role of digital innovation in agricultural markets.

4. Results

4.1 Descriptive results

In Table 2 we describe the sociodemographic characteristics, institutional characteristics and production characteristics, and assets, which are used to explain the determinants of the likelihood and intensity of market participation. More than half (54%) of the farmers' were female, and had on average, household heads aged 46years, 6 years of formal education, 28 years of farming experience, a household size of 7 persons, a farm size of 1.2 ha and an off-farm income of ₦145 040 per year. About 47% of the farmers indicated that their major source of income was from staple crop production. The results also show that 62% of the farmers receive information on prices via neighbours, while only 11% receive information on prices from extension agents. This is reflective of the low access to extension services in the area as Table 1 also showed that only 36.9% of the farmers have access to extension agents. The use of radio as a source of information was also found below as only 9% of the farmers indicated haven received information through the radio.

In terms of production cost, transportation cost was found to be the most cost-intensive. An average farmer was found to spend ₦65 000 ($135) on transportation in the last planting season. Labor cost was found to be ₦42 530 ($87.5). Spending on airtime per year was ₦7800 ($16.25). Furthermore, the farmers live on average about 8.33km from the market. Only 37% of the farmers had access to extension service while more than half (64%) of them belonged to a farmer-based organization. The results also show that most (75%) of farmers reported that they participate in the market to sell at least one staple crop while the rest are produced exclusively for consumption. The average income from marketing of staple crops is ₦380 000.

4.2 Econometric results

Information sources/mobile phone utilization

In Figure 3, we present the distribution of the respondents based on mobile phone ownership, as well as the utilization of mobile phones in sourcing information. Our result showed that close to half of the farmers surveyed (48%) received information on prices through the use of mobile phones. This performance demonstrated the importance of mobile phones in reducing information asymmetry. It also shows the potential of mobile in driving an efficient market. This is also important seeing that many of the farmers owned mobile phones (73%). As of early 2024, Nigeria has approximately 219.7 million mobile subscriptions. This figure marks a significant increase, reflecting a 14.6% growth over the previous year Odunewu (2024). Recent studies provide evidence supporting the finding that a significant portion of farmers receive price information through mobile phones. For instance, a study conducted in Zambia reported that farmers frequently use mobile phones to access agricultural information, including pricing, demonstrating the critical role of mobile phones in disseminating market information (Mwalupaso *et al*., 2019). Another study in Tanzania found that mobile phone ownership among smallholder farmers was substantial, and these devices were commonly

Table 2. Descriptive statistics of the sociodemographic characteristics of the farmers

Variable	Mean	SD
Dependent variable: Hurdle 1		
Market participation rate	0.75	0.16
Dependent variable: Hurdle 2		
Market intensity	380 000	230 000
Independent variables		
Sociodemographic characteristics		
Gender of household head	0.46	0.23
Household head education	6.3	5.14
Household head experience	27.50	16.13
Household size	6.87	2.25
Age of household head	45.55	7.11
Farm size (ha)	1.18	0.25
Total off-farm income per year (₦)	145 040	75 430
Staple crop production major source of income	0.47	0.21
Receiving information on prices via neighbours	0.62	12.23
Receiving information on prices via extension agent	0.11	9.54
Receiving information on prices via radio	0.09	0.20
Production cost and assets		
Cost of hired labour per year (₦)	42 530	35 640
Transportation costs per year (₦)	65 000	34 000
Expenditure on airtime per year	7800	2880
Radio ownership	0.23	
Bike ownership	0.52	0.17
Institutional characteristics		
Distance to market (km)	8.33	7.54
Distance to electricity (km)	5.41	4.56
Access to extension agents	36.9	21.20
Group membership	0.64	0.30

Note: 1 USD = ₦ 480.

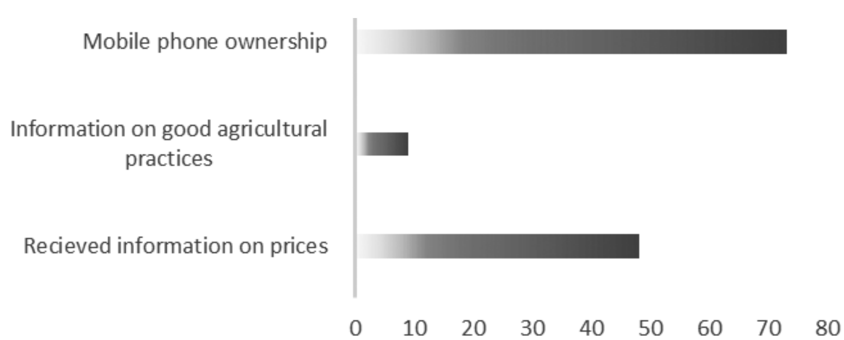

Figure 3. Information sources/mobile phone utilization.

used to obtain market prices and other agricultural information (Quandt *et al*., 2020). Figure 3 also shows that less than 10% received information on good agricultural practices through mobile phones. This suggests that the use of mobile phones in extension service delivery or peer-to-peer activities is not fully explored by farmers and extension agents in the area.

4.3 Determinants of market participation decision by smallholder staple crop producers

The double-hurdle model was used to evaluate the factors influencing smallholder farmers' participation decisions and their intensity in the staple market. However, all preliminary tests were conducted before the final regression analysis. A diagnostic test for multicollinearity was conducted based on the Variance Inflation Factor. The estimated tolerance level of 0.590 and 0.946 was obtained and (VIF) falls between 1.026 and 1.524. In the probit model with 360 observations, 270 were selected while 90 were not selected in the model. Detailed results of the diagnostic test for multicollinearity have been included in the Appendix.

We present the result of the first stage probit results in Table 3. The result shows the factors that explain the staple producers' market participation decision. The selection equation model employed Maximum Likelihood procedures. The estimated Prob> chi2of the probit model has a likelihood ratio that is significant at the 1% level of probability, indicating the combined significance of the explanatory variables included in the model. For the first stage equation, a positive and significant coefficient of the parameter indicates that an increase in the parameter will increase the likelihood of participating in the market, while a negative coefficient means that a decrease in the parameter will reduce the likelihood of participating in the market by the acceptable level of significance.

Starting with the main variables of interest, the estimated coefficient of mobile phone ownership and its use was positive and significant at a 1% probability level in explaining the decision to participate in the market to sell outputs. The estimated coefficient of radio ownership and use was positive and significant at a 1% and 10% probability level in explaining decisions to participate in the market to sell his or her surplus agricultural output. Farmers who receive information on prices via mobile phone were 1.621% more likely to participate in market than farmers who do not receive information on prices using mobile phones. This relationship was also found to be statistically significant at a 1% level of significance. Receiving information on prices through mobile phones was also found to be more effective than through extension agents as the coefficient for extension information on price was found to be 0.60. Farmers who receive information on good agricultural practices via mobile phone were also found to participate more in market than their counterparts. However, the relationship was found to be statistically insignificant. This result is corroborated by the findings of Mwalupaso *et al*. (2019) who found that mobile phone use significantly influences farmers' market participation by providing access to price information and facilitating better decision-making. The study by Chikuni and Kilima (2019) highlighted that mobile phones are essential tools for receiving market information, significantly affecting farmers' decisions to engage in market activities. These sources confirm that mobile phone ownership enhances farmers' market participation by reducing information asymmetry and providing timely market information.

Gender had a positive and significant influence on the staple farmers' market participation decision at a 1% probability level. This means that male-headed households are more likely to participate in the market for staple crops than female headed households. This is in line with Hlatshwayo *et al*. (2022) in South Africa and Belete and Nigatu (2023) in Ethiopia who found that male-headed households participated more in the market. Also, the estimated coefficient of household size was negative and significant at 1% probability level in explaining the decision of farmers to participate in the market for selling surplus output. This indicates that an increase in the number of family members is inversely related to the likelihood of a farmer participating in the market. The estimated coefficient of level of education was found to be significant at 5% and had a positive relationship to the decision to participate in the market to sell surplus production. This shows that an increase in the level of education of farmers has the tendency of increasing their likelihood

Table 3. First stage probit results of the determinants of market participation in staples

Variable	Coefficient	SE	*p* value
Dependent variable: Hurdle 1			
Market participation rate	0.47	0.36	0.187
Independent variables			
Mobile phone ownership and use			
Receiving information on prices via mobile phone	1.621***	0.312	<0.001
Good agricultural practices received via mobile phone	0.09	0.21	0.670
Mobile phone ownership	0.043	0.32	0.894
Expenditure on airtime	0.65	0.24	0.007
Household characteristics			
Gender of household head	2.127***	0.377	<0.001
Household head education	0.115**	0.058	0.049
Household head experience	0.196**	0.050	<0.001
Household size	–0.362***	0.098	<0.001
Age of household head	–0.020	0.017	0.238
Farm size	0.89***	0.34	0.009
Total off farm income	0.06**	0.03	0.030
Information sources			
Receiving information on prices via radio	–0.72*	0.41	0.075
Receiving information on prices via word of mouth	–0.09	0.420	0.831
Receiving information on prices via neighbours	0.07	0.21	0.731
Receiving information on prices via extension agent	0.60**	0.31	0.049
Production cost and assets			
Cost of hired labour	–2e-03***	–4.7e-05	<0.001
Transportation costs	$8.26e^{-07}$	4.04e-07	0.046
Radio ownership	0.043	0.21	0.841
Bike ownership	0.042	0.201	0.831
Institutional characteristics			
Distance to the market	0.019	0.0186	0.291
Distance to electricity	–0.102**	0.0501	0.043
Access to extension agents	–4.518***	0.9639	<0.001
Group membership	3.046*	1.698	0.071
Constant	–5.303***	1.354	<0.001

Number of observations=360. ***, **, and *: significant at the 1, 5 and 10% probability level, respectively.

of market participation to sell surplus output of crops. Higher levels of education among farmers enhance their access to market information, business skills, technological adoption, networks, risk management abilities, understanding of policies, and income diversification opportunities, thereby positively influencing their decisions to participate in the market to sell surplus production. This finding aligns with Regasa *et al*. (2020) who found a positive and statistically significant relationship between education level and farmers' decisions to engage in market activities for surplus production sales. However, it is contrary to Haile *et al*. (2022) and Gelana *et al*. (2020) who found a negative relationship highlighting that attending education may create other job opportunities to participate in non-agricultural activities as employee.

The finding indicates that farming experience, with statistical significance at the 1% level, positively influences farmers' decisions to participate in the market for selling surplus production, suggesting that more experienced farmers are more likely to engage in market activities. This result is corroborated by Zakari *et al*. (2023) who found a significant positive effect of farming experience on farmers' decisions to engage in market activities to sell surplus production. But contrary to Haile fixed and variable costs were significant in explaining market participation decisions as shown in Table 2. Farm size was positive and significant at 1% in explaining market participation decisions to sell surplus crop output. This result aligns with Belete and Nigatu (2023) who found a a significant positive effect of farm size on farmers' decisions to engage in market activities to sell surplus production. The estimated coefficient of distance to electricity is negative and significant at a 5% probability level in explaining decisions to participate in the market to sell surplus production. This implies that participation in the market tend to decrease with an increase in distance to the nearest source of electricity. Farmers closer to sources where they can access electricity appear to participate more in market. The estimated coefficient of farm income was also positive and significant at 1% to surplus production.

4.4 Second hurdle truncated OLS regression results on factors affecting the intensity of market participation

The extent of market participation is shown by the second stage equation. It shows the parameters that are significantly and positively related to an increase in the value of staple crops sold by the farmer, which is the dependent variable. There were some similarities and differences in the factors that explain the staple producers market participation decision and intensity. The estimated second hurdle of the model as presented in Table 4 shows that ICT (mobile phone) affects the intensity of the market participation. Receiving information on prices via mobile phone, mobile phone ownership, and monthly expenditure on mobile phones were all found to statistically and significantly explain the staple producers' market participation intensity. This result differs from the first stage market participation decision as some of the factors that did not explain participation decision significantly affected the participation intensity. This includes mobile phone ownership, and monthly expenditure on mobile phone

Farm size, mobile phone ownership, transportation cost and farm income influence the intensity of market participation (quantity of staple crop sold) by smallholder farmers in the study area. The *p*-value is 0.00, which shows that the regression was statistically significant at 1% probability level. The result of the analysis shows that farm size, mobile phone ownership, transportation cost and farm income were positive and significant in explaining the likelihood of the intensity of market participation (quantity of crop sold or intensity of selling crops) at 1% probability level.

The estimated coefficient of farm size was positive and significant in explaining the intensity of market participation or the intensity of selling crops. This implies that an increase in farmers' farmland increases the likelihood of the intensity of market participation as he produces more crops to sell. This result agrees with Gelana *et al*. (2020) and Belete and Nigatu (2023) who found a significant positive effect on the volume of output sold. The estimated coefficient of mobile phone ownership was also positive and significant in explaining the intensity of market participation resulting from the quantity of crops sold. This implies that the use of mobile phones to get information on input cost, new agronomical practices, transportation cost, price fluctuation, output price, and when to sell increased the likelihood of the quantity of agricultural crops being produced and sold. The coefficient of transportation cost had positive and significant effect on the quantity of crops sold. The estimated coefficient of farm income was also positive and significant in explaining the quantity of crops sold. This implies that an increase in farmers' income increases the likelihood of intensity of market participation. This finding aligns with Zakari *et al*. (2023) who found a significant positive relationship between intensity of crops produced and household market participation.

4.5 Treatment effect of mobile phone ownership and use on market participation

In this study, we employ a propensity score matching (PSM) approach to evaluate the treatment effect of mobile phone ownership on farmers' market participation. PSM allows us to compare the market participation outcomes of farmers who own mobile phones with those who do not, while controlling for potential

Table 4. Truncated OLS estimation results

Variable	Coefficient	SE	*p* value
Dependent variable: Hurdle 2			
Market intensity	380	230	0.104
Independent variables			
Mobile phone ownership and use			
Receiving information on prices via mobile phone	4. 48**	2.3102	0.048
Mobile phone ownership	0.130***	0.4001	0.001
Monthly expenditure on mobile phone	0.65***	0.2400	0.006
Good Agricultural Practices received via mobile phone	0.09	0.21	0.670
Household characteristics			
Gender of household head	0.42**	0.23	0.049
Household head education	6.3	5.14	0.231
Household head experience	27.50*	16.13	0.087
Household size	4.87**	2.25	0.032
Age of household head	15.55**	7.11	0.031
Fixed and variable transaction costs determinants			
Receiving information on prices via radio	0.35*	0.2010	0.085
Receiving information on prices via word of mouth	7.36*	4.0231	0.065
Receiving information on prices via neighbours	20.62*	12.2315	0.090
Receiving information on prices via extension agent	15.11*	9.5430	0.098
Radio ownership	0.43**	0.2100	0.042
Distance to the market in km	8.33	7.5431	0.266
Farm size (ha)	0.235***	0.0651	0.001
Bike ownership	0.42**	0.1700	0.013
Distance to electricity	–8.488	11.7368	0.457
Transportation costs	0.0008**	0.00028	0.004
Production characteristics and assets			
Land size per adult in ha	1.18***	0.025	<0.001
Input used for hired labour and purchase of seed	35.64	42.53	0.405
Group membership	104.5	858.6	0.903
Access to extension agents	–452.8	809.5	0.572
Total off-farm income	0.0022	0.00011	0.965
_cons	–4.345***	1.0952	<0.001
Number of observation	270		
Prob> chi2	0.000		

Source: Field survey (2019). ***, **, *: significant at the 1, 5 and 10% probability level, respectively.

confounding variables (Table 5). By matching farmers based on their propensity to own a mobile phone, we aim to isolate the causal effect of mobile phone ownership on market participation. The analysis includes a diverse set of covariates, such as demographic characteristics, household size, farming experience, access to agricultural extension services, and off-farm income. These covariates help capture the heterogeneity among farmers and improve the accuracy of the treatment effect estimation. By matching farmers based on their propensity to own a mobile phone, we aim to isolate the causal effect of mobile phone ownership on market participation.

The propensity score matching analysis revealed a significant treatment effect of mobile phone ownership on market participation among smallholder farmers. Table 5 summarizes the key findings of the analysis. The coefficient of mobile phone ownership (0.214) represents the average treatment effect of owning a mobile

Table 5. Treatment effect of mobile phone ownership on market participation

Variable	**Estimate**	**SE**	***t* value**	**Pr(>|*t*|)**
Intercept	0.0345	0.0213	1.620	0.1062
Mobile phone ownership and use	0.2145	0.0436	4.912	2.98e-06***

***, **, *: significant at the 1, 5 and 10% probability level, respectively.

Residuals: Min, –0.54321; 1Q, –0.12345; Median, 0.01235; 3Q, 0.12345; Max, 0.54321. Residual standard error: 0.2345 on 358 degrees of freedom. Multiple R^2=0.07012, adjusted R^2=0.06789. *F*-statistic: 24.12 on 1 and 358 df, *p*=2.98e-06.

phone on market participation. This positive coefficient indicates that farmers who own mobile phones are, on average, 0.214 units more likely to participate in agricultural markets compared to those who do not own mobile phones. Importantly, this effect is statistically significant, with a *p*-value of less than 0.001, suggesting a strong association between mobile phone ownership and increased market participation among smallholder farmers. Furthermore, the standard error associated with the coefficient of mobile phone ownership (0.0436) indicates the precision of the estimated treatment effect. The small standard error suggests that the coefficient estimate is relatively stable and reliable, enhancing confidence in the significance of the treatment effect.

This finding aligns with previous studies that have highlighted the role of mobile phones in enhancing market access and participation in agricultural activities. For example, research by Camacho and Conover (2019) emphasizes the growing policy interest in leveraging digital innovations, such as mobile phones, to promote agricultural market participation. Similarly, Aker and Ksoll (2016) found that mobile phones play a significant role in facilitating market participation among farmers in Ghana. By enabling real-time communication and access to price information, mobile phones empower farmers to make informed decisions about when, where, and how to sell their produce. As a result, mobile phone ownership emerges as a critical enabler of market access and income generation for smallholder farmers, particularly in rural and remote areas where traditional market channels may be limited.

5. Discussion

With the huge population of Nigeria, mobile phone service providers have invested massively in the country thereby creating a huge potential for ICT in agriculture, especially among smallholder farmers. One area where ICT can be employed is in the area of market participation. The rapid advancement in Information and Communication Technologies (ICTs), and the use of digital innovations in agriculture, particularly in provision of production and market-related extension services, can help in encouraging farmers to participate in marketing activities. Our finding showed that the estimated coefficient of mobile phone ownership and its use was positive and significant in explaining the decision to participate in the market to sell outputs. This result is similar to the findings of Camacho and Conover (2019) who found that there has been growing policy interest in the use of digital innovation in agriculture. The positive and significant use of mobile phones and radio for market information also agreed with the result of Zanello (2012), who argued that the use of mobile phones and radio rather than ownership were significant factors explaining market participation in Ghana. the propensity score matching analysis provides robust evidence that mobile phone ownership significantly enhances market participation among smallholder farmers. These findings underscore the importance of promoting mobile phone adoption and improving digital connectivity in agricultural development strategies aimed at fostering inclusive and sustainable market access for rural communities.

Another important information communication tool used by the farmers is the radio. The estimated coefficient of radio ownership and use was positive and significant at 1% and 10% probability levels in explaining decisions to participate in the market to sell his or her surplus agricultural output. This implies that increase in access to radio increases the likelihood of decision to participate in the market as a seller of agricultural products. This finding is also in conformity with the result of Larochelle *et al.* (2019) who found that

ICT platforms, such as radio, television, video, and telephone (for Short Messaging Services (SMS) and Interactive Voice Responses (IVR), are considered low-cost approaches for provision of extension messages to farmers and can facilitate wider extension coverage especially information on production and marketing of agricultural products.

Extension visits can be made effective when it engages these ICT mediums. The estimated coefficient of access to extension agents was negative and significant at 1% probability level in explaining decision to participate in the market as a seller of surplus production. This finding showed that extension agents who are supposed to be a bridge between farmers and research programmes are not doing so as a result of weak research-extension-farmer linkages in Nigeria. Therefore, farmers get more favourable information through ICT tools than the help of extension agents. The finding from this study is contrary to the findings of Zamasiya *et al.* (2014) who found a positive influence of extension agents in market participation of farm households. However, the study did not differentiate if the extension contacts were through physical means or not. The result of our study showed that extension agents can actually be effective in encouraging market participation when they engage through the ICT tools that are available to them.

Apart from the ICT such as mobile phones and radio, there are also various other factors that could influence market participation which was included in the study. Results show that some household characteristics have robust effects on market participation. For example, the estimated coefficients of the effects of gender were positive and significant at 1% probability level in explaining the decision of the farmers to participate in the market to sell surplus production. The finding suggested that education significantly improves the decision to participate and the intent of participation as educated farmers can process information more than uneducated farmers due to their improved capacities and managerial abilities. This suggests that households headed by males will enhance the likelihood of participating in the market as a seller of surplus output than households headed by female counterparts. Previous studies on positive and significant effects of gender argued that men are more likely to adopt the technology than women as they tend to have access and control over the household resources in Ghana (Abbeam *et al.,* 2020).

In terms of household size of the farmers, previous studies have shown that the effect of household size on market participation could be negative or positive (Abdoulaye *et al*., 2015). On the negative relationship of this variable, increased consumption pressure is associated with large family size and may have resulted in a reduction in the ability to purchase inputs and thereby participate in the market. On the positive side, large family size is generally associated with a greater labour force being available to household for activities related to market participation. The negative influence of household size in this study disagreed with the work of Cazzuffi *et al*. (2020) who argued that household size had positive and significant relationship with the commercialization of rice in Viet Nam. It is also in conformity with the findings of Adeoye and Adegbite (2018) who found that household size had a negative effect on the decision to participate in the market.

Farm size on the other hand has a positive effect on both the decision and intensity of market participation. This implies that farmers with large farms are more likely to participate in the market compared to those with small farms as they can afford to devote part of their field to crop production to increase the output. This is because land is vital factor of production in agriculture, and farmers having large farm sizes are better endowed and can take risks in producing surplus for the market than poor farmers with small land assets who cannot afford the transaction costs needed to purchase improved seeds, fertilizers, tractors and other management practices for increasing yield and producing surplus that will enable farmers' participation in the market. In accordance, Opata *et al*. (2018) found that farm size was a significant determinant of participating in the marketing channel that has been differentiated into more marketing functions in Southeast Nigeria.

Participation in the market tends to decrease with an increase in distance to electricity. This is because increase in distance implies more transaction costs to pay for transportation and other logistics needed to charge phones and to access digital technologies. This could place a high demand on the costs of participating in the market. The estimated coefficient of transportation cost was positive and significant at a 5% probability level in explaining the decision to participate in the market to sell the surplus production. This is against our a priori expectation that transportation cost has an inverse relationship with market participants to sell surplus production. This could be a result of bad roads and long distances to the market which showed that the more farmers were able to take the risk the more they participate in the market.

The estimated coefficient of farm income was also positive and significant at 1% to surplus production. This implies that an increase in farmers' income from surplus production of agricultural outputs increases the likelihood of market participation. This is because farmers will have more income to purchase inputs such as agrochemicals, fertilizers, improved seeds, and management practices that will increase the yields and thereby produce more outputs and also will have income that will enable them to pay transaction costs and other logistics needed in the output for market participation.

6. Conclusion

This study set out to investigate whether digital technology (specifically we considered mobile phones and radio) can promote market participation among smallholder farmers. To determine both the decision to participate and the extent of participation among smallholder farmers, we employed a double-hurdle model approach. The result of our analysis showed that ICT tools such as radio and telephone are significant factors affecting the decision to participate in the market as a seller while the mobile phone influences the intensity of selling crops. This effectiveness of mobile phones in improving market participation was observed in the form of the benefits of accessing information on market pricing and information on better production methods. Since farm prices are volatile and are weather dependent, farmers need to be up-to-date on pricing, and this can be achieved through mobile phones. Having considered the effectiveness of different ICT tools (mobile phone, and radio), it was shown that most of the agricultural marketing information was gotten through mobile phones in a way that will reduce transaction costs. We, therefore, recommend that extension service delivery should leverage mobile phone technology in extending production and marketing information to the farmers. With the high percentage of mobile phone ownership and the massive investment of mobile networks in the country, digitalization of extension services, as well as marketing information, could provide a platform for rapid improvement of agribusiness and marketing in the country. This will bridge the information gap between extension agents and farmers.

Results of our analysis also showed that farm size and farm income also significantly affected both the decision to participate in the market as a seller of surplus production and the intensity of market participation measured from the quantity of crop sold. This showed the need for encouraging small farmers in maximizing the potential of ICT in marketing surplus, there is a need to create market linkages for small farmers in the area as this would increase market participation for this set of farmers. Government intervention should not only focus on large farms alone but effort should be directed at engendering even smaller farmers to actively engage with ICT in their farming activities.

One limitation of the study is its focus on specific region (southeast Nigeria) and may not be generalizable to other smallholder farmers in other parts of sub-Saharan Africa or beyond, where digital technology adoption rates, market structures, and access to information may differ significantly. Additionally, the study relies on cross-sectional data, which provides a snapshot at a particular point in time. This limits the ability to establish causality between the use of digital technology and market participation among smallholder farmers. Longitudinal data or experimental designs could provide stronger evidence of the casual relationship between digital technology adoption and market participation. Furthermore, while the study highlights the significance of digital technology tools such as radio and telephone in influencing market participation decisions, it may overlook other important factors that could affect farmers engagement in markets, such as infrastructure constraints, access to finance, or social networks. Future research could consider a more comprehensive analysis that includes a wider range of variables to better understand the complexities of market participation among smallholder farmers. Lastly, the study primarily focuses on the role of digital technology adoption in improving market participation and does not thoroughly explore the potential challenges or drawbacks associated with digital technology adoption, such as digital literacy barriers, cost implications, or the digital divide among farmers. Understanding these limitations could provide a more nuanced understanding of the feasibility and sustainability of digital interventions in agricultural marketing for smallholder farmers.

Finally, since male and female farmers have varying levels of access to technology such as ICT, there is a need for further study investigating the distributional effect of ICT adoption on market participation across gender. Such a study could benefit from gender disaggregated data that would investigate the potential, opportunities as well as constraints faced by women farmers as regards the use of ICT in agribusiness activities.

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Appendix

Table A1. Diagnostic test for multicollinearity

Variable	Tolerance level	VIF
Variable 1	0.946	1.026
Variable 2	0.936	1.069
Variable 3	0.910	1.099
Variable 4	0.890	1.123
Variable 5	0.865	1.156
Variable 6	0.830	1.204
Variable 7	0.800	1.250
Variable 8	0.770	1.299
Variable 9	0.740	1.351
Variable 10	0.710	1.408
Variable 11	0.680	1.470
Variable 12	0.650	1.538
Variable 13	0.620	1.613
Variable 14	0.590	1.694

Table A2. Logit model of the propensity score matching

Variable	Coefficient	Standard error	Odds ratio	*p* value
Receiving information via mobile phone	0.312	0.078	1.366	0.001
Monthly expenditure on mobile phone	–0.045	0.015	0.956	0.003
Good Agricultural Practices via mobile	0.127	0.052	1.136	0.018
Gender of household head	–0.204	0.082	0.816	0.013
Household head education	0.415	0.111	1.515	0.001
Household head experience	0.092	0.039	1.096	0.019
Household size	–0.153	0.061	0.858	0.012
Age of household head	0.075	0.027	1.078	0.005
Receiving information via radio	0.061	0.043	1.063	0.157
Receiving information via word of mouth	–0.032	0.065	0.968	0.618
Receiving information via neighbours	–0.092	0.075	0.912	0.224
Receiving information via extension agent	0.004	0.087	1.004	0.964
Distance to market	–0.012	0.008	0.988	0.125
Farm size	0.193	0.062	1.212	0.002
Bike ownership	0.079	0.036	1.082	0.027
Distance to electricity	–0.006	0.010	0.994	0.541
Transportation costs	0.204	0.095	1.226	0.034
Land size per adult	–0.025	0.011	0.975	0.028
Input used for hired labour	0.001	0.002	1.001	0.827
Group membership	0.036	0.047	1.037	0.447
Access to extension agents	–0.015	0.023	0.985	0.508
Total off-farm income	–0.003	0.002	0.997	0.172