Heliyon 9 (2023) e19043

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Information and Communication Technology deployment and agricultural value chain nexus in Nigeria

Oluwatoyin A. Matthew [a,b,*], Romanus Osabohien [a,b], Olanrewaju Olaniyi Omosehin [b,c], Nasreen Jawaid [d], Timothy Aderemi [e], Opeyemi Olanrewaju [f], Patience N. Evans-Osabuohien [g]

[a] Department of Economics and Development Studies, Covenant University, Ota, Nigeria
[b] Centre for Economic Policy and Development Research (CEPDeR), Covenant University, Ota, Nigeria
[c] Federal University of Technology, Akure, Nigeria
[d] Department of Computer Science, ILMA University, Karachi, Pakistan
[e] Bells University of Technology, Ota, Nigeria
[f] Internal Food Policy Research Institute, Abuja, Nigeria
[g] Department of Business Management, Covenant University, Ota, Nigeria

ARTICLE INFO

Keywords:
ICT deployment
Agricultural value chain
Information access
Value chain actors

ABSTRACT

This study examined the point of the agricultural value chain where the deployment of Information and Communication Technology (ICT) is significant. The study used the data sourced from wave 4 (2018/2019) of the Living Standards Measurement Study – Integrated Survey on Agriculture (LSMS-ISA) and applied the Multinomial Logit (MNL) regression. The result showed that ICT deployment is significant for all actors along the agricultural value chain. However, though significant for all actors on the value chain, the estimated coefficients slightly differ. Information and Communication Technology (ICT) is helpful for all the actors along the chain from the estimated coefficients but higher at the farmgate collectors. This can be based on the rationale that, unlike other actors in the chain, the farmgate collectors interact directly or more with the farmers, making ICT more crucial for them than other actors in the chain. The study concludes that ICT can provide farmers and value chain actors with information about the market, among others, new production skills and processes that will help them upgrade, leading to entry into higher-value markets.

1. Introduction

The usage of Information and Communication Technologies (ICTs) are not only needed for employment in the information sector, the requirement for ICT usage cuts across all facets of the economy - from agriculture and construction to education and service organisations [1–5]. In agriculture, frequent and on-time information empowers farmers to monitor prices and weather variations, and take advantage of value chains [6,7].

* Corresponding author. Department of Economics and Development Studies, Covenant University, Ota, Nigeria.
E-mail addresses: oluwatoyin.matthew@covenantuniversity.edu.ng (O.A. Matthew), romik247@gmail.com (R. Osabohien), omosehinolaniyi@gmail.com (O.O. Omosehin), nasreen.jawaid@ilmauniversity.edu.pk (N. Jawaid), aderemi.timothy@gmail.com (T. Aderemi), opeyemi.olanrewaju@cgiar.org (O. Olanrewaju), patikor79@gmail.com (P.N. Evans-Osabuohien).

https://doi.org/10.1016/j.heliyon.2023.e19043
Received 21 July 2022; Received in revised form 26 July 2023; Accepted 8 August 2023
Available online 25 August 2023

The expansion of technological adoption plays a crucial role in enlarging job prospects, and helping farmers go beyond the farmgate [8]. For example, mobile financial services like the Mobile-Money (*M*-PESA) in Kenya support farmers in ordering and pay for services rendered and promote their agribusiness activities. Mobile payment systems and timely information are the two significant aspects of contributions of ICT resources to agriculture [9–11]. Mobile payment systems' availability helps agribusinesses undertake financial transactions outside the banking hall [1,3]. When farmers can transfer money rapidly and safely, it becomes simpler for agribusinesses to thrive [9]. This will increase the effectiveness of the marketplace and eliminate difficulties associated with business growth [12]. In developed countries, ICT innovations in agriculture, especially the mobile phone, assist in transferring information distribution to knowledge sharing [1,10].

The findings of previous studies regarding the relationship between information and communication and agriculture report mixed findings. The gap identified in the literature is that, concerning information and communication technology, previous studies [such as 13, 14, 5,15], did not account for the point on the value chain where the deployment of ICT is significant. Also, these studies focused on ICT adoption and its impact on agricultural productivity without taking cognizance of the relevance of agricultural value chain in the distribution process. Therefore, this study is one of the very few to examine the point on the agricultural value chain where the deployment of ICT is significant.

It is good to note that since 2015, in Africa, mobile phone usage and the internet has steadily progressed in bridging information asymmetry [9] and the number of individuals hooked to the internet through mobile devices is rising quickly [13]. The proportion of people connecting to the internet increased from about 5.2% in 2005 to about 17.8% in 2019 [9]. In a survey carried out in Kenya [13], examined the influence of ICT on agriculture finds that ICT adoption in agriculture vastly improved productivity through value chain development. The study posited that ICT adoption helped to improve the welfare of the farmers via boosting agricultural efficiency by 20% in Kenya. However, this is unlike the situation in Nigeria where agricultural efficiency is low with just 8% improvement.

The significant challenges that the agricultural sector is experiencing in Nigeria are weak infrastructure, the high rate of insecurity and low ICT adoption. These challenges account for why agricultural efficiency is lower than that of what obtains in Kenya. Building technological capability in Nigeria is essential to enhance productivity. Infrastructure should be established to allow the usage of connectivity in farming to link farmers to the market. Though it is worthy to note that the coverage of connectivity is improving across the six geo-political zones in Nigeria. It is expected that by 2030, there will be an estimated connectivity structure of ICT of about 60% in Nigeria where the rural areas will be covered by internet connectivity [14].

The rationale behind this study is due to the fact that, identifying the point(s) or actors on the value chain where the deployment of ICT is significant is necessary to spur agricultural efficiency. The use of ICT will help to aid the distribution of agricultural output because the farmers will be able to communicate with their customers as to where the agricultural produce can be purchased, and which individual(s) that are distributor(s) to buy from. In addition, ICT has helped to minimize the cost of accessing information and evolving skills and is generating numerous contemporary prospects across sectors, including agriculture [13].

Furthermore, it is important to note that there are various ways ICT can help unlock the potentials of agriculture along its value chains, ranging from; policy implementation and dissemination, agricultural extension and advisory services, enhancement of environmentally sustainable farming, disaster management and early warning system, improve access to market, financial inclusion, insurance and risk management and capacity building and empowerment. In the light of the foregoing, this study contributes to knowledge by identifying the point on the agricultural value chain where deployment of ICT is significant, using the Multinomial Logit technique.

This study intends to proffer answer to the research question: *at what point on the agricultural value chain is ICT deployment significant?* The contributions of this study to literature and policy is timely based on the fact that identifying the areas where ICT deployment is significant allows for targeted resource allocation. Limited resources can be directed towards the specific points in the value chain where ICT can have the most significant impact. This ensures that investments in ICT infrastructure, technologies, and training are strategically utilized for maximum benefit. Also, by identifying the specific points where ICT can be deployed effectively, stakeholders can streamline processes, automate tasks, and reduce manual labour. This can result in time savings, cost reductions, and improved overall productivity. The study is structured into five sections; following this introductory section is the review of related literature, section three is the methodology of the study. The empirical results and discussion of the results are in sections four, while conclusion and recommendations of the study are in the fifth section.

2. Insights from the literature

Studies have shown that unemployment, poverty and food insecurity remain some of the significant challenges faced by developing countries. In some countries, unemployment is about 60% of the total population. Similarly, two out of five persons is unemployment and poor in developing countries [5,15–18]. On the other hand, across the globe, the agricultural sector has been observed to be one of the sectors that contribute effectively to growth and development, especially in developing countries [19].

Growth from the agricultural sector tends to be three to five times better in terms of poverty reduction and the attainment of food security than growth resulting from other sectors of the economy [20–23]. It has been observed that agricultural productivity is slowing due to some factors such as socioeconomic shocks [5], land grabbing [19] among others. Therefore, raising agricultural efficiency through value chain development is necessary to enhance the livelihood of poor households who depend on agriculture for survival. It is also essential for attaining the United Nations (UN) Sustainable Development Goals, especially SGD-1 and SGD-2, which are to "reduce extreme poverty by half and achieve food security for all through agriculture".

The agricultural value chain comprises the actions meant to transport products from the farm to the final consumers [24,25]. Another definition of agricultural value chain is that it is made of the world of production, procession, distribution, marketing and

consumption of commodities [24,25]. Failure to develop the agricultural sector and add value to its commodities may cause many underdeveloped economies to expect the danger of producing low-value commodities and keep on struggling to gain meaningful value-added proportion in the world market [24,26,27]. Hence, boosting the agricultural value chain is necessary to improve emerging economies agricultural efficiency. To unlock the farm sector's potential in developing countries, especially, Nigeria, the various value chains should be recognised, prioritised, and digitised.

The overall economic prospect for ICT usage throughout the value chain will serve as a value addition to agriculture [17,28]. The whole value chain, if developed effectively, is expected to add to the growth rate of GDP and contribute the employment and livelihood. Increasing dissemination of mobile network coverage, including the local communities, will help farmers upgrade their farming mechanisms and link them to the market, thus addressing post-harvest waste and loss [26]. Engaging a panel data consisting of about 482 farmers [25]. examined the effect of value chain development on cassava productivity in Nigeria. The study applied the endogenous switching regression (ESR) and found that cassava farmers were observed to operate below the technical efficiency without developing the value chain.

Using the Probit regression and data obtained from the household survey of the upper west region of Ghana [29], found that access to information is a strong determinant of smallholder farmers' market decisions. With perfect information, small-scale farmers are easily linked to the market. Therefore, ICT is required to connect farmers to the market. In another study, the problem concerning ICT adoption and agricultural value chain development should be addressed. In line with this [27], using the Logit and the Chi-square methods, examined how digital technology will help tackle issues associated with the agricultural value chain in Nigeria. The study found that agricultural value chain development significant impact on the food supply in Nigeria. The compression of how strategies impact price diffusion and motivations for farmers and end-users along the value chain is necessary due to the more globalised nature of the agricultural value chain.

In developing countries, the agricultural sector has attracted policy and research attention. Using the nominal rate of protection (NRP) approach [24], examined the import-export oriented oil palm and cocoa value chain in Nigeria. The study found that oil palm, as a result of defensive trade mechanism and local plans, the NRP at the farmgate for such commodity revealed that the manufacturers had been protected. In this wise, the development of both national and world value chains may be ascribed to different elements, especially technological progress in ICT [22,30]. The global agricultural value chain development will contribute to employment creation [26]. Engaging a conceptual framework approach [26], found that the agricultural value chain development can increase job growth in Africa.

The knowledge of the agricultural value chain is necessary for growth. In this regard [31,32,32], examined the knowledge about the value chain enhancement in Africa, Asia and Latin America. The study found that value chain development increases the opportunities for the expansion of agricultural commodities and reduce the problem of linking small-scale farmers to the market [32]. engaged a study that drew on four contrasting cases of value chain development in Nicaragua to assess approaches and tools used in its design and implementation. The study interviewed 28 representatives from the international non-governmental organisations (NGOs) leading the interventions, the local NGOs that participated in implementation, principal buyers, and co-operatives. Despite the complexity of market systems, results showed a relatively basic approach to the agricultural value chain, reflected in; (1) reliance on a single tool for design and implementation; (2) expected outcomes based on technical assistance and training for smallholders and cooperatives; (3) local NGOs and cooperatives with crucial roles in implementation, and (4) limited engagement with other chain actors and service providers.

[33] engaged the data obtained from interviews with NGOs, government organisations, buyers, and smallholder business organisations in a six-case approach in Uganda. Findings emanating from the study show that the use of available value chain development guides and tools facilitated productive partnerships among actors on the chain. Also, results from the study guide Non-Governmental Organisations (NGOs), government agencies, and researchers to better understand the circumstances of resource-poor chain actors, the

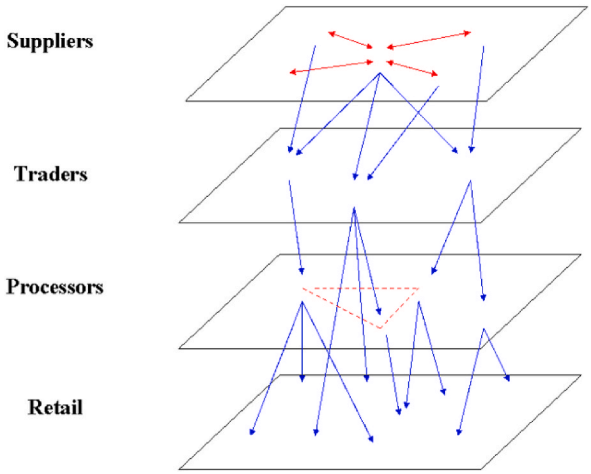

Fig. 1. Netchain (Lazzarini et al., 2001) adapted from Trienekens (2011).

implications of value chain development on gender relations, and the cultural and business context when designing and implementing value chain policies. The most general information and communication technology in developing countries today is the mobile phone [33]. Most people in developing countries are in rural areas, and their livelihood depends on agriculture. The study by Ref. [34] investigated the use of mobile phones among farmers in rural Tanzania to offer empirical evidence on the developmental role of ICT. The results showed improved access to communication and information that mobile phones provide impacts with the entire cyclic farming life during the year. This information has resulted in considerable changes in the whole livelihood concepts, increased opportunities and reduced risks for rural farmers.

3. Methodology

3.1. Analytical framework

This study presents a conceptual framework called the Netchain according to Ref. [35] adapted from Ref. [36]. Based on this Netchain, a network structure is made up of dual components, which are the vertical and horizontal dimensions. It implies that the vertical component shows the movement of commodities and services from the manufacture to the final-users. On the other hand, the second dimension, which is the horizontal component posit the correlation existing among players in the same chain link (between farmers, between processors, among others). Lazarrini [35] formulated the concept of the netchain in order to depict interconnection between the two components in the supply chain, as shown in Fig. 1.

Fig. 1 posits the vertical connection among the different actors along the supply chain and horizontal correlation among actors in the same chain. Vertically connect could pass through all phases in the supply chain or may skip value chain links, for instance, relationships between traders and retail. Horizontal relationships between actors may likewise have different spheres, such as farmer cooperatives or price agreements between traders. The structure of a network (netchain in Fig. 1) is greatly relying on the market chains which are selected by different actors.

3.2. Data source and measurement of variables

In this study, an effort is made to examine the point on the agricultural value chain where the deployment of ICT is significant. This section outlines the variables, definition, measurement and the reasons for including them and the corresponding source. The study engaged quantitative data from Wave 4 (2018/2019) of the Living Standard Measurement Study- Integrated Surveys on Agriculture (LSMS-ISA).

The LSMS-ISA data for Nigeria covers the 36 States of the country, including the Federal Capital Territory (FCT), Abuja [7,22]. The LSMS-ISA data is grouped into community, households, and agriculture level for two agricultural seasons (post-planting and post-harvest). Wave 4 of the survey comprises of 60 Primary Sampling Units (PSUs) or Enumeration Areas (EAs) chosen from each of the 37 States in Nigeria, making a total of 7586 EAs nationally. Each EA contributes 10 households to the Generalised Household Survey (GHS) sample, resulting in a sample size of 26,557 households.

The household questionnaire was administered to all household heads in the sample. The agriculture questionnaire was administered to all household heads engaged in agricultural activities such as crop farming, livestock rearing and other agricultural and related activities. The community questionnaire was administered to the community to collect information on the socioeconomic indicators of the enumeration areas where the sample households reside. The household questionnaire provides information on demographics; education; health; labour; food and non-food expenditure; household non-farm income-generating activities; food security and shocks; safety nets; housing conditions; assets; information and communication technology; and other sources of household income. Agriculture questionnaire solicits information on land ownership and use; farm labour; inputs use; land areas household plots; agricultural capital; crop harvested and adoption; animal holdings and costs; and household fishing activities. Some information is collected at the crop level to allow for a detailed analysis of individual crops.

As a way of data management, the first step is to identify the variables of interest and the location of such variables in the LSMS-ISA databank, with the help of the questionnaire. The second step followed is to sort the identified variables from their respective locations. The third step followed is by merging the variables of interest as specified from different locations in the dataset for both the post-planting and post-harvest seasons. After combining the variables, the next step was to clean the data sorted, by dropping missing observations and variables that are not useful for the present study. The next step was collapsing the variables of interest at the households' level using households' identification number (hhid). Therefore, the analysis was based on a household level, using household identification. This is because, some significant variables, such as agricultural productivity, can only be measured at the household level (farm-level productivity). After disaggregation at the household level, the data for the analysis was made of 4980 household heads.

3.3. Estimation technique and model specification

The multinomial Logit was used to express the probability of using technology (viz a viz mobile phone and internet) along the various agricultural value chains. Though multinomial logit (MNL) among others, such as the multivariate probit (MVP) model are commonly used for analysing discrete choice data, here are some reasons why we used the multinomial logit model. First it is based on computational simplicity - the multinomial logit model is computationally simpler compared to the multivariate probit model. Estimating the MNL model is relatively straightforward and can be done using maximum likelihood estimation. On the other hand,

estimating the MVP model requires more complex numerical methods, such as simulation-based techniques like Markov Chain Monte Carlo (MCMC) methods.

The second rationale is based on the Independence of irrelevant alternatives (IIA) - the Multinomial Logit model exhibits the IIA property, which means that the relative odds of choosing one alternative over another are unaffected by the presence or attributes of other alternatives. This property can be desirable in certain cases where the independence assumption is reasonable or when analysing large choice sets. The third is as a result if interpretability - the coefficients in the multinomial logit model have a straightforward interpretation in terms of log-odds ratios. In summary, the multivariate probit model relaxes the IIA assumption and allows for correlation among the error terms of different alternatives, which can be advantageous when analysing complex choice situations where interdependencies between alternatives are significant. However, the choice between the multinomial logit model and the multivariate probit model, among others, depends on the specific context, the data at hand, the assumptions one is willing to make, and the research objectives.

Six points or actors along the chain were considered in this study. The chain consists of farmers (producers), farmgate or on the farm collectors (wholesalers), processing, distribution (marketers), retailers, while the final consumers are used as a base for the analysis. Given these actors of the value chain, scholars have argued that there no difference between production and farm gate in the value chain. However, this study justifies that there exists a difference between production and farm gate on the chain. This based on the fact that production refers to the initial stage in the agricultural value chain where crops or livestock are grown or raised on farms [27]. It involves activities such as land preparation, planting, cultivation, irrigation, fertilization, pest control, and animal husbandry.

The production stage primarily focuses on the primary production of agricultural commodities and encompasses all activities related to growing or raising crops and livestock on the farm. On the other hand, farm gate stage is the point at which agricultural products leave the farm and are ready for sale or further processing. It represents the immediate output of the production stage and is often considered the starting point of the value chain. At the farm gate, the products are typically in their raw or unprocessed form and have not yet undergone any significant value addition or transformation. The term "farm gate" is used metaphorically to represent the exit point of the farm, similar to a gate on a fence.

The model for this study is predicated on the utility derivable by the adopters of mobile phone and internet (technology indicators) in making a choice. In this wise, let U_{ij} denote the utility that a farmer i derives from participating in a specific value chain j, the model is given as:

$$U_{ij} = \gamma_j S_{ij}^{'} + e_{ij} \tag{1}$$

Where U_{ij} is the utility derived by household i in being in value chain j. In same way, where γ_j is the constant term, $S_{ij}^{'}$ is the covariate of technology (mobile phone and internet) which is assumed to remain constant across alternatives, and e_{ij} is a stochastic term. The error term reflects intrinsically random choice behaviour, measurement or specification error and unobserved attributes of the choices of the household heads. Based on this theory, this study leans on the Multinomial Logit regression. The Multinomial Logit is used when categories are unordered. That is, when the outcome variable e is nominal in nature with more than two levels. This method best suits this study because, the outcome variable has more than two levels. The outcome variable, actors along the value chains has production, farmgate, wholesaling, retailing and consumption as the levels.

Following [37], one value (typically the first, the last, or the value with the most frequent outcome of the dependent variable) is designated as the reference category. In this study, the consumer is designed as the reference variable. This is based on the fact that the study believes that at the consumption stage, mobile phone and the internet may be less useful compared to other stages. In this study, assuming that the dependent variable (actors along the value chain) has T categories, this requires the calculation of $T-1$ equations, one for each category relative to the reference category, to describe the relationship between the dependent and the outcome variables. In the multinomial logit, we have

$$in\frac{P(y=k|x)}{P(y=k|x)} = \beta_0^{(k)} + \beta_{1_0}^{(k)} x_1 + \ldots + \beta_{p_0}^{(k)} x_p, k-1, \ldots, k-1 \tag{2}$$

Table 1
ICT deployment along the value chain.

	1	2	3	4	5
ICT	Production	Farmgate	Processing	Distribution	Retailing
1	1.326* [0.007]	1.326* [0.007]	1.200** [0.015]	1.199** [0.015]	1.246** [0.011]
2	1.025** [0.043]	1.039** [0.041]	1.043* [0.041]	1.055** [0.038]	1.077** [0.034]
3	1.211* [0.005]	1.274* [0.003]	1.271* [0.003]	1.260* [0.004]	1.289* [0.003]
4	1.394 * [0.005]	1.533* [0.002]	1.396* [0.005]	1.470* [0.003]	1.5293* [0.002]
5	0.8670*** [0.078]	0.964*** [0.052]	0.852*** [0.089]	0.868*** [0.083]	0.929*** [0.062]
Log likelihood	−1279.140	−1265.101	−1230.6076	1330.2076	−1256.661
Pseudo R^2	0.033	0.0222	0.0305	0.0205	0.0100
Prob > chi2	0.000	0.000	0.0000	0.0000	0.0448
LR chi2	86.06	57.99	77.51	77.51	25.40

Note: The p-values are in parentheses [ ], *, ** and *** means significant at 1%, 5% and 10% respectively.
Source: Researchers' Computation using the LSMS-ISA.

Based on this equation, the ratio of any two-group membership likelihood is a log-linear function of x, .

$$ln\frac{P(y=j|x)}{P(y=k|x)} = \left(\beta_0^{(j)} - \beta_0^{(k)}x_1\right) + \left(\beta_{11}^{(j)} - \beta_{11}^{(j)}\right)x_1 + \ldots\left(\beta_{pp}^{(j)} - \beta_{pp}^{(k)}\right)x_p \quad (3)$$

for any j and k, including the reference point category K assuming $\beta_i^{(k)} = 0$ for $i = 0, 1, \ldots, p$, a suitable way to confirm model identifiability.

4. Results and discussion

4.1. ICT deployment and agricultural value chain nexus

As presented in Table 1, at the farm level (production), there is the likelihood of mobile and internet improving farmers' efficiency by between 0.87 and 1.33 units. At the farmgate (wholesale), there is the likelihood of mobile phone and the internet to improve efficiency by 0.85–1.39 units. Similarly, ICT is significant and positive at the distribution and retailing stages. At the distribution stage, ICT has the likelihood of increasing efficiency by 0.87–1.20 units. In contrast, ICT has the likelihood of increasing efficiency by 0.93–1.25 units at the retailing stage. In this wise, deployment of ICT is crucial along the value chain. The study remains inconclusive with respect to the particular point on the value chain where the deployment of ICT is more significant. This is because the deployment of ICT is significant across the points on the value chain, which means that ICT is helpful for all the actors on the value chain.

Furthermore, it can be argued that though the use of mobile phone and internet (ICT) is significant for all the actors of the supply chain, looking at the coefficients, in column 4, the coefficient of farmgate 1.533 is higher than the coefficients of all other actors. Thus, it can be concluded that the deployment of mobile phone and the internet along the chain is more significant at the farmgate. The justification for this result can stem from the fact that the farmgate collectors interact more direct with the farmers more than any other actors on the chain.

4.2. Discussion of results

Different value chains need to be identified and digitalised to solve the problem in the agricultural sector in less developed economies. This is essential based on the following reasons – first, improved efficiency: by identifying and digitizing agriculture value chains, it becomes easy to streamline and optimize the flow of information, goods, and services throughout the entire agricultural system. This leads to improved efficiency in production, distribution, and marketing processes. Digitalization enables real-time data collection, analysis, and decision-making, allowing stakeholders to make more informed choices and reduce waste.

The second reason is - improved traceability and quality control: Digitalization helps establish transparent and reliable traceability systems for agricultural products. With proper identification and tracking mechanisms, it becomes easier to trace the origin, production methods, and quality of products throughout the value chain. This enhances food safety, enables effective quality control, and builds consumer trust. Third, because of market access and fair trade. Digitalizing agriculture value chains provides opportunities for smallholder farmers and producers to access wider markets, both locally and globally. Digital platforms can connect producers directly with buyers, bypassing intermediaries, and reducing transaction costs. This empowers farmers to negotiate fair prices for their products, improving their income and livelihoods.

The fourth rationale is resilience and risk management. Digital technologies facilitate better monitoring and early warning systems for weather conditions, pest outbreaks, and disease detection. By integrating these tools into agriculture value chains, farmers and other stakeholders can anticipate and manage risks more effectively. This resilience helps mitigate losses, improve crop yields, and adapt to changing climatic conditions. In a nutshell, identifying and digitalizing agriculture value chains offer numerous benefits, including increased efficiency, improved traceability, market access, data-driven decision making, resilience to risks, and sustainable practices. These advancements contribute to the overall transformation and modernization of the agricultural sector, benefiting farmers, consumers, and the environment.

The result presented shows that the deployment or the availability of mobile phone and the internet along all the stages of the supply chain will enhance the efficiency of the actors. It means that when the actors from farmer to the end-users have access to the mobile and internet availability efficiencies will improve. Akin to the findings of prior studies such as [7,27,24], showed that with the growing dissemination of mobile network coverage, including the local communities, farmers will be able to enhance their farming methods and link them to the market.

Similarly, the findings is tandem with that of [25] that found that the value chain improves the farmers' technical efficiency. This is based on the fact from result from columns 1 to 5, different times the analysis was conducted to validating the potential of mobile and the internet deployment along the supply chains proves that mobile phone and the internet is useful for all the actors along the value chain. In this wise, the usage of mobile phone and the availability of the internet (ICT components) serves as an avenue for value addition.

[38] argued that in selling of excess farm produce, smallholder farmers have two significant choices to make; (a) selling at the farmer or farmgate at a lesser amount or (b) taking it to the market square or supply to companies, where a higher amount will be offered. However, with the availability of mobile phone and the internet, farmers are easily linked to the market because, it mobile phone and the internet will enhance access to information which is a strong determinant of the smallholder farmers' market decision capable of minimising losses. With perfect information, small scale farmers are easily linked to the market. Therefore, in summary,

mobile phone and internet as ICT indicators are necessary to connect farmers to the market. The problem concerning ICT and the development of the agricultural value chain should be addressed.

5. Conclusion and recommendations

The agricultural sector has undergone different transformation phases, leading to improved proficiency, increased yield, and productivity. The upsurge of technology in agriculture could be the most transformative agent. This is because; agricultural innovation will not only transform farming mechanisms but as well, change the entire value chain. The study used mobile phone and the internet to measure ICT.

Concerning the point on the agricultural chain where ICT deployment is significant, the Multinomial Logit regression was applied. The result showed that across the agricultural value chain, mobile phone and internet usage is significant for all the actors. However, though significant for all actors on the value chain, the estimated coefficients slightly differ. ICT is helpful for all the actors along the chain from the estimated coefficients but higher at the farmgate collectors. This can be based on the rationale that, unlike other actors in the chain, the farmgate collectors interact directly or more with the farmers, making ICT more crucial for them than other actors in the chain. Value chains are influenced considerably by technology adoption as this can further be done by deploying technology, particularly, mobile phone and internet along the agricultural value chain. This is because, mobile phone and the internet can provide information about the market, among others, new production skills and processes that help farmers and value chain actors' upgrade, leading to entry into higher-value markets.

The study recommends, therefore, that the Nigerian Communication Commission (NCC) in conjunction with the Federal Ministry of Science and Technology should improve on internet connectivity in Nigeria via increasing/providing and lowering the cost of internet servers across in all localities to improve accessibility and affordability. This is because the findings of this study suggested that with the availability of mobile and the internet farmers are linked to the market, efficiency is enhanced and has the capacity of minimising post-harvest losses along the supply chain. This will improve Nigeria's likelihood of achieving the United Nations Sustainable Development Goals (SGDs), especially, SDG-1 "to end poverty", SDG-2 "to reduce by half extreme hunger, achieve food and nutrition security through the promotion of agricultural productivity" and SGD-9 "to achieve decent work and economic growth through technological upgrading and innovation".

Furthermore, this study is not without limitation. Some of the limitations is that first, due to data availability, the study only engaged mobile phone and internet usage as ICT indications without taking into consideration the potential of other ICT components. Second, the study only considered the point of the supply chain where the deployment of mobile phone and internet is significant without accounting for actual value addition at each point of sales. As a recommendation, given data availability, further studies should consider the inclusion of a broader component of ICT tools other than mobile phone and the internet while studying the concept of ICT and value chain. In addition, future researchers should consider capturing the actual value addition at each stage of the value chain.

Acknowledgements

The authors are grateful to the Management of Covenant University through her Centre for Research, Innovation and Discovery (CUCRID) for the financial assistance given towards the publication of this paper.

Author contribution statement

Oluwatoyin A. Matthew: Conceived and designed the experiments.

Romanus Osabohien, Olanrewaju Olaniyi Omosehin: Analyzed and interpreted the data; proofread the manuscript for general editing.

Timothy Aderemi, Nasreen Jawaid; handled the discussion of results section.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

List of Abbreviations

GDP	Gross Domestic Product
EAs	Enumeration Areas

ESR	Endogenous Switching regression
FCT	Federal Capital Territory
GHS	Generalised Household Survey
HH	Household
HHH	Household heads
ICT	Information and communication technology
IIAT	Independence of irrelevant alternatives
ITU	International Telecommunication Union
ISA	Integrated Surveys on Agriculture
LSMS	Living Standard Measurement Study
MNL	Multinomial Logit
MCMC	Markov Chain Monte Carlo
MVP	Multivariate probit
NBS	National Bureau of Statistics
NPR	Nominal rate of protection
PSU	Primary Sampling Units
UN	United Nations
SDGs	Sustainable Development Goals

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