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Title:

**"Digital transformation and agribusiness efficiency: examining the role of mobile apps, e-commerce and digital infrastructure among smallholder farmers in Uganda. A case of farmers in the Luwero region."**

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## Abstract

The study examines the role and impact of digital tools, including mobile apps, e-commerce platforms and digital infrastructure on improving agribusiness efficiency amongst the smallholder farmers in Luwero, Uganda. The study used a mixed methods research design where qualitative and quantitative data collection techniques were used. The study managed to collect quantitative data from 89 respondents using a close ended questionnaire tool together with an open-ended interview tool which was used to guide in-depth interviews where 30 respondents participated. The research was guided by three theoretical framework models, Diffusion of Innovations (DOI), Technology Acceptance Model (TAM) and the Societal Cognitive Theory (SCT). Using those frameworks, the data analysis and interpretation of findings were conducted.

The study leveraged descriptive and inferential statistics where correlation and regression analyses were used to come up with deductions from the primary quantitative data. Key findings indicate that 75.3% of the study population was aware of digital tools yet adoption of these tools varied significantly with mobile payment platforms were the most utilized (65.2%), followed by mobile apps (28.1%), and e-commerce platforms (20.2%). Regression analysis revealed that usage of mobile apps, e-commerce and digital literacy significantly influenced agribusiness outcomes, including productivity, market access, income and cost reduction. Digital literacy was identified as a critical determinant of agribusiness efficiency, highlighting the need for targeted training programs.

Qualitative data provided deeper understanding of usage patterns, perceived impacts, and barriers to digital tool adoption. Farmers reported benefits such as improved access to real time data, market prices and broader market access. as the key benefits while high data costs, limited digital literacy, internet connectivity and access to smart devices stood out as major barriers to digital adoption.

In conclusion, digital tools have a huge potential to transform agribusiness efficiency in rural farming areas like Luwero. However, interventions are necessary to address the identified barriers and enhance adoption rates of digital tools. This study offers valuable insights for policy makers, development partners,

and agribusiness practitioners aiming to promote digital transformation in agriculture.

**Key words:** Agribusiness efficiency, digital adoption, digital tools, mobile apps, e-commerce, digital infrastructure, smallholder farmers, Uganda, Luwero, digital literacy, market access, productivity.

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## List of acronyms

AI	Artificial Intelligence
DOI	Diffusion Of Innovations
GDP	Gross Domestic Product
PEOU	Perceived ease of use
PU	Perceived usefulness
SCT	Societal Cognitive Theory (SCT)
SD	Standard Deviation
SNS	Smart Nkunganire System (SNS)
TAM	Technology Acceptance Model
UBOS	Ugandan Bureau of Statistics
UCC	Uganda Communications Commision

# 1 Chapter 1: Introduction

## 1.1 Background of the study

### 1.1.1 Overview of agriculture and smallholder farming in Uganda

Uganda, also known as the “Pearl of Africa”, is endowed with fertile soils, a favourable climate and abundant freshwater resources that help to support diverse farming practices. Agriculture is considered the backbone of the country and it contributes about 24% of its GDP (UBOS 2020). Its strong involvement in agriculture has earned it a reputation of being the food basket of the region and its key agricultural outputs include both food crops and cash crops. Cereal grains like maize millet and sorghum, bananas, and beans are its main food crops while cash crops include coffee, and cotton, where coffee is the major agricultural export of the county contributing a substantial proportion of its export earnings (UBOS 2022b).

Despite its strong agricultural base, Uganda’s productivity is relatively low and this is attributed to the reliance on traditional farming methods and limited access to improved seed varieties, fertilizers and mechanised tools that are capable of delivering a larger output (World Bank Group 2018). Furthermore, post-harvest, farmers also continue to register losses and this loss is estimated to range from 23 - 30% especially for food crops. This is made worse by inconsistencies in climate and poor road infrastructure that limit access to markets (Strecker/Bitzer/Kruijssen 2022). Additionally Uganda will have to fight the climate change and prepare itself to mitigate the risk which could increase losses from food crops even more. A Study from 2023 at the Potsdam Institute for Climate Impact Research calculates possible crop losses for Maize from 6.2% up to 18.9% until 2030 and even more losses up to 47.3% by the end of the century (2090) in the West Nile subregion (von Loeben et al. 2023).

Alarmingly, inefficiencies across the value chain from seedling acquisition to post harvest handling continue to affect smallholder farmers limiting their potential to make significant revenue from their inputs. Furthermore, the Ugandan agricultural sector limits the use of modern technologies because the farms are overly fragmented with farm areas averaging at 1.3ha and over 67% of households even

below 1ha and only 13% over 2ha. This makes the majority of farmers to remain trapped in subsistence agriculture where they produce just enough to feed their families and to sell the surplus for a small income (UBOS 2022a)

### 1.1.2 The role of technology in agriculture

The Ugandan agricultural sector presents enormous potential for digital transformation as a means of enhancing productivity. This digital transformation can be achieved through the use of mobile applications and digital platforms to offer practical solutions to the issues that smallholder farmers face (Tsan et al. 2019). According to UCC 2023, the country's data on mobile penetration stood at 81% at a GSMA Mobile Connectivity Ranking Index of only 59% at infrastructure and total index Score of 45 in 2022. According to the official GSMA webpage Uganda is still lacking compared to the USA with a 90.3 or Germany at 88.0 score in 2022. In 2023 it even went down to 42.3 whereas the USA and Germany could further increase their GSMA Index (GSMA 2025).

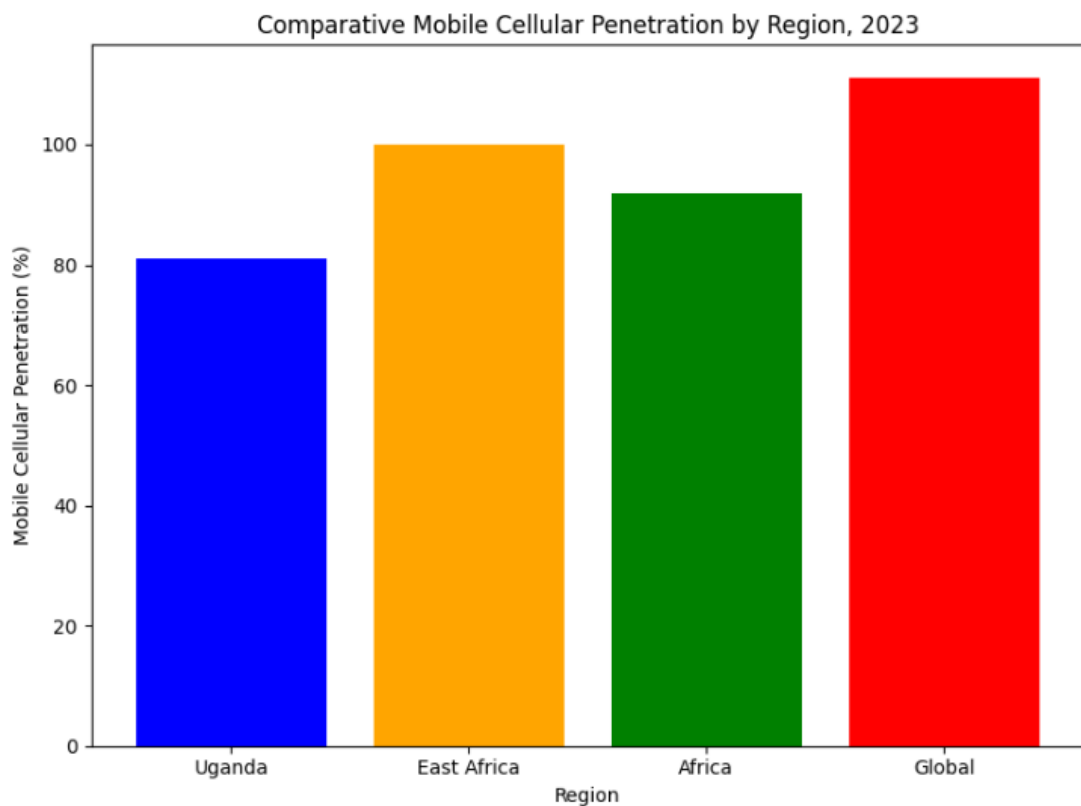


Figure 1: Comparative Mobile Cellular Penetration by Region, own representation based on UCC-Annual-Communications-Sector-Report-2023

This implies that there is a significant opportunity to leverage mobile technologies to improve access to raw materials and markets. The Ugandan agritech ecosystem is also seen to be taking off, albeit at a slow pace, with digital platforms like “EzyAgric”, “Hello Tractor”, and others entering the sector to improve smallholder farmers' access to farming advice, mechanization services, real-time market information, and more efficient supply chain management as shown in Figure 3 and **Fehler! Verweisquelle konnte nicht gefunden werden..**



Figure 2: Screenshot App “HelloTractor”

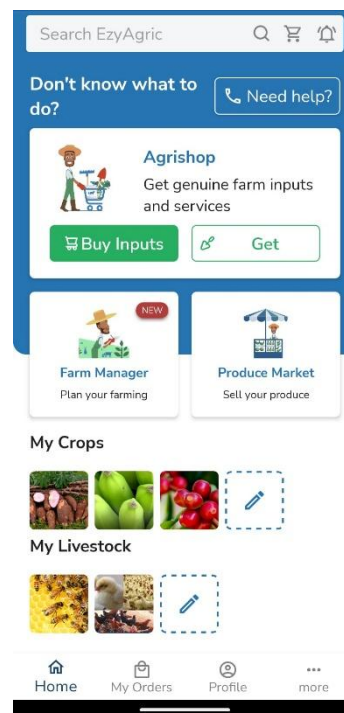


Figure 3: Screenshot App “EzyAgric”

Such innovations have been found in other places already to reduce the gap between smallholder farmers and markets, thus enabling them to sell their produce more efficiently, at higher prices, and to diversify their customer base (AgriLink 2022). However, according to Baumüller 2018 and Mirembe et al. 2023, while these technologies are becoming increasingly available, their adoption among smallholder farmers remains relatively low. This can be attributed to factors such as limited digital and non-native language literacy, affordability issues and unreliable internet connectivity. Despite those challenges, recent developments indicate some progress in this sector. For instance, a report by Feed the Future highlighted six use cases of Agritech, including "advisory and

information, market linkages and access, financial access, supply chain management, enterprise management and efficiency, and enterprise research and development".

The proliferation of e-commerce in the post-COVID period is also believed to have increased smallholder farmers' direct access to national and international markets by eliminating traditional barriers caused by middlemen. This has helped to improve the bargaining power of farmers, leading to better income. Moreover, the increased adoption of mobile financial services, such as mobile money, has improved financial inclusion by helping farmers access mobile banking services, including savings, credit, and payment reception, which support their operations (GSMA 2020; Toe/Wallace 2021).

Recent initiatives further underscore the growing importance of agritech in Uganda. For example, the launch of the Uganda DeepTech Centre of Excellence in late 2024 marks a significant step towards fostering applied research and commercialization in the agritech sector. This development suggests that 2025 could be a pivotal year for DeepTech startups in Uganda, particularly in areas such as agritech solutions leveraging artificial intelligence, climate tech innovations aimed at mitigating the effects of climate change, and FinTech platforms designed to deepen financial inclusion (Abuin 2024)

### **1.1.3 Agribusiness efficiency**

Agribusiness efficiency can be primarily understood as the ability of smallholder farmers to maximize their productivity and income while minimizing costs and waste of resources. To achieve this, it involves processes that help to optimize the use of labour, land, inputs, financial resources, and streamlined supply chain management while improving access to markets. Agribusiness efficiency is critical to smallholder farmers as it helps them improve their livelihood and overall farm performance. Recent studies show farmers with smaller land holdings ( $\leq 0.5$  ha) can achieve 21% higher technical efficiency than larger farms due to intensive resource management (Rapsomanikis 2015; Girma Asefa/Ayalew Muluken 2024).

The adoption of digital tools offers smallholder farmers a direct pathway to improving their efficiency. For instance, mobile apps can help farmers access real-time data such as prevailing market prices and crop management advice. This information enables effective planning and adaptive responses to changing conditions (Chhachhar et al. 2014). E-commerce platforms could facilitate efficient supply chain tracking from field to market, reducing post-harvest losses through optimized logistics.

Moreover, digital tools are able to reduce transaction costs by minimizing the reliance on intermediaries (e.g., transport operators). Direct communication with buyers/suppliers via these platforms allows farmers to retain most of their profits compared to traditional methods. Consequently, increased digital adoption enhances operational sustainability while boosting average especially increasing the rate of return slightly for lower income farmers as a study from Luo/Zhu/Song 2023 shows.

#### **1.1.4 Smallholder farmers and the existing digital infrastructure**

In Uganda, smallholder farmers especially in upcountry districts like Luwero have been found to face challenges in adopting digital tools and this can be attributed to lack of adequate digital infrastructure. According to whereas the rate of mobile penetration has reached 75% across the country, access to a reliable internet connection, irregular power supply and high data costs continue to inhibit the adoption of digital tools amongst smallholder farmers. Furthermore, the level of digital literacy among these farmers also remains a challenge. These people lack the knowledge and skills to effectively use digital devices and services to optimise their operations

Finally, whereas digital tools present an opportunity for farmers to increase their efficiency, the ongoing expenses on data also limit the ability of smallholder farmers to adopt digital tools. These issues are further exacerbated by the lack of affordable financial solutions that can help to boost farmers' access to digital solution that they can adopt to improve their operations (Baumüller 2018).

However, recent initiatives could already show some promise: With bundled digital training programs e-seed purchases among Ugandan farmers through new

platforms as EazyAgric was conducted successfully by onboarding 14 training hubs with each supported by four so called “youth digital Agriculture Champions” which help others to use and navigate through the new digital platform (CIGAR 2024). However, sociocultural factors persist – mainly affecting elderly farmers which prefer traditional methods due to mistrust of automated systems (Ajambo et al. 2024).

## 1.2 Problem statement

Despite the recognised potential of digital tools and improved digital infrastructure to improve agribusiness efficiency, their slow adoption continues to inhibit smallholder farmers from optimising the returns from their efforts, particular in upcountry districts like Luwero (Kikulwe et al. 2018). Whereas digital transformation has the capability to enhance access to important market information, financial inclusion and supply chain management, a number of small holder farmers continue to operate inefficiently by relying on traditional farming methods that yield low productivity and income (Chhachhar et al. 2014).

Furthermore, the rate of adoption of digital tools remains low amongst smallholder farmers despite the increasing penetration of mobile technologies (UBOS 2022b). These low adoption rates are more pronounced in rural settings, like Luwero, and are driven by low levels of digital literacy, costly mobile data, unreliable internet connectivity and limited knowledge on how to integrate these tools into their farming practices (Sseguya et al. 2012). According to UBOS 2024, internet usage vastly remains low at usage rates of 16,6% in urban regions to even lower usage rates in rural places with only 4,3%. Additionally the usage gender gap between woman and men is 19.2% woman and 27.9% men (World Wide Web Foundation 2020) over 75% of woman working in the agricultural sector compared to men averaging around 67% according to World Bank Uganda Profile of 2022. This connectivity constraint poses a significant challenge to smallholder farmers who want to adopt e-commerce and other digital tools to access wider markets and to enhance the efficiency of their operations. Additionally, other infrastructure challenges like stable power also limits their ability to fully integrate digital tools in their daily farm practices (Ategeka 2022).

Finally, smallholder farmers also face a problem of lack of sufficient financial resources to acquire digital innovations (Baumüller 2018), emphasizes that smallholder farmers in rural districts lack access to affordable financial solutions that can help to boost their access to the much-needed digital tools in order to improve their agribusiness efficiency. This is worsened by the Ugandan financial system that struggles with inclusivity whereby a significant portion of smallholder farmers remains unbanked and underbanked (GSMA 2020). This limits their access to financial services, including agricultural credit.

Therefore, by investigation the effectiveness of the current digital tools and digital platforms in addressing the challenges faced by smallholder farmers, the study aims to generate recommendations that when implemented can boost the adoption of digital solutions and ultimately boost the efficiency of farmers at increasing productivity and income.

### **1.3 Importance of the study and underlying research questions**

This study is intended to establish how digital tools can improve the efficiency of smallholder farmers in Uganda, particularly in Luwero. By investigating how these technology innovations increase access to market information, financial services and supply chain efficiency, the study aims to promote agricultural productivity and to reduce farmers' transactional costs. Further, the study will also help to reveal barriers to the adoption of digital tools amongst smallholder farmers. Here, by proposing viable solutions to these barriers, the study will help to bridge the digital divide and hence foster a broader adoption of such solutions in rural settings. Finally, this study can be used to inform policy makers, development partners and private sector stakeholders on crafting customised interventions to promote digital transformation of the Ugandan agricultural sector. The two underlying scientific questions for this research study are as follows:

- 1. What is the actual state of the digital transformation and usage of digital tools among smallholder farmers in Luwero, Uganda.*
- 2. What are the results of the use of digital tools to the agribusiness efficiency and what are the main constraining barriers which prevent the use of digital tools.*

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## **2 Literature Review**

### **2.1 Theoretical literature review**

This study is grounded in three theoretical frameworks: the Diffusion of Innovations (DOI) theory, the Technology Acceptance Model (TAM), and the Resource-Based View (RBV). These frameworks were selected because they collectively provide a robust foundation for analyzing how digital tools are adopted and their subsequent impact on agribusiness efficiency among smallholder farmers in Luwero, Uganda.

#### **2.1.1 The diffusion of innovations (DOI) theory**

The Diffusion of Innovations (DOI) theory has been adopted because it offers a comprehensive framework for analyzing how new ideas, technologies, and practices are integrated into social systems (Rogers 2003). It posits that the adoption of innovations occurs through a process comprising five core elements: (1) innovation, (2) communication channels, (3) social systems, (4) perceived attributes of innovation, and (5) the adoption process itself. Tidd and Bessant (2018) define innovation as a novel idea, practice, or technology introduced to a system. In the context of this study, innovation refers to digital tools that, when adopted, improve agribusiness practices among smallholder farmers in Luwero, Uganda. Tsan et al. (2019) emphasize that effective communication acts as a key driver of information exchange about new initiatives, and the choice of communication channel significantly influences adoption rates. For instance, Kikulwe et al. (2018) note that rural areas such as Luwero face limited access to formal information sources, leading farmers to rely on interpersonal communication as their primary mode of information exchange. This reliance underscores the critical role of social networks in disseminating agricultural knowledge (Tsan et al. 2019).

Rogers (2003) defines social systems as the broader societal structures—encompassing cultural, economic, and institutional contexts—that shape the perception and acceptance of digital innovations. Tsan et al. (2019) suggest that these systems exhibit unique dynamics, such as social norms and peer influence, which can accelerate or hinder the adoption of new initiatives. For example,

smallholder farming communities that engage in collective decision-making and experience-sharing can significantly influence how innovations are perceived and adopted. Consequently, farmers who participate in collective learning and knowledge-sharing demonstrate greater success in adopting digital tools compared to those operating in isolation (Tsan et al. 2019).

Therefore, according to Rogers (2003), the innovation diffusion process aims to reduce uncertainty, and he proposes five attributes which will be used to explain the adoption of digital tools among smallholder farmers in Luwero. These attributes include : relative advantage, compatibility, complexity, trialability, and observability.

1. Relative advantage demonstrates the perceived benefits of a new initiative compared to existing practices (Rogers 2003). For instance, digital tools that provide real-time market information to facilitate informed decision-making offer a relative advantage over traditional farming methods (Kikulwe et al. 2018).
2. Compatibility refers to the alignment of the innovation with current farming practices (Rogers 2003). Farmers are more likely to adopt tools that complement their existing workflows, such as mobile apps tailored to local crop cycles (Kikulwe et al. 2018).
3. Complexity is defined as the perceived difficulty of using a new initiative (Rogers 2003). Tools requiring minimal technical expertise—for example, voice-based agricultural advisories—are more likely to gain traction among farmers with limited digital literacy.
4. Trialability refers to the ability to test an innovation on a small scale before full adoption (Rogers 2003). Providing trial opportunities, such as free short-term access to digital platforms, helps farmers build trust and confidence in the tool's utility.
5. Observability involves the visibility of tangible outcomes among peers using the innovation (Rogers 2003). For example, farmers observing increased yields in neighbors using soil-testing apps may be persuaded to adopt similar tools (Kikulwe et al. 2018).

However, Rogers' theory is limited by its assumption of homogeneous social systems and its failure to account for socioeconomic disparities, infrastructural barriers, and digital literacy gaps. Tsan et al. (2019) emphasize that factors like accessibility, affordability, and technical support critically influence adoption in contexts like Luwero, yet these are not addressed in the framework. For example, limited electricity access and high device costs in rural Uganda disproportionately affect marginalized groups, creating adoption inequities (Kikulwe et al. 2018)

### **2.1.2 The Technology Acceptance Model (TAM)**

The Technology Acceptance Model (TAM) was developed by Fred Davis and is recognized for its ability to explain and predict technology adoption behaviors (Davis 1989). This theory focuses on perceived usefulness (PU) and perceived ease of use (PEOU) to explain an individual's decision to adopt and consistently use a particular technology.

Perceived Usefulness (PU) refers to the degree to which an individual believes a certain technology is capable of improving their efficiency (Davis 1989). In the agricultural context, this may refer to the extent farmers perceive digital tools as enablers of their access to reliable market information, improved productivity, and enhanced operational efficiency. When farmers determine that these tools are directly relevant to their livelihood and productivity, they are more likely to adopt them.

Perceived Ease of Use (PEOU) refers to the extent to which an individual finds a technology to be user-friendly (Davis 1989). According to (Chuttur 2009), the perceived complexity of a technology deters its adoption, especially in areas where digital literacy levels are low. In the context of this study, for smallholder farmers with relatively limited experience with digital tools, PEOU can be a critical determinant for adoption. Interfaces with visual aids and language options can reduce the perceived complexity and facilitate wider adoption among users (Venkatesh/Davis 2000).

Therefore, TAM offers a structured framework to support the understanding of adoption behaviors of smallholder farmers regarding digital tools. Kikulwe et al. (2018) suggest that the drive to integrate information and communication

technology (ICT) to improve agricultural productivity has made digital innovation increasingly relevant in rural settings like Luwero. In such areas, PU has been related to financial benefits or the risk reduction capability of a given tool, and farmers perceive digital tools as enhancers of their earnings or mitigators of unpredictable market prices (Tsan et al. 2019). Yet, PEOU is very important as the high levels of digital illiteracy in Luwero can become a significant barrier (Kikulwe et al. 2018). Therefore, digital tools with intuitive user interfaces and language options are more likely to be adopted as they are more practical for individuals with limited technology exposure.

Despite its vital role in predicting technology adoption behaviors, some studies find the theory limited because of its focus on only PU and PEOU while ignoring the diverse, real-world conditions that affect technology adoption (Bagozzi 2007; Chuttur 2009). For instance, the adoption of digital innovation in Luwero may be limited by infrastructural challenges, internet connectivity, and other factors such as electricity, which, for example, was only available to 35% of people in rural regions (Trading Economics 2022). Furthermore, TAM barely addresses societal factors in Luwero where norms and shared practices influence decision-making at an individual level (Bagozzi 2007). For instance, it does not account for potential resistance that can arise from traditional practices and distrust toward technology among the smallholder farmer population in Luwero. Such factors could impede the adoption of digital tools. Therefore, this study will use TAM alongside other models that account for external environmental factors."

### **2.1.3 The Societal Cognitive Theory (SCT)**

The Social Cognitive Theory (SCT) has been adopted because it offers a comprehensive framework for understanding how behaviour, personal factors, and environmental factors interact to form human actions (Bandura 1986). This theory stands out because it combines both behavioural and cognitive dimensions, thus suggesting that individuals are motivated not only by internal factors but also by external factors. The SCT is a triadic model that integrates behaviour, personal factors, and environmental factors to reveal how people learn through observing others, develop beliefs about their capabilities, and evaluate the outcomes of diverse actions (Bandura 1986).

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Observational learning, one of the core elements of the SCT, helps to describe how individuals learn new practices and skills by observing others. This contrasts with other classical theories that focus on learning through direct experiences (Bandiera/Rasul 2006). According to Bandura (1986), when individuals observe successful outcomes from others' behaviours, they develop a sense of the benefits and challenges associated with a certain course of action. For instance, when smallholder farmers in Luwero observe their peers successfully leveraging a digital tool or initiative, they can be persuaded to adopt a similar method. Therefore, the SCT presents observational learning not just as imitation, but as a cognitive process where individuals gauge the actions of others to establish how these behaviours align with their goals and available resources (Bandura, 1986). This implies that individuals not only copy but incorporate their observed behaviours with their personal experiences and expectations.

Self-efficacy is another key component of the SCT. Bandura (1986) defines it as a person's belief in their capacity to execute behaviours needed to produce specific outcomes. He suggests that self-efficacy is very important as it influences the actions that individuals take, the amount of effort they invest, and the resilience they demonstrate when they encounter setbacks. In this context, individuals with a high sense of self-efficacy will attempt challenging tasks and persist through obstacles, while those with low self-efficacy will demonstrate avoidance and are highly likely to abandon tasks when faced with obstacles. For smallholder farmers, those who believe they can use new tools and practices are more likely to adopt them even when faced with resource constraints (Bandura 1986).

Outcome expectations is the third key component of the SCT. Bandura (1986) suggests that individuals are highly likely to adopt new practices when they anticipate positive outcomes from their actions. This component resonates with the smallholder farmers' community in Luwero, where they might consider the adoption of new initiatives or digital tools if they perceive that the changes will bring improvements to their productivity (Davis 1989). For instance, when farmers anticipate that adopting a new technology or farming practice will likely improve their yields, they become inclined to implement it in order to meet their expectations.

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In the context of this study, Bandiera & Rasul (2006) established that farmers in rural settings like Luwero rely on social networks to determine the adoption of new technologies. These farmers use the experiences of their peers to determine the efficacy of these new tools. This reliance on social learning and self-efficacy can be attributed to low digital literacy and resource constraints, making peer influence the primary source of information (Sebatta et al. 2018). Therefore, the theory offers a valuable lens for examining how smallholder farmers embrace digital tools and innovative farming practices. Observational learning stands out strongly as farmers are more likely to adopt digital tools after seeing their peers benefit from them. This aligns with the Diffusion of Innovations theory, which suggests that noticeable success from early adopters boosts wider acceptance of an innovation within a community (Rogers 2003).

However, despite its applicability to smallholder farmers, SCT has limitations when applied to resource-constrained areas like Luwero. The theory does not comprehensively address the structural barriers that limit the adoption of new technologies or initiatives (Davis 1989). For instance, farmers may have high self-efficacy and positive outcome expectations but have limited access to digital infrastructure, poor technical support, and face high costs. The theory also assumes that individuals have the autonomy to act on their beliefs and observations, but this is not always the case in rural settings where socio-economic constraints limit their decision-making capacity (Davis 1989).

The integration of these theories has been used to generate a comprehensive approach that captures both personal motivations and broader environmental factors that are relevant in improving digital adoption among smallholder farmers.

## **2.2 Empirical work review**

### **2.2.1 Digital transformation in agriculture**

Studies on digital transformations in the Ugandan agriculture sector have revealed that digital tools are paramount in improving farm productivity and efficiency. For instance, Baumüller (2018) and (Paparrizos/Vignola/Sutanto 2024) have demonstrated that digital platforms offer smallholder farmers access to real-time market information, weather forecasts, and other best practices in crop management. Such information has been found to have a strong positive correlation with improved resource allocation and decision-making and can help to reduce costs for fertilizers by up to 50%. In these studies, digital tools like PlantVillage, an AI-powered app for diagnosing crop diseases, and Hello Tractor, a platform for connecting farmers to tractor owners, as well as Apps like DROP, a hydro-climatic information service, have been found to be transformative. While these studies find such tools improve productivity, their effectiveness of use has been found to rely on a farmer's awareness, accessibility, and ease of use. This implies that smallholder farmers require digital literacy programs and infrastructure support in order to maximize the use of the available platforms.(CIGAR 2024)

### **2.2.2 Mobile technology adoption and use**

Studies on mobile adoption among smallholder farmers have found it to be widely varied and greatly limited by literacy, income levels, and local infrastructure. For instance, (Tuheirwe-Mukasa et al. 2019) showed that there is a moderate adoption rate, especially among younger farmers who have the literacy to acknowledge the technology's utility in improving agricultural productivity. Additionally, Aker and Mbiti (2010) identified barriers that discourage the use of technology, which included limited technical knowledge and cultural opinions. Tuheirwe-Mukasa et al. (2019) also suggest that farmers who adopt mobile technology benefit from improved communication with buyers and suppliers, have more efficient processes, and are able to eliminate middlemen. However, these studies highlighted the requirement for customized interventions such as local language applications, training programs, and strategies to improve accessibility for less literate smallholder farmers.

### **2.2.3 E-commerce and market access**

E-commerce platforms have been found to have positive effects on how smallholder farmers access markets. Wossen et al. (2017) found e-commerce to have a reducing effect on geographical constraints by allowing farmers to reach a larger and more diverse customer base with higher bargaining power. For instance, in Kenya, a platform like M-Farm has been relied upon for real-time market prices, helping farmers to reduce price exploitation from middlemen (Wossen et al. 2017). Furthermore, empirical data from other regions with similar conditions to Luwero, e.g., Kenya and Tanzania, have underscored the importance of e-commerce in increasing revenue. This is especially true for perishable goods like fruits and vegetables that require reduced time to market. However, challenges, particularly poor internet access and trust issues, continue to impede the adoption of digital payment systems, and this requires additional measures to secure farmers' trust and participation.

### **2.2.4 Financial services in agribusiness**

Digital financial services, presented as mobile money and digital credit platforms, are used to improve financial inclusion among smallholder farmers. A study by Suri and Jack (2016) on the adoption of M-Pesa in Kenya revealed that mobile money strongly increases financial security for smallholder farmers, thus improving their access to credit and savings. In Uganda, Kasirye and Masum (2021) reveal that mobile money enhanced farmers' access to inputs. Here, they are more able to buy seeds, fertilizers, and pesticides directly through their mobile transactions. They also showed that farmers have access to more credit options, e.g., Farmer's Friend, that help them overcome liquidity limitations, especially during planting seasons. However, farmers continue to face limitations from high transaction-associated costs and low digital literacy levels. These factors limit extensive adoption, thus underscoring the need for affordable, farmer-friendly digital financial services (Kasirye/Masum 2021).

### **2.2.5 Limitations of digital infrastructure**

Poor internet connectivity and irregular power connections are the most significant limitations to digital adoption among smallholder farmers in rural areas like Luwero. For instance, according to (Nyasimi, Mary 2022), digital adoption in rural areas faces numerous connectivity gaps that limit the ability of smallholder farmers to fully exploit digital tools. UBOS (2024) displayed that more than 80% of rural households lacked consistent internet access, creating a barrier to e-commerce and digital financial services adoption. Furthermore, lack of a consistent power supply also limits the usability of digital tools as farmers frequently have depleted device batteries. The adoption of solutions like solar-powered devices and offline-enabled applications are put forward as potential mitigation strategies for these challenges. Studies need to be performed to generate insight into the effectiveness of these strategies in rural settings.

### **2.2.6 Similar case comparisons**

There are a number of comparative studies that have demonstrated successful adoption of digital tools in rural areas like Luwero, and these can be used for revealing best practices and possible adaptable solutions. For instance, (Sartas et al. 2024) reveal a successful tool in Rwanda, Smart Nkunganire System (SNS), that has been adopted to connect farmers with agro-dealers and financial institutions. This has helped to improve input purchases and access to credit digitally. The success of this tool is attributed to government support, strong digital infrastructure, and farmer training. Another case is in Ghana, where a tool, Farmerline, is used to provide digitally oriented agricultural education through mobile voice services in local languages (Senyo 2018). This demonstrated the importance of adapting local languages in driving adoption among rural farmers. Therefore, these studies present a lesson that for rural areas like Luwero, integration of government assistance with local language services and improvements in infrastructure can enhance the adoption and use of digital tools.

### **2.2.7 Identification of the Knowledge Gap**

Whereas existing studies underscore the importance of digital transformation for smallholder farmers in rural areas, there still exist gaps in understanding the long-term impacts and scalability of specific digital tools. For instance, limited studies have focused on examining the sustained economic importance of mobile apps and e-commerce for farmers outside the initial adoption phase (Paparrizos/Vignola/Sutanto 2024). Also, a gap exists in the gendered effects of digital transformation. The study by Kikulwe et al. (2018) revealed that women often face added barriers to digital access, and studies examining possible solutions to this challenge are limited. Therefore, addressing such gaps will be very important in developing a sustainable and inclusive digital strategy for smallholder farmers.

## 2.3 Conceptual framework

A conceptual framework to demonstrate the relationship that are believed to exist between variables as shown in Figure 4.

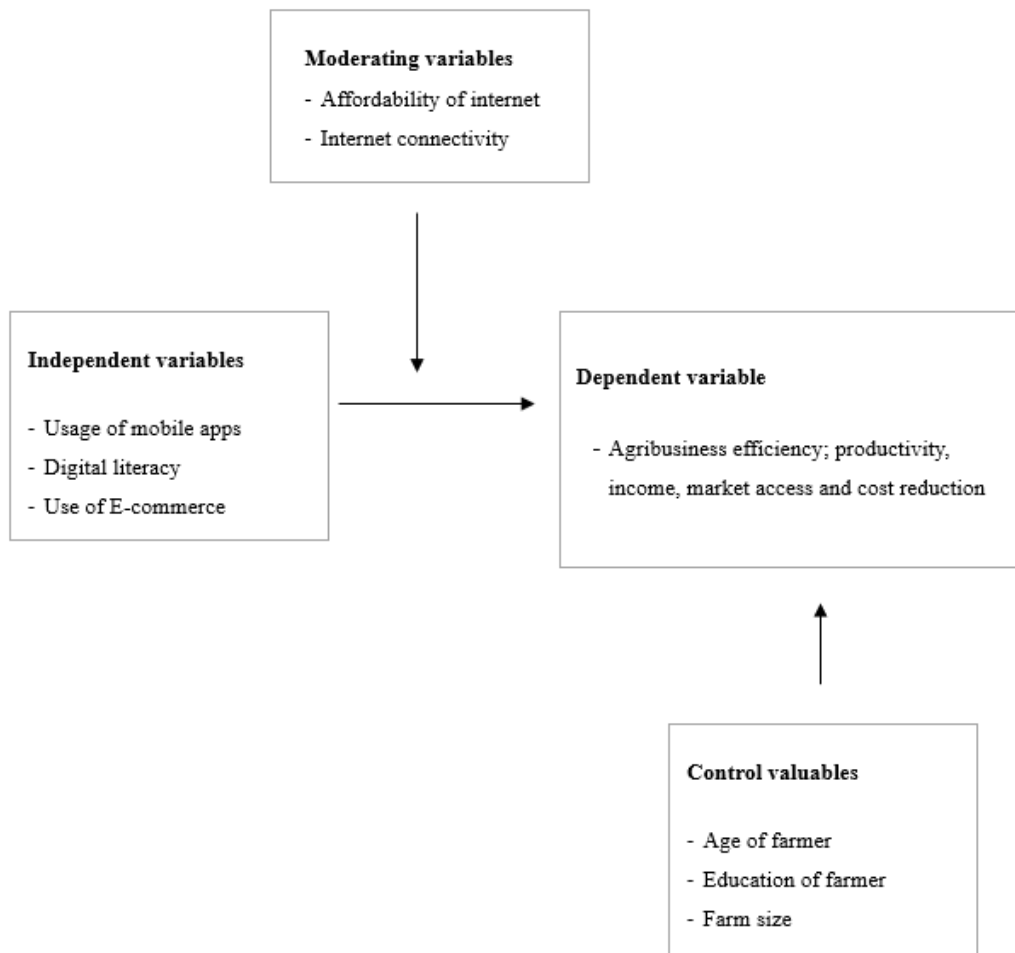


Figure 4: Conceptual framework, own representation

### **3 Methodology**

This chapter details the methodological research approach to examine the role of digital tools and digital infrastructure in improving agribusiness efficiency among smallholder farmers in Luwero, Uganda. The study employs a mixed-methods approach to comprehensively assess the impact of mobile apps, e-commerce platforms, and digital infrastructure on agricultural productivity and market access.

#### **3.1 General Research design**

The study adopts a mixed methods research design where both qualitative and quantitative approaches are used to generate a comprehensive understanding of digitalization in agribusiness. This design helps the researcher integrate data on efficiency and digital transformation with qualitative insights into farmer experiences and perceptions (Plano Clark/Ivankova 2016). In this design, quantitative data is collected using a structured closed-ended questionnaire administered to the sample population. Qualitative data is collected using semi-structured interviews and focus group discussions conducted with a section of the study population. Data from both approaches is then combined through triangulation to help the researcher draw comprehensive conclusions (Creswell/Plano Clark 2018).

#### **3.2 Sampling technique and sample size**

The study adopts a purposive sampling technique where the researcher intentionally chooses participants based on their direct experiences or insights into digital tools in agribusiness (Patton 2002). This technique has been adopted because not all smallholder farmers in Luwero use digital tools in agribusiness, thus enabling the study to capture the perspectives of only those with first-hand information about the usability, benefits, and challenges of the available digital tools (Etikan/Musa/Alkassim 2015). Furthermore, using this technique helps the research to sample those who have actively used, have engaged with, and those who have chosen not to adopt digital tools. This generates rich and comprehensive insights into the adoption process, challenges, and the impacts of digital tools on agribusiness efficiency (Creswell/Poth 2018). Finally,

participants are drawn from diverse regions across Luwero in order to capture variations in adoption rates across subgroups of smallholder farmers. This enables the study to offer a broad and relevant set of perspectives about the study variables.

The study considers 30 participants for in-depth interviews, including farmers (small and medium scale) who actively use or have attempted to use digital tools, agribusiness owners who have integrated digital platforms in their operations, and agricultural extension officers knowledgeable about digital adoption trends in the area. The researcher believes that the sample size is large enough to collect diverse perspectives. This population may vary dependent on when data saturation is achieved (Guest/Bunce/Johnson 2006).

Table 1: Study population for the qualitative tool

Stakeholder group	Sample size	Percentage
Farmer	15	60
Agribusiness owner	10	33
Extension officer	5	17
<b>Total</b>	<b>30</b>	<b>100</b>

The study employs a sample of 100 respondents for its quantitative component seen in Table 1. This sample size is designed to generate broader responses and produce generalizable findings (Krejcie/Morgan 1970). The larger quantitative sample complements the in-depth qualitative data, providing a more comprehensive understanding of digital tool adoption and usage patterns among smallholder farmers in Luwero.

### 3.3 Methods for data collection and data collection instruments

The study follows a mixed methods research design and relies on both quantitative and qualitative data collection methods to capture a comprehensive view of the study variables. Qualitative data generates a deeper contextual

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understanding while quantitative data provides measurable insights of the variables (Creswell/Plano Clark 2018).

A closed-ended questionnaire serves as the primary instrument for collecting quantitative data. It is structured to capture demographic information of participants, their patterns of using digital tools and infrastructure (i.e., mobile apps, internet, mobile financial services), and their perceived impact of digital tools on agribusiness efficiency (i.e., productivity, income, market access, cost efficiency). This tool is ideal because it ensures consistency across the study population (Bryman 2016).

An interview guide with semi-structured questions is used to collect qualitative data and is designed to capture key areas including: farmers' and agribusiness owners' experiences with digital technologies, barriers and facilitators of digital tool adoption, and perceived impact of digital adoption on agribusiness outcomes. This tool has been adopted because it allows the researcher to probe deeper into the participants' responses, leading to more comprehensive findings (Creswell/Poth 2018).

### **3.4 Validity and reliability instruments**

Validity and reliability of quantitative research:

Content validity will be established through expert review, with agricultural experts and digital tool users in agribusiness examining the tool items to ensure they adequately address the study objectives. Construct validity will be assessed by aligning the questionnaire items with credible frameworks on digital adoption and agribusiness efficiency (Creswell/Plano Clark 2018). To ensure the questionnaire's reliability, the researcher will conduct a pilot test of the instrument on a small sample of respondents before the main data collection phase. This activity will allow the researcher to examine and improve any ambiguous items to ensure consistent responses (Kumar 2018).

Validity and reliability of qualitative research:

The researcher will use triangulation to cross-verify findings, ensuring data credibility (Patton 2002). Member checking will be employed to validate the

interpretation of interview responses by allowing participants to review and confirm the accuracy of their submissions (Lincoln/Guba 1985). While there is no universally accepted approach or set of criteria for evaluating qualitative research, it remains crucial to assess the quality of such investigations in terms of reliability, validity, and scientifically sound evidence. The absence of standardized metrics underscores the need for nuanced and context-specific assessment strategies (Noble/Smith 2024).

The dependability of data will be ensured by keeping detailed records of the data collection process, interview, and focus group procedures. This will help the research offer transparency and ensure replication of findings by other researchers (Creswell/Poth 2018). Finally, the researcher will maintain an audit trail where all decisions are recorded, including interpretations and processes.

### **3.5 Procedure of data collection and data analysis**

The research begins data collection by securing approval from respondents and ensures that the study adheres to research ethical guidelines, particularly regarding confidentiality and informed consent (Bryman 2016). Quantitative data collection occurs through administering a questionnaire either in person or electronically, depending on respondents' access to digital tools. A trained data collector with competencies in local languages assists the researcher to ensure accurate responses. Qualitative data is collected through focus group discussions in convenient locations. Each session is recorded, with participants' consent, and the researcher also takes field notes to record non-verbal cues and contextual information. The data collection is expected to take 2 weeks.

Quantitative data is processed and analysed using descriptive and inferential statistics. Descriptive statistics such as mean, median, and frequency are used to summarize demographic characteristics and digital tool usage patterns of respondents, while inferential statistics, including correlation and regression analysis, are used to examine relationships between study variables (Bryman 2016). SPSS serves as the statistical software for this analysis. Qualitative data is analyzed using thematic analysis following a process that includes: familiarization with data, coding, identifying themes, reviewing themes, defining themes, and final write-up (Braun/Clarke 2006). NVivo is utilized for this analysis

### **3.6 Ethical considerations**

The researcher protects the rights of respondents through the following measures: ensuring that no respondent is named during the study and subsequent thesis, selecting respondents without compulsion, and fully briefing participants about the reason and purpose of the study. Additionally, informed consent is obtained from all participants prior to data collection, with clear explanations of how their information will be used and stored. Participants are informed of their right to withdraw from the study at any point without consequences. All data is anonymized during analysis and reporting, with identifying information removed to maintain confidentiality. Data security protocols are implemented to protect participant information throughout the research process.

## **4 Presentation and interpretation of findings**

This chapter presents the findings from both qualitative and quantitative data collection on the role of digital tools and digital infrastructure in improving agribusiness efficiency among smallholder farmers in Luwero. A qualitative data collection tool was used to interview 30 participants, while 89 respondents out of the 100 anticipated were able to participate in the closed-ended questionnaire. The response rate of 89% for the quantitative component provides a robust basis for statistical analysis and generalizable insights into digital tool adoption patterns among the target population.

### **4.1 Quantitative analysis**

This section follows a structured approach where descriptive analysis is used to generate a basic understanding of respondent characteristics and usage of digital tools, while inferential analysis examines the relationships between the independent variables and the dependent variables. The mixed-methods design enables triangulation of findings, with quantitative data providing measurable patterns and qualitative insights offering deeper contextual understanding of digital tool adoption among Luwero farmers.

#### **4.1.1 Demographic characteristics of respondents**

These findings are evaluated to generate an understanding of the context within which digital tools are adopted and leveraged by smallholder farmers. Table 2 contains a summary of their key demographic characteristics.

Table 2: Demographic characteristics

Demographic data	Category	Frequency (n)	Percentage (%)
<b>Gender</b>	Male	52	58.4
	Female	37	41.6
<b>Age</b>	18 – 30	25	28.1
	31 – 40	39	43.8
	41 – 50	20	22.5
	51+	5	5.6
<b>Level of education</b>	No formal education	11	12.4
	Primary school	37	41.6
	Secondary school	31	34.8
	Tertiary school	10	11.2
<b>Size of the farm</b>	Less than 1 acre	15	16.9
	1 – 3 acres	48	53.9
	4 – 6 acres	18	20.2
	More than 6 acres	8	9.0

The study population is predominantly male (58.4%) with female respondents constituting 41.6%. This indicates that men dominate the smallholder farmer population in Luwero. The majority of respondents (43.8%) are aged between 31-40 years, while only 5.6% are aged above 50 years. This suggests that the smallholder population engaged in farming innovations is largely youthful. Furthermore, 34.8% of participants have attained secondary level education, and most have at least primary level education, with only 12.4% having no formal education. This implies that most of the smallholder farmer population is able to read and write. Finally, the average farm size is 1-3 acres (53.9%), followed by 4-6 acres (20.2%), with relatively few smallholder farmers (9%) having more than 6 acres.

### 4.1.2 Usage of digital tools

The study also analyzes the level of awareness of digital tools and their usage, with results presented in Table 3 below.

Table 3: Usage of digital tools

	<b>Response</b>	<b>Freq (n)</b>	<b>Percentage (%)</b>
<b>Awareness of digital tools</b>	Yes	67	75.3
	No	22	24.7
<b>Usage of tools</b>	Mobile apps for farming	25	28.1
	Ecommerce platforms	18	20.2
	Mobile payment platform	58	65.2
	None	22	24.7

The study finds that 75.3% of the study population is aware of the presence of digital tools, while 24.7% were not aware of them at all. This indicates that most smallholder farmers have knowledge of digital tools, though their level of awareness and usage of individual tools differs. In terms of usage, mobile payment platforms are most common at 65.2%, followed by mobile apps for farming at 28.1%. Additionally, e-commerce platforms are least used at 18%, while 24.7% do not use digital tools at all. This implies that the adoption of mobile financial services is strong, while that of e-commerce is low.

### 4.1.3 Descriptive statistics of key variables

The mean and standard deviation (SD) of key variables was calculated as per findings in Table 4 below.

Table 4: descriptive findings

Variable	Mean	Standard deviation	Minimum	Maximum
Usage of mobile apps	3.48	0.82	1	5
Usage of e-commerce	2.79	0.91	1	5
Digital literacy	3.62	0.89	1	5

#### a. Usage of mobile apps

The usage of mobile apps is analyzed to determine the extent to which smallholder farmers use mobile apps in their day-to-day activities. Respondents are asked to rate their usage of mobile apps for agribusiness on a 1-5 Likert scale, where 1 represents "never used" and 5 represents "very frequently use." The mean usage of mobile apps is 3.48, implying that smallholder farmers moderately use mobile apps in their farming practices. The standard deviation of 0.82 demonstrates that the responses of participants in the study are moderately dispersed around the mean.

#### b. Usage of e-commerce

The use of e-commerce is analyzed to determine how smallholder farmers use e-commerce to improve their access to markets and agribusiness efficiency. Respondents are asked to rate their usage of e-commerce platforms for buying or selling farm produce on a 1-5 Likert scale, where 1 represents "never used" and 5 represents "very frequently used." Findings reveal a mean score of 2.79, implying that farmers report a low to moderate use of e-commerce platforms. Moreover, a standard deviation of 0.91 indicates a relatively high level of variability in the usage of e-commerce. This suggests that whereas some farmers use e-commerce platforms regularly, others rarely or never use them.

### c. Digital literacy

Establishing the level of digital literacy is crucial in the adoption of digital tools for agribusiness. Respondents are asked to rate their level of digital literacy on a 1-5 Likert scale where 1 represents "very low" and 5 represents "very high." Findings reveal a mean score of 3.62 for digital literacy, implying that respondents possess moderate digital literacy skills. The standard deviation of 0.89 demonstrates that whereas some farmers have higher digital literacy, others have limited knowledge, which affects their ability to use digital tools.

#### 4.1.4 Pearson correlation coefficient analysis

A Pearson correlation coefficient analysis was used to assess the strength of the relationship between the independent variables and the dependent variable. The results of this analysis are presented in Table 5 below.

Table 5: Pearson correlation coefficient analysis

Variable	1	2	3	4	5	6	7
<b>Usage of mobile apps (1)</b>	1						
<b>Use of e-commerce (2)</b>	0.624**	1					
<b>Digital literacy (3)</b>	0.712**	0.624**	1				
<b>Productivity (4)</b>	0.652**	0.572**	0.678**	1			
<b>Market access (5)</b>	0.421**	0.482**	0.543**	0.621**	1		
<b>Income (6)</b>	0.382**	0.442**	0.512**	0.634**	0.576**	1	
<b>Cost reduction (7)</b>	0.345**	0.312**	0.497**	0.481**	0.439**	0.563**	1

N = 89, \*p < 0.05, \*\*p < 0.01

A Pearson product moment correlation coefficient ( $r$ ) is computed to assess the relationship between the independent variables (usage of mobile apps, digital literacy, use of e-commerce) and their impact on the outcomes of agribusiness efficiency (productivity, market access, income and cost reduction).

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The usage of mobile apps reveals a significant positive correlation with all four outcomes of agribusiness efficiency at 95% confidence level. It correlates strongly with productivity ( $r = 0.652, p < 0.01$ ), market access ( $r = 0.421, p < 0.01$ ), income ( $r = 0.382, p < 0.01$ ) and cost reduction ( $r = 0.345, p < 0.01$ ). This implies that an increase in the use of mobile apps enhances agribusiness efficiency. This is consistent with the Technology Acceptance Model (TAM) which suggests that smallholder farmers are more likely to use mobile apps if they identify them to be resourceful and user-friendly (Davis 1989).

The use of e-commerce also has a strong significant relation with the outcomes of agribusiness efficiency at 95% confidence levels whereby: productivity ( $r = 0.572, p < 0.01$ ), market access ( $r = 0.482, p < 0.01$ ), income ( $r = 0.442, p < 0.01$ ) and cost reduction ( $r = 0.312, p < 0.01$ ). These findings suggest the strongest association to be with productivity, implying that e-commerce facilitates access to markets which helps smallholder farmers to generate better outputs. This finding is supported by the Diffusion of Innovation (DOI) theory which suggests that early adopters of e-commerce can enjoy a competitive advantage through better market access (Rogers 2003).

Digital literacy demonstrates the strongest positive correlation with all four outcomes of agribusiness efficiency: productivity ( $r = 0.678, p < 0.01$ ), market access ( $r = 0.543, p < 0.01$ ), income ( $r = 0.512, p < 0.01$ ) and cost reduction ( $r = 0.497, p < 0.01$ ). The high correlation with productivity demonstrates that smallholder farmers with higher levels of digital literacy are better positioned to adopt digital tools. This is consistent with Social Cognitive Theory (SCT) which suggests that self-efficacy enhances technological adoption (Bandura 1986).

#### 4.1.5 Regression analysis

A multiple regression analysis was performed to measure the extent at which independent variables predict agribusiness outcomes amongst smallholder farmers in Luwero. A standard multiple linear regression model was adopted for this analysis (Wooldridge 2016).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where:

Y = Agribusiness efficiency measured using its outcomes

$\beta_0$  = constant

$\beta_1 \beta_2 \beta_3$  = coefficients of independent variables

$X_1$  = usage of mobile apps

$X_2$  = use of e-commerce

$X_3$  = digital literacy

$\varepsilon$  = error

Table 6: Regression analysis for productivity

<i>Variable</i>	<i>Unstandardised coefficient (B)</i>	<i>Standard Error (SE)</i>	<i>Standard Coefficient (<math>\beta</math>)</i>	<i>t- value</i>	<i>p-value</i>
<i>Constant</i>	1.233	0.413	-	2.99	0.004**
<i>Usage of mobile apps</i>	0.411	0.086	0.432	4.78	0.000**
<i>Use of e-commerce</i>	0.321	0.095	0.318	3.38	0.001**
<i>Digital literacy</i>	0.498	0.089	0.521	5.59	0.000**
<i>R<sup>2</sup></i>	0.631				
<i>Adjusted R<sup>2</sup></i>					
<i>F – statistic</i>	42.18				
<i>p-value (F-test)</i>	0.000				

N = 89, \*p < 0.05, \*\*p < 0.01

The findings explain 63.1% ( $R^2 = 0.631$ ) of the variability in productivity, implying a solid predictive ability of the independent variables. The regression coefficients for usage of mobile apps ( $B = 0.411$ ), use of e-commerce ( $B = 0.321$ ), and digital literacy ( $B = 0.498$ ) are all statistically significant at 95% confidence levels. This means that any increase in any of these variables will result in an increase in productivity. Moreover, the variable digital literacy ( $\beta = 0.521$ ) has the strongest ability to influence productivity, underscoring the importance of smallholder farmers' ability to apply digital tools effectively.

Table 7: Regression results for market access

<i>Variable</i>	<i>Unstandardised coefficient (B)</i>	<i>Standard Error (SE)</i>	<i>Standard Coefficient (<math>\beta</math>)</i>	<i>t- value</i>	<i>p-value</i>
<i>Constant</i>	1.412	0.512	-	2.76	0.007**
<i>Usage of mobile apps</i>	0.287	0.072	0.421	3.99	0.000**
<i>Use of e-commerce</i>	0.458	0.103	0.476	4.44	0.000**
<i>Digital literacy</i>	0.382	0.078	0.439	4.90	0.000**
<i>R<sup>2</sup></i>	0.589				
<i>Adjusted R<sup>2</sup></i>	0.576				
<i>F – statistic</i>	36.82				
<i>p-value (F-test)</i>	0.000				

N = 89, \*p < 0.05, \*\*p < 0.01

The model explains 58.9% ( $R^2 = 0.589$ ) of the variability in market access. The regression coefficients for usage of mobile apps ( $B = 0.287$ ), use of e-commerce ( $B = 0.458$ ), and digital literacy ( $B = 0.382$ ) are all statistically significant at 95% confidence levels. This means that any increase in any of these variables will result in better market access. Moreover, the variable use of e-commerce ( $\beta = 0.458$ ) has the strongest impact on market access. These findings are consistent with the Diffusion of Innovation (DOI) theory that suggests early adopters of e-commerce technologies access larger and more diverse markets (Rogers 2003).

Table 8: Regression results for income

<i>Variable</i>	<i>Unstandardised coefficient (B)</i>	<i>Standard Error (SE)</i>	<i>Standard Coefficient (<math>\beta</math>)</i>	<i>t- value</i>	<i>p-value</i>
<i>Constant</i>	1.197	0.567	-	2.11	0.038*
<i>Usage of mobile apps</i>	0.254	0.084	0.312	3.02	0.003**
<i>Use of e-commerce</i>	0.297	0.089	0.342	3.34	0.001**
<i>Digital literacy</i>	0.381	0.099	0.478	3.85	0.000**
<i>R<sup>2</sup></i>	0.527				
<i>Adjusted R<sup>2</sup></i>	0.509				
<i>F – statistic</i>	28.74				
<i>p-value (F-test)</i>	0.000				

N = 89, \*p < 0.05, \*\*p < 0.01

The model explains 52.7% ( $R^2 = 0.527$ ) of the variability in income. The regression coefficients for usage of mobile apps ( $B = 0.254$ ), use of e-commerce ( $B = 0.297$ ), and digital literacy ( $B = 0.381$ ) are all statistically significant at 95% confidence levels. This means that any increase in any of these variables will result in an increase in income. Moreover, the variable digital literacy ( $\beta = 0.381$ ) has the strongest ability to influence income. This finding is consistent with the Social Cognitive Theory (SCT) which underscores the importance of self-efficacy in influencing the decision-making ability of smallholder farmers at an individual level (Bandura 1986). This implies that farmers with strong self-efficacy are more likely to use mobile apps and e-commerce platforms to boost their income.

Table 9: Regression results for cost reduction

<i>Variable</i>	<i>Unstandardised coefficient (B)</i>	<i>Standard Error (SE)</i>	<i>Standard Coefficient (<math>\beta</math>)</i>	<i>t- value</i>	<i>p-value</i>
<i>Constant</i>	1.129	0.465	-	2.43	0.017*
<i>Usage of mobile apps</i>	0.292	0.078	0.412	3.74	0.000**
<i>Use of e-commerce</i>	0.389	0.089	0.451	4.37	0.000**
<i>Digital literacy</i>	0.421	0.093	0.482	4.53	0.000**
<i>R<sup>2</sup></i>	0.564				
<i>Adjusted R<sup>2</sup></i>	0.564				
<i>F – statistic</i>	38.92				
<i>p-value (F-test)</i>	0.000				

N = 89, \*p < 0.05, \*\*p < 0.01

The model explains 58.2% ( $R^2 = 0.582$ ) of the variability in cost reduction, implying a solid ability to predict the impact of independent variables. The regression coefficients for usage of mobile apps ( $B = 0.292$ ), use of e-commerce ( $B = 0.389$ ), and digital literacy ( $B = 0.421$ ) are all statistically significant at 95% confidence levels. This indicates that an increase in any of these variables will result in better cost reduction. The findings are consistent with the Diffusion of Innovation (DOI) theory that suggests early adopters of e-commerce incur lower transaction costs because they are able to overcome reliance on middlemen in the value chain (Rogers 2003)

#### 4.1.6 Conclusion of the regression analysis

The  $R^2$  values (e.g., 0.631 for productivity, 0.589 for market access, 0.527 for income, and 0.564 for cost reduction) indicate that the independent variables explain a reasonable portion of the variance in the dependent variables. This is acceptable in social science research.

The F-statistic values are significant ( $p < 0.01$ ), which means that the overall regression models are statistically valid.

##### 4.1.6.1 Accuracy of Regression Components

###### ***Regression Coefficients (B):***

The coefficients for mobile apps, e-commerce, and digital literacy in all models are positive, which aligns with theoretical expectations. For example:

- Productivity:  $B_{\text{mobile apps}}=0.411$ ,  $B_{\text{e-commerce}}=0.321$ ,  $B_{\text{digital literacy}}=0.498$
- Cost reduction:  $B_{\text{mobile apps}}=0.292$ ,  $B_{\text{e-commerce}}=0.389$ ,  $B_{\text{digital literacy}}=0.421$ .

These values suggest that an increase in the use of digital tools is associated with improvements in agribusiness efficiency.

###### **Standard Errors (SE):**

The reported standard errors are within an acceptable range, showing that the coefficient estimates are stable.

However, some standard errors appear slightly large relative to their coefficients, which may indicate multicollinearity. Checking for variance inflation factors (VIF) would help confirm this.

###### **t-values and p-values:**

All variables show statistically significant t-values ( $p < 0.01$  or  $p < 0.05$ ), which confirms that each independent variable significantly contributes to explaining agribusiness efficiency.

The constant term (intercept) is significant in some models but not in others. This could imply that some unknown factors affecting agribusiness efficiency are missing from the model.

#### **4.1.6.2 Potential Issues and Recommendations**

##### **1. Multicollinearity Concern:**

The high correlation values between digital literacy and both mobile apps ( $r = 0.712$ ) and e-commerce ( $r = 0.624$ ) suggest possible multicollinearity.

A VIF test should be conducted to verify whether collinearity affects the reliability of coefficient estimates.

##### **2. Model Fit Adjustments:**

The adjusted  $R^2$  values are slightly lower than the  $R^2$  values, indicating that some independent variables may not add much explanatory power.

Adding control variables such as education level, farm size, and access to extension services might improve model accuracy.

##### **3. Heteroskedasticity Test:**

The model assumes homoskedasticity (constant variance of errors). Performing a Breusch-Pagan test would verify if heteroskedasticity is present.

If heteroskedasticity is found, using robust standard errors is recommended.

#### **4.1.6.3 Overall Assessment**

The coefficients, standard errors, and p-values are mostly appropriate, though some minor concerns (e.g., multicollinearity, large standard errors) can be addressed to enhance the findings. Including additional diagnostic tests (VIF for multicollinearity, Breusch-Pagan for heteroskedasticity) can also enhance the robustness of the findings (Kim 2019; Lee 2025). This however is not considered in this study as the statistical analysis is used in combination with qualitative analysis and would therefore be beyond the scope of this work.

## 4.2 Qualitative data analysis

This section presents the findings based on the data collected from 30 in-depth interviews with three categories of respondents: smallholder farmers, agribusiness owners, and agricultural extension workers. The researcher used thematic analysis to identify, analyze, and report on recurring patterns and themes. The findings have been organized into key themes that reflect the objectives of the study.

### 4.2.1 Thematic analysis and Key themes from the qualitative data

The study follows Braun and Clarke's (2006) six-step framework that involves familiarization, code generation, theme searching, reviewing of themes, defining and naming themes, and finally a coherent analysis.

#### 4.2.1.1 Awareness and Use of digital tools

##### **Theme 1. The awareness of digital tools for use in agribusiness varies amongst farmers**

The awareness of digital tools among smallholder farmers is relatively high. Smallholder farmers cite mobile money payment as the most common digital tool, while e-commerce platforms are the least preferred. Respondents emphasize that the usage of mobile payment platforms, like Airtel Money and MTN Mobile Money, is very common in their daily practices.

*A 32-year-old farmer states: "For us, mobile money helps us a lot, we use it to receive money from buyers and make payments to suppliers easily with our phones. Without mobile money, performing our daily farming business would be somewhat difficult."*

This reliance on mobile money is consistent with the findings in quantitative data analysis that found that 65.2% of respondents demonstrated frequent usage of mobile payment platforms. However, the limited usage of e-commerce by smallholder farmers is attributed to unfamiliarity with the platforms and internet instability.

An extension worker states: *"Many farmers have never used e-commerce platforms, like EzyAgric, because they do not know how to use them. Many fear that their money or produce might get lost."*

This finding underscores the relevance of digital literacy in promoting e-commerce adoption and is consistent with the Diffusion of Innovation theory where late adopters express significant concern about the visibility of benefits (Rogers 2003).

#### **4.2.1.2 Benefits of digital tools**

### **Theme 2. Digital tools enhance productivity and efficiency in agribusiness**

Productivity - Participants cite that whereas digital tools have a limited impact on income, they strongly contribute to productivity, market access, and operational efficiency. Smallholders who report that their planning and decision-making abilities improved rely on mobile apps for weather and market information. A participant illustrates:

*"I rely on a weather app to determine when to plant my beans so that the season does not run out before I harvest. This is contrary to the past when we relied on instinct to determine when to plant."*

This finding suggests that access to timely information helps to improve productivity and is consistent with (Kikulwe et al. 2018) who found that access to real-time information through mobile apps enhances productivity.

Mobile payment platforms emerged as essential digital tools that have transformed financial transactions in agribusiness. Farmers reported reduced dependence on cash-based sales, which previously exposed them to security risks and limited their transaction capabilities. A respondent noted that Mobile Money has made it safer for him to receive payments. He no longer has to worry about carrying large amounts of cash to and from the market. The tool of mobile money could already show its benefits helping over 2% of the Kenyan Population out of poverty (Suri/Jack 2016).

Additionally Smallholder farmers cite that digital tools help them to overcome middlemen in their value chain and they directly engage with buyers through

WhatsApp and other communication platforms. On the other hand, many smallholder farmers have no kind words for the use of e-commerce, due to the complexity it comes with and poor internet connectivity. A smallholder farmer states:

*"I have heard that we can sell our products directly to buyers online but I do not know how to do it. So, I end up using WhatsApp to communicate with potential buyers."*

This finding is consistent with the Technology Acceptance Model that suggests that Perceived Ease of Use (PEOU) enhances adoption, and smallholder farmers who find e-commerce platforms complex end up not adopting them (Davis 1989).

#### **4.2.1.3 Barriers to adoption**

##### **Theme 3. cost, literacy and connectivity limit digital adoption**

The findings from this analysis suggest that smallholder farmers face a number of barriers including: high cost of mobile data, low digital literacy, poor internet connectivity, and limited access to smartphones. A farmer explains:

*"I find the cost of data too high. I end up spending UGX 3,000 each day I want to check prices from my phone. If there is a way to reduce this cost, I would use the apps more regularly."*

The issue of mobile data costs is a national challenge, and findings from the UCC 2023 report indicated that prices already come down from 2019 to 2023 by up to 50% to UGX 5000 per 1GB. But given the lower net income of smallholder farmers, especially in rural areas end up paying too much for data and have a poor network infrastructure at the same time. Furthermore, elderly participants also report the issue of limited digital literacy, and this finding is consistent with Social Cognitive Theory which highlights the role of self-efficacy in influencing behavioral change (Bandura 1986). In this case, older smallholder farmers with low digital skills are less confident with using mobile apps and e-commerce platforms. An extension worker states:

*"It's true some older farmers have smartphones, but the problem is they do not know how to integrate them in their farming practices. Such farmers require training to help them utilize them."*

This finding underscores the need for capacity building initiatives that can help to enhance farmers digital literacy and confidence with digital tools.

#### **4.2.1.4 The Role of Social Networks and Peer Influence**

##### **Theme 4: Social learning as an enabler of digital tool adoption**

The research revealed that social networks and peer influence play a crucial role in facilitating digital tool adoption among smallholder farmers. Many respondents indicated that observing successful implementation by peers significantly influenced their decision to adopt digital technologies. Farmer groups emerged as important platforms for encouraging technology adoption through collective learning and support. These groups often provided informal training and troubleshooting assistance that helped overcome individual barriers to adoption. Some farmers reported that they started adopting digital tools as soon as they saw their peers benefiting from it. Here often young farmers adopted digital innovations first. The data highlighted the role of young farmers as early adopters and technology diffusion agents within farming communities. Their greater comfort with digital technologies positioned them as informal technology ambassadors. This finding is consistent with research by Bandiera and Rasul (2006), who demonstrated that social learning and network effects significantly influence agricultural technology adoption decisions, with farmers more likely to adopt new technologies when they can observe successful implementation within their social networks.

#### **4.2.1.5 Trust and Security Issues**

##### **Theme 5: Farmers have limited trust about online transactions and data privacy**

Trust emerged as a critical factor influencing farmers willingness to engage with digital platforms, particularly for financial transactions. Several respondents reported experiences with fraud in mobile money transactions, which had eroded

their confidence in digital payment systems. The research found that farmers often avoided using e-commerce platforms for high-value transactions due to concerns about security and the potential for fraud. Some stated, that they would sell their goods rather in person to be sure to receive the payment directly. Respondents also emphasized the need for digital literacy training to build trust and confidence in using digital platforms. Many believed that government or stakeholder-led initiatives could address knowledge gaps that contribute to vulnerability. Some suggested, that if they had proper training on how to identify and avoid scams, then they would trust these digital services more. Here a recent study states that the technology is often seen as a black box, with farmers tend to be sceptical about. Policies were mentioned could have a positive effect to enhance trust of farmers in digital tools (McFadden/Casalini/Antón 2022).

#### **4.2.1.6 Recommendations from the smallholder farmers**

##### **Theme 6: Farmers offered practical interventions that can be done to improve digital adoption**

Respondents offer valuable suggestions on how to increase the adoption of digital tools. Key suggestions include: (a) subsidized data packages for farmers – they believe that an affordable package can enhance their access to digital tools more frequently; (b) initiatives to train them on the use of digital tools and smartphones – they believe that such initiatives will help to boost their confidence, and use of smart devices and digital tools will become more effective; (c) improved access to smartphones – some farmers suggest that smartphones are not easily affordable, hence hindering their use of farming apps.

A 25-year-old smallholder farmer suggests: *"I wish government or an NGO would step in to make smartphones more affordable, then more farmers would easily access them and install these digital tools and then easily learn how to use them."*

These recommendations are consistent with the Diffusion of Innovation and Technology Acceptance Model frameworks that stress the importance of reduced barriers and enhanced visibility of early adopters to encourage adoption by late adopters and align with findings from research in rural Kenya, where farmers did

barely use the existing technology to access market prices on their phones (Wyche/and Steinfield 2016).

### **4.3 Triangulation of findings**

This section presents a comprehensive analysis of the convergence and divergence in the data, integrating insights from both qualitative and quantitative data to form a robust understanding of the impact of digital tools on agribusiness efficiency among smallholder farmers in Luwero.

#### **4.3.1 Awareness and usage of digital tools**

**Convergence:** Both data sets demonstrated a strong level of awareness of digital tools amongst smallholder farmers. The quantitative findings showed that 75.3% of smallholder farmers knew about digital tools, and this was supported by qualitative findings. In the interviews, many smallholder farmers showed that they were familiar with mobile payment platforms (like Airtel Money and MTN Mobile Money) and they commonly used them to complete transactions. The qualitative findings also demonstrated that most smallholder farmers associated digital tools primarily with mobile money platforms, and very few were aware of e-commerce platforms.

**Divergence:** Whereas quantitative data revealed that 24.7% of respondents reported that they had never used digital tools, qualitative data demonstrated that some smallholder farmers had interacted with these tools indirectly, e.g., by relying on a friend's account for mobile transactions. This implies that the self-reported quantitative measure of non-usage may understate the level of indirect exposure to these tools. This is consistent with the Diffusion of Innovation (DOI) theory that suggests that indirect interactions through early adopters within a social system may positively influence late adopters (Rogers 2003).

**Complementarity:** Whereas quantitative data recorded usage frequencies, qualitative data was able to elucidate the reasons responsible for these usage patterns. For instance, quantitative data reported that 20.2% of respondents used e-commerce, yet qualitative data revealed that the low usage was attributed to poor internet reliability and issues of trust. Such insights align with the Technology Acceptance Model's (TAM) constructs of Perceived Ease of Use (PEOU) and

Perceived Usefulness (PU) that suggest smallholder farmers are less likely to adopt internet-based applications that lack reliability when needed (Davis 1989).

#### **4.3.2 Perceived impacts of digital tools**

**Convergence:** Both data sets revealed that digital tools were the most impactful on productivity whereby quantitative data indicated that 40.4% of respondents agreed that these tools had improved their productivity, and this was supported by qualitative findings. Furthermore, many smallholder farmers suggested that mobile apps provided them with access to real-time weather information, farming tips, among others, which helped them to make more informed decisions. This was supported by qualitative data, and smallholder farmers suggested that it led to better planning and increased yields. This finding is consistent with the Diffusion of Innovation (DOI) theory that suggests that visibility of benefits enhances adoption (Rogers 2003).

**Divergence:** The most noticeable divergence was concerning the impact of digital tools on income. Quantitative data revealed that 29.2% of respondents agreed that these tools boosted their income, yet interviewees suggested that they experienced notable increases in their income. When further exploration was performed, it was revealed that the disparity could be attributed to seasonal fluctuations in the prices of produce that caused some smallholder farmers to experience increases in their income while others saw no change or marginal increases. This observation underscores the impact of contextual factors on how influence is perceived. This aligns with the Social Cognitive Theory's (SCT) concept of outcome expectations that suggests that farmers can have varying expectations of the associated benefits of a tool (Bandura 1986).

**Complementarity:** The findings from quantitative data revealed that productivity was the most significant impact area, yet those from qualitative data revealed how productivity was achieved. Respondents cited specific benefits of mobile apps like access to real-time weather information, market price updates, among others. These benefits were found to be consistent with the Perceived Usefulness (PU) in the decision-making process, which consequently influences the adoption of digital tools. This aligns with the Technology Acceptance Model (TAM) theory (Davis 1989).

### 4.3.3 Barriers to the adoption of digital tools

**Convergence:** Findings from quantitative data revealed that the top barriers to adoption were: high cost of mobile data at 56.2%, low digital literacy at 47.2%, and poor internet connectivity at 52.8%. These findings aligned with qualitative findings whereby respondents identified the heavy cost of mobile data bundles and poor network connectivity as major limitations. This convergence is consistent with the Diffusion of Innovation (DOI) theory that recognizes the significance of external barriers and the concept of Perceived Ease of Use (PEOU) of the Technology Acceptance Model (TAM) theory that recognizes that high data costs and connectivity challenges reduce the ease of use of digital tools (Davis 1989).

**Divergence:** Whereas quantitative findings highlighted poor internet connectivity (52.8%) as the strongest barrier, qualitative findings highlighted varying experiences. For instance, some smallholder farmers cited that network outages were more common in rainy seasons, and such a response was not captured in the quantitative survey. Such a context-specific finding suggests that infrastructure limitations are more severe in rural areas like Luwero beyond what is captured by the quantitative data. This divergence aligns with the concept of environmental determinants of the Social Cognitive Theory (SCT) model that suggests that factors beyond an individual's control may affect their behavior (Bandura 1986).

**Complementarity:** Whereas quantitative data revealed the strongest barriers to the adoption of digital tools, qualitative data generated deeper understanding of the drivers of these barriers. For instance, while quantitative data revealed that 47.2% of respondents suggested limited digital literacy, qualitative data demonstrated that most smallholder farmers rely on peer-to-peer learning to mitigate this limitation. Many farmers suggested that they relied on their informal community sharing platforms to learn how to use mobile payments and e-commerce platforms. This is consistent with the SCT concept of social modeling and observational learning to influence behavior change (Bandura 1986).

## 5 Discussion of the results

This chapter presents an in-depth discussion of the key findings of the study on the role of mobile apps, e-commerce and digital infrastructure in boosting agribusiness efficiency amongst smallholder farmers in Luwero.

### 5.1 Usage of digital tools

The study established that the awareness of digital tools amongst respondents was 75.3% and only 28.1% of them had used mobile apps. Also, the usage of e-commerce platforms was found to be 20.2% while only 65.2% had used mobile payment platforms. These patterns align with Tinzaara et al. (2021) who found 94.3% phone ownership but varying digital service utilization among Ugandan farmers. Overall, the adoption of mobile payments was found to be higher than the use of other digital tools, which reflects the popularity of mobile financial services such as MTN Mobile Money and Airtel Money in the rural areas of Uganda like Luwero. Findings from Muto and Yamano (2009) further demonstrate how mobile money adoption increases with visible financial benefits in rural economies. According to the Diffusion of Innovation (DOI) theory, this pattern can be explained by the presence of early adopters of mobile payments whose use of the platforms helped to demonstrate their relative advantage over cash-based transactions (Rogers 2003). The Perceived Ease of Use (PEOU), a concept of the Technology Acceptance Model (TAM), also explains this pattern as mobile payments are perceived to reduce transaction time and offer a more transparent payment alternative (Davis 1989).

The low e-commerce adoption corresponds with Ajambo et al. (2024), who identified three exclusion-risk personas among Ugandan farmers, where older subsistence farmers showed 38.2% smartphone inaccessibility. This aligns with Mhlanga and Ndhlovu (2023) framework emphasizing digital infrastructure as a prerequisite for agricultural technology integration and is also consistent with the findings of Baumüller (2018), who suggested that low levels of digital literacy and poor internet connectivity hinder the adoption of e-commerce platforms in rural areas. The qualitative findings of the study also established that e-commerce platforms are generally perceived as complex and not easily navigable by the respondents. Finally, according to the TAM theory, the low adoption of e-

commerce platforms can be attributed to the low PEOU, which is evidenced by the platforms' complexity and limited usability. Therefore, addressing such challenges requires a deliberate capacity-building intervention to help smallholder farmers become more comfortable with these digital tools and realize their potential benefits in agricultural value chains.

### **5.1.1 Productivity**

According to the quantitative findings, only 40.4% of respondents cited that digital tools improved their productivity. This aligns with (Kikulwe et al. 2018) findings that mobile money adoption increased crop yields in Kenya through improved input access. An Ugandan study from Sekabira and Qaim (2017) showed that mobile money users could increase their household income up to 26%, thereby enhancing their food security and dietary diversity alongside. Qualitative findings also revealed that respondents emphasized that mobile apps have improved their access to real-time weather information, farming tips, and other agricultural resources. Such information was useful in their planning, and it helped them to improve their yields and to control losses. This finding is consistent with (Paparrizos/Vignola/Sutanto 2024), who established that farmers using weather apps made better planting decisions and thereby were able to mitigate crop failure risks. In general, the results are consistent with the trialability concept of the DOI theory that suggests that farmers who observed early adopters leveraging weather apps were more likely to integrate these technologies into their own farming practices.

### **5.1.2 Market access**

Analysis of quantitative data revealed that 28.1% of respondents support the fact that digital tools promoted their access to markets. This corresponds widely with the findings of Muto and Yamano (2009), where sales of banana in remote places could increase due to mobile network access. Furthermore, findings from the qualitative data revealed that smallholder farmers used WhatsApp to negotiate directly with potential buyers to bypass middlemen. These findings align with Wossen et al. (2017), who demonstrated that farmers using WhatsApp or SMS-based platforms had better bargaining power in price negotiations.

On the other hand, the poor adoption of e-commerce platforms is a strong indicator of a technology gap in rural areas of Uganda. According to the observational learning concept of the Social Cognitive Theory (SCT), this low uptake can be attributed to the fact that many farmers did not have knowledge of peers who had successfully used e-commerce platforms in their agribusiness practice (Bandura 1986). This is consistent with the Diffusion of Innovation (DOI) theory that suggests that farmers are persuaded by evidence of success (observability) before they integrate new platforms into their daily practices (Rogers 2003). The absence of visible success stories regarding e-commerce adoption among peer farmers likely contributes significantly to the hesitation in embracing these potentially beneficial digital marketing channels.

### **5.1.3 Income**

Whereas the quantitative findings of the study established that digital tools increased income, qualitative findings established otherwise. Some smallholder farmers reported increased income as a result of increased productivity and elimination of middlemen, yet others reported that they experienced no change in income. This finding aligns with those of Suri and Jack (2016), who suggested that mobile money adoption enhances financial security and farmers' liquidity, thus enabling them to participate in more profitable practices. This finding is consistent with the principle of outcome expectations of the Social Cognitive Theory (SCT). It suggests that farmers' expectations of growth in income influence their willingness to integrate digital tools (Bandura 1986). On the other hand, expectations alone might not be enough where there is an absence of early adopters to offer sufficient visible evidence of economic benefits.

### **5.1.4 Cost reduction**

Findings from quantitative data revealed that only 30.3% of respondents were agreeable that digital tools reduce operational costs. Furthermore, the regression analysis revealed that usage of mobile apps and e-commerce platforms has a positive but small implication for cost reduction. On the other hand, findings from qualitative data revealed that farmers cited that mobile apps reduced their need for physical travel, thus helping them to save on transportation expenses. This

finding is consistent with the findings of (Baumüller 2018), who established that apps enabled remote advisory services, thus proving useful at reducing costs.

## **5.2 Barriers to adoption of digital tools**

### **5.2.1 Cost of mobile data**

Findings from quantitative data highlighted that 56.2% of respondents revealed that the high cost of mobile data bars them from adopting digital tools, and this is supported by findings from qualitative data where respondents revealed that buying data bundles was costly. This finding is consistent with the findings of (UCC 2023) that revealed the price per GB at \$1.3 USD in a context where the net living income is estimated at only \$151 per month (Khan/Buyinza 2019). This issue limits the regular use of mobile apps and e-commerce platforms, thus constraining the rate of digital adoption. Addressing this challenge requires the intervention of multiple stakeholders, including telecommunications companies, government agencies, and development partners, among others.

### **5.2.2 Low level of digital literacy**

The findings of the study suggest that 47.2% of respondents had low levels of digital literacy. Respondents cited that they lacked the skills needed to navigate apps and interpret e-commerce platforms. This finding aligns with (Kasirye and Masum (2021), who suggested that farmers with higher levels of digital literacy were more likely to adopt and leverage digital tools. This supports Steinke & Schumann's (2022) inclusivity framework recommending context-specific literacy programs (Steinke et al. 2024). The finding is also consistent with the self-efficacy concept of the Social Cognitive Theory (SCT), which suggests that smallholder farmers with strong confidence in their ability to leverage digital tools are more likely to adopt them. Therefore, introducing these smallholder farmers to training programs can help improve their Perceived Ease of Use (PEOU) and, hence, enhance the adoption of digital tools (Davis, 1989).

### **5.2.3 Poor internet connectivity**

Both qualitative and quantitative findings cited poor internet connectivity as a barrier to the adoption of digital tools. Respondents noted that the connectivity challenge was worse during rainy seasons, and this is consistent with the findings of Mhlanga and Ndhlovu (2023) which highlighted that the lack of connectivity and digital infrastructure is one of the main challenges for the digitalization in African agriculture. This barrier limits the ability of smallholder farmers to access key information, such as market prices, that they need to make more informed decisions in real-time. Addressing this barrier would require a multi-stakeholder approach involving government agencies, telecommunications companies, and regulatory bodies.

### **5.2.4 Limited access to smartphones**

Findings from quantitative data revealed that 38.2% of respondents cited that they had limited access to smartphones, and this was attributed to affordability and digital literacy challenges, which corresponds with recent findings of (Ajambo et al. 2024). The results in general align with Social Cognitive Theory (SCT) that highlights how environmental determinants also influence the ability to adopt digital tools (Bandura, 1986). Therefore, lack of smartphones limits the farmers' ability to fully leverage mobile apps and e-commerce platforms. One approach to mitigating this challenge may be through subsidizing smartphones through financing schemes where smallholder farmers can pay in small installments. Additionally, partnering with telecom companies to introduce low-cost smartphones with pre-installed farming applications could help to accelerate smartphone adoption among rural agricultural communities.

## **6 Conclusion and Recommendations**

This chapter provides a summary of the key findings of the study on the role of digital tools, mobile apps, e-commerce platforms and digital infrastructure on improving agribusiness efficiency amongst smallholder farmers in Luwero, Uganda. It also presents key conclusions based on the study objectives as well as actionable recommendations for key stakeholders especially policy makers, smallholder farmers and development partners. The chapter also suggests areas that can be addressed by future studies.

### **6.1 Summary of key results**

The study established that the level of awareness of digital tools amongst smallholder farmers was high and 75% of respondents cited that they had knowledge of tools. However, the disparity in the usage of various tools was significant. Mobile payment platforms were the most common and 65.2% of smallholder farmers had utilized these in their agribusiness practices. Mobile apps and e-commerce were used by 28.1% and 20.2% of respondents respectively and the limited knowledge, and poor connectivity were found to be responsible for the low usage of e-commerce. These findings were consistent with Baumüller (2018) who established that digital literacy, affordability and internet connectivity are critical in the adoption of digital tools in rural settings.

The study also assessed the impact of digital tools on agribusiness and the key outcomes of agribusiness focused on were productivity, market access, income and cost reduction. The findings revealed that digital tools were most impactful on productivity and 40.4% of respondents cited that they had helped them to improve their productivity. The adoption of mobile apps that offered real-time updates, weather information and farming advice was found to benefit farmers by supporting them to take informed decisions; this improved their productivity. Also, 37.1% of farmers cited that digital tools enhanced their access to broader markets. However, digital tools were found to offer no meaningful impact on income. Finally, cost reduction also had mixed reactions as some smallholder farmers agreed that digital tools help them to reduce costs through timely access to information and elimination of middlemen. On the other hand, others

suggested that the cost of mobile data and acquiring a smartphone is very high thus they choose to avoid digital tools.

The study also established a number of barriers that limit the adoption of digital tools amongst the study population. The most significant barrier was mobile data at 56.2% and this was consistent with the report by the Uganda Communication Commission which highlighted that users in rural areas pay higher data costs compared to those in urban areas. Poor internet connectivity was also another critical barrier and 52.8% of respondents reported connectivity interruptions especially during the rainy season. 47.2% of respondents highlighted that their low-level digital literacy limited their adoption of digital tools and this underscores the need for training initiatives to improve the farmers' competence in tools. Finally, access to smart devices also limited adoption with 38.2% of the farmers admitting that they did not own smartphones.

## **6.2 Conclusion**

Digital tools, i.e., e-commerce platforms, mobile apps and digital payment systems, have the potential to significantly boost the efficiency of agribusiness amongst smallholder farmers in Luwero. The findings suggest that the adoption of mobile apps enhances productivity through improved access to critical information, while the adoption of e-commerce platforms was relatively low despite the fact that their ability to improve market access was distinct. The study established that digital literacy is a key enabler of digital tools adoption and farmers with higher levels of digital literacy used mobile apps, e-commerce platforms and digital payment systems the most.

Notwithstanding the potential benefits, the study established that the high cost of mobile data, poor internet connectivity, limited access to smartphones and poor digital literacy as critical barriers that limit the wider adoption of digital tools. Such barriers call for targeted interventions that rely on affordability, development of infrastructure and training. The findings also highlight the importance of the guiding theoretical frameworks, where the TAM emphasizes the importance of PEOU and the PU in influencing behavior, the DOI theory highlighted the importance of social influence, visibility and relative advantage in influencing digital tools adoption amongst the study population, and finally the SCT

underscored the importance of observational learning and self-efficacy in driving the adoption of digital tools.

### **6.3 Recommendations**

The study recommends that smallholder farmers in Luwero are in need of targeted training initiatives to boost their adoption of digital tools. These initiatives should be focused on educating them on the use of mobile apps, e-commerce platforms and digital payment systems. These trainings should be hands-on and practical in order to boost the farmers' confidence and self-efficacy. Also, government agencies like the UCC, development partners and agricultural extension officers also need to work together to deliver these trainings in local languages (Senyo 2018).

There is also a need to address the issue of affordability of mobile data and digital devices. Smallholder farmers need to collaborate with telecom companies to lobby for subsidized mobile data packages hence reducing the cost of access to e-commerce platforms and mobile apps. There is also a need for government interventions through subsidies that can improve the affordability of smartphones to smallholder farmers. Such interventions will help farmers to gain access to affordable devices and this will enhance their access to more digital tools.

Finally, it is also very critical to collaborate with financial institutions in order to improve access to affordable credit. This will enable smallholder farmers to acquire the devices needed to participate in digital agribusiness. Digital payment systems should also be broadly leveraged to support more functions like saving and microloans beyond the cardinal functions of sending and receiving money. This can help to promote more adoption of e-commerce platforms.

## **6.4 How the study has contributed to knowledge**

The study has contributed to both theoretical and practical understanding of digital transformation in agribusiness in a rural setting. The application of DOI theory, TAM and the SCT has helped the study to offer a multi-theoretical approach to the understanding of the adoption of digital tools amongst smallholder farmers. The findings contribute to empirical understanding of the role of PEOU, PU, self-efficacy and social setting in the adoption of digital tools.

On the practical level, the study has highlighted specific barriers that rural based smallholder farmers face in adopting digital tools. Such insights can be valuable material that can be adopted by policy makers, development partners and agribusiness practitioners that are interested in designing specific interventions to support the scale up of the adoption of digital tools amongst smallholder farmer in rural settings.

## **6.5 Proposed areas for future research**

Whereas the study has contributed valuable findings, there remains gaps that need to be addressed by future studies. Firstly, there is a need to understand the impact of digital tools on smallholder farmers' livelihood with a focus on changes in household income, poverty reduction and food security. Also, a study that is focused on tracking the adoption process over a period of time in order to generate an understanding of the adoption behavior is also timely. Finally, another study examining the role of gender in the adoption of digital tools is also timely and will help to generate insights into the differences in gender in relation to digital adoption observed in this study.

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**Attachments**

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## Used Questionnaires

### Quantitative data collection tool

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#### Digital Transformation and agribusiness efficiency survey

##### Instructions

Dear Participant

This survey tool has been designed to collect data on the role of digital tools (e.g., mobile apps, ecommerce) and digital infrastructure, amongst smallholder farmers in improving agribusiness efficiency.

You are required to respond to the following questions by ticking the appropriate box or filling in the blank spaces accordingly. Your responses shall be kept confidentially and shall remain anonymous.

##### Section 1. Demographic data

1. Gender?

Male

Female

2. Age?

18 – 30

31 – 40

41 – 50

51 and above

3. Level of education?

No formal education

Primary school

Secondary school

Tertiary and above

4. What is your farm size (acres)?

Less than 1

1 – 3

4 – 6

more than 6

1. What is your primary type of farming?

Crop farming	<input type="checkbox"/>	Livestock farming	<input type="checkbox"/>
Mixed farming	<input type="checkbox"/>	Others (specify)	_____

**Section 2. Digital tools used**

2. Are you aware of digital tools such as apps or e-commerce platforms for farming?

Yes  No

3. Have you used any of the following digital tools in your farming practices (tick all that apply)?

Mobile apps for farming	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
E-commerce platforms to sell your produce	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Mobile financial services (e.g., mobile money)	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
None	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>

Others (specify) \_\_\_\_\_

4. How often do you use digital tools in your farming activities?

Daily  weekly  Monthly  Rarely

5. By what percentage has your overall income improved as a result of using a digital tool(s)?

0 – 30%  31 – 40%  41 – 50%  50% and above

**Section 3. Impacts of digital tools on agribusiness efficiency**

1. To what extent do you agree with the following statements?

(1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree)

Statement	1	2	3	4	5
Digital tools have improved my productivity					
I have gained better access to markets					
My income has increased due to digital tools					
I spend less on input costs using digital platforms					

**Section 4. challenges in adopting digital tools**

2. What challenges have you faced in adopting digital tools (tick all that apply)?

High costs of mobile data	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Poor internet connectivity	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Lack of knowledge/ digital literacy	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Lack of access to devices	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Others (specify)	_____			

3. What would help you to adopt tools more effectively?

Affordable data and devices	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Training programs	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Improved internet connectivity	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Government or organisational support	Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
Others (specify)	_____			

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**Qualitative data collection tool**

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**Digital Transformation and agribusiness efficiency; insights from smallholder farmers**

Dear Participant

The purpose of this interview is to generate a deeper understanding of your experiences, challenges, and perceptions regarding the adoption of digital tools in agribusiness.

This interview is expected to last between 30 to 45 minutes and you can skip any question if you feel comfortable.

Your responses will be kept confidential.

**Interview questions****a) Background information**

1. Could you briefly tell me about your farming practices?
2. What crops or livestock do you mainly focus on?

**b) Digital tool awareness and usage**

3. Are you aware of digital tools like mobile apps and ecommerce platforms for farming; if yes, please name them?
4. Can you share your experience with using these tools in your farming practices

**c) Benefits of digital tools**

5. What benefits have you experienced from using digital tools in your farming operations?
6. How has your productivity, market access, or income changed after adopting these tools?

**d) Challenges in adopting digital tools**

7. What challenges have you faced while adopting digital tools (e.g., mobile apps, e-commerce)?
8. How do issues like affordability, internet connectivity, or digital literacy affect your ability to use these tools

**a) Support needs and suggestions**

1. What kind of support (e.g., training, financial or technical) would help you adopt digital tools more effectively?
2. Are there specific improvements you would recommend for the digital tools available to you?

**b) Observational insights**

3. Have you seen other farmers using digital tools? If so, what have you observed about their experiences?
4. Has observing their success or challenges influenced your decision to adopt digital tools?

**c) Final thoughts**

Is there anything else you would like to share about your experience with digital tools and agribusiness?

Intermittent

Frequent

# Collected data summary

Nr.	Gender	Age group	Level of educ	Farm size	Awareness of digital tools	Usage of e-commerce	Usage of mobile apps	Impact on productivity	Impact on market access	Impact on income	Impact on cost reduction	Data cost challenge	Connectivity challenge	Digital literacy challenge	Access to digital device	Training intervention	Subsidized data intervention	Connectivity intervention	Access to digital device intervention	Government support intervention
1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	1	3	1	0	1	0	2	1	1	2	1	0	1	1	0	1	1	0
3	1	2	3	2	1	3	3	1	3	4	3	4	0	1	1	0	1	0	1	0
4	1	3	1	3	1	2	1	1	5	2	2	1	1	1	1	1	1	1	1	1
5	2	2	2	2	1	5	4	1	4	5	4	3	1	0	0	0	0	1	0	0
6	1	2	3	2	1	3	2	1	3	3	2	3	1	1	0	0	1	1	0	0
7	2	1	2	1	1	2	1	1	3	2	2	2	1	0	1	1	0	1	1	0
8	1	3	2	3	1	4	3	1	4	4	3	3	4	0	1	0	0	1	0	1
9	2	2	1	2	0	1	1	0	2	1	1	1	1	1	1	0	1	1	1	0
10	1	4	3	4	1	3	2	1	3	3	2	2	0	1	1	0	1	0	1	0
11	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
12	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
13	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
14	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
15	2	1	3	1	1	2	1	1	2	1	2	1	0	1	1	0	1	1	1	0
16	1	3	2	3	1	4	3	1	4	4	3	4	0	1	0	0	1	0	1	0
17	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
18	1	4	3	4	1	3	2	1	3	3	2	2	0	1	0	0	1	0	1	0
19	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
20	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
21	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
22	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
23	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
24	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
25	2	1	2	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
26	1	4	3	4	1	3	2	1	4	3	2	2	0	1	1	0	1	0	1	0
27	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
28	1	1	2	1	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1
29	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	0	1	0	0
30	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
31	2	1	3	1	1	2	1	1	2	2	1	2	1	0	0	0	1	0	1	0
32	1	3	1	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
33	2	1	2	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
34	1	4	3	4	1	3	2	1	3	3	2	2	0	1	1	0	1	0	1	0
35	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
36	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
37	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
38	1	3	2	3	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
39	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
40	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
41	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
42	1	4	3	4	1	4	3	1	4	3	2	2	0	1	1	0	1	0	1	0
43	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
44	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
45	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
46	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
47	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
48	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
49	2	1	2	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
50	1	4	3	4	1	3	2	1	3	3	2	2	0	1	1	0	1	0	1	0
51	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
52	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
53	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
54	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
55	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	2	0	1	1	0
56	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
57	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
58	1	4	3	4	1	3	2	1	3	3	2	2	0	1	1	0	1	0	1	0
59	2	2	2	2	1	4	3	1	4	4	3	3	0	0	0	0	1	0	0	0
60	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
61	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
62	1	2	1	2	1	1	1	1	2	2	1	2	1	1	1	1	0	1	1	0
63	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
64	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
65	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
66	1	4	3	4	1	3	2	1	3	3	2	2	0	1	0	0	1	0	1	0
67	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
68	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
69	2	1	3	1	1	2	1	1	3	2	1	3	0	1	0	0	1	0	1	0
70	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
71	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
72	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
73	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
74	1	4	3	4	1	3	2	1	3	3	2	2	0	1	1	0	1	0	1	0
75	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
76	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
77	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
78	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
79	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
80	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
81	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0
82	1	4	3	4	1	3	2	1	3	3	2	2	0	1	1	0	1	0	1	0
83	2	2	2	2	1	4	3	1	4	4	3	3	1	0	0	0	1	0	0	0
84	1	1	3	1	1	2	2	1	3	2	2	2	1	1	1	1	1	1	1	1
85	2	3	1	3	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	0
86	1	2	2	2	1	3	2	1	3	3	2	3	0	1	0	0	1	0	1	0
87	2	1	3	1	1	2	1	1	2	2	1	2	1	0	1	1	0	1	1	0
88	1	3	2	3	1	4	3	1	4	3	4	3	0	1	0	0	1	0	1	0
89	2	2	1	2	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0

Variable coding  
 Gender 1= Male, 2=Female  
 Age group 1= 18-30, 2=31-40, 3= 41- 50, 4= 51+  
 Level of educ 1= No formal, 2= primary, 3= secondary, 4= tertiary  
 Farm size 1 = <1acres, 2 = 1-3 acres, 3 = 4-6 acres, 4 = >6 acres  
 Awareness of digital tools 0= No, 1= yes  
 Usage of mobile apps 1 = rarely, 4 = Daily  
 Usage of e-commerce 1 = rarely, 4 = Daily  
 Usage of mobile money 1 = rarely, 4 = Daily  
 Impact on productivity 1 = strongly disagree, 5 = strongly agree  
 Impact on market access 1 = strongly disagree, 5 = strongly agree

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Use of generative AI:

- Perplexity AI with Claude 3.7 for correcting text passages.