PREPRINT

Not Peer Reviewed

RESEARCH ARTICLE

# Is Cash still King? Evidence from digital finance use along horticulture value chains in Nigeria

[version 1]

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**v1** **First published:** 14 Jan 2026, **3**:29
https://doi.org/10.12688/verixiv.2738.1

**Latest published:** 14 Jan 2026, **3**:29
https://doi.org/10.12688/verixiv.2738.1

## Abstract

Digital finance (DF) is recognized as important for agricultural transformation, yet adoption among agri-food value chain actors remains uneven and poorly understood. Using survey data from 3,366 input suppliers, wholesalers, retailers, and processors in horticulture value chains (VCs), we examine the patterns and determinants of DF use in two economically and culturally distinct Nigerian states. We find that DF use is higher than expected, with over 40% of the sample using it for business purposes and over 70% in some value chain segments. DF adoption varies significantly by VC segment, region, gender, and transaction type. Input suppliers and wholesalers use DF more than processors and retailers. Surprisingly, usage is higher in Nigeria's poorer northern region than in the wealthier south. Gender patterns differ by node: Men are more likely to use DF across all nodes, with the exception of tomato processors, where women appear more likely to use DF. Finally, DF use is more for sales than procurement, especially with trusted clients and formal channels. These findings highlight the need for tailored interventions, infrastructure expansion, and trust-building to promote inclusive DF adoption.

## Keywords

Digital finance, adoption, agri-food value chain actors, transactions, relational contract, heterogeneity, Nigeria

This article is included in the Gates Foundation gateway.

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**Author roles: Olaoye IJ**: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Liverpool-Tasie LSO**: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Yami MG**: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – Review & Editing

**Competing interests:** No competing interests were disclosed.

**Grant information:** This work was funded in part by the Gates Foundation via the project INV-034790_2021 RSM2SNF
*The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.*



**How to cite this article:** Olaoye IJ, Liverpool-Tasie LSO and Yami MG. **Is Cash still King? Evidence from digital finance use along horticulture value chains in Nigeria [version 1]** VeriXiv 2026, **3**:29 https://doi.org/10.12688/verixiv.2738.1

**First published:** 14 Jan 2026, **3**:29 https://doi.org/10.12688/verixiv.2738.1

## 1. Introduction

Digital financial (DF) innovations offer significant opportunities to empower value chain (VC) actors and mobilize finance for efficient food systems (Choruma et al., 2024; FAO & AFRACA, 2020; Pazarbasioglu et al., 2020). Yet, in many developing countries, agrifood enterprises' investment and adoption of DF tools is considered minimal, often due to a lack of suitable financial products (Ambler et al., 2023; FAO, 2025; Ilie & Kelly, 2021; World Bank, 2018). Although financial products and technologies are increasingly available (Abiri et al., 2023; Adeleke, 2024; Yang et al., 2023), empirical evidence on DF usage levels and drivers, especially across Africa remains limited. DF applications can reduce transaction costs, provide proof of transactions, and mitigate cash-related risks such as theft, fire, loss of value, and shortages (Sands et al., 2017; Simatele & Mbedzi, 2021). However, DF tools also carry financial costs and risks, particularly in contexts with weak infrastructure and regulatory systems (Ozili, 2018; Xi & Wang, 2023).

The existing literature on DF in developing regions largely focusses on financial inclusion, technology adoption and poverty reduction, particularly among farming households (Choruma et al., 2024; Lei & Su, 2023; Li et al., 2020, 2024; Parlasca et al., 2022; Prodhan et al., 2024) and it impact on productivity (Ky, 2025; Liu et al., 2024; Traore & Moussa, 2025; Wu et al., 2025), profitability and sustainability (Demirgüç-Kunt et al., 2018; Dong et al., 2023; Geng et al., 2024; Jack & Suri, 2014). The conditions for DF use in a low- to middle-income country will vary depending on market and enterprise characteristics, as well as on infrastructure and kinds of transactions. Despite the key roles paid by non-farm VC enterprises in connecting farmers with input and output markets and as an important source of livelihoods, they are often hidden from debates in most developing economics studies (Barrett et al., 2022; Reardon, 2015; Reardon et al., 2021). Within the limited literature on the hidden middle, evidence on DF use among non-farm actors along value chains is extremely thin. Three exceptions are Adong et al. (2025), Ambler et al. (2023), and He et al. (2024).

Ambler et al. (2023) review the literature on the financial needs of midstream actors in agricultural output value chains. They emphasize node-specific factors (such as search costs, delivery commitment and export orientation) that are likely to influence financial needs. While they note potential values of DF and the dearth of studies on the topic among non-farm actors, they do not employ empirical data of VC actor transactions and/or use of DF. Adong et al. (2025) use primary data to provide a rich descriptive analysis of DF use among traders and processors in two countries: Bangladesh and Uganda. They note that the overwhelming majority of VC activities (80% -90%) are still cash-based across the value chains studied and that DF use is more common in sales transactions than procurement. However, the authors' descriptive analysis does not explain why different VC actors adopt DF, nor does it capture heterogeneity in adoption across different contexts for each of the products considered. Factors supporting or hindering the adoption of DF might vary across heterogeneous conditions for the same product, such as infrastructure, trust, market dynamics, and cultural norms. He et al. (2024) consider the impact of DF on the social responsibility of 395 agricultural enterprises engaged in processing and distribution in China. While the study confirms the heterogeneity of DF impacts, the study does not consider why firms adopt DF nor consider if DF use varies across business type and regions within China.

Thus, this study contributes to the literature on DF in agrifood systems by examining the extent and determinants of DF adoption among VC actors at four key nodes—input suppliers, wholesalers, processors, and retailers—in two horticultural value chains (tomatoes and green leafy vegetables) in Nigeria. In largely informal agrifood systems, DF adoption is influenced not only by cost considerations but also by relational capital—trust, mutual confidence, and repeated interactions among value-chain actors (Shahzad et al., 2018). The analysis here is based on detailed transaction-level data across regions with distinct economic and cultural characteristics within the same country. This is the first study (the authors are aware of) to systematically assess DF adoption among Micro, Small, and Medium Enterprises (MSMEs) across multiple nodes of the same value chain, while accounting for transaction type, client characteristics and preferences, and regional heterogeneity.

We make four main contributions to the literature on Africa's food systems transformation and DF use in developing countries. First, we go beyond existing DF studies by distinguishing DF use not only by transaction type (sales vs. purchases) but also by client characteristics (regular vs. new customers) and by market channel preferences (formal vs. informal), offering a more granular understanding of adoption behavior. We explicitly include input suppliers—an understudied but important node of agrifood value chains (Barrett et al., 2022; Liverpool-Tasie et al., 2020, 2025a; Reardon et al., 2021)—allowing us to assess whether DF use is primarily linked to the nature of the transaction (sales vs. procurement) or to the characteristics of the trading relationship (e.g. trading with farmers). Second, we deliberately explore whether regional differences in infrastructure and social norms matter. We capture location using state, rural–urban location of actors and georeferenced data on internet use intensity at the enterprise location. Third, we analyze DF use along two different commodity value chains with some distinct VC attributes in Nigeria; degree of perishability and VC length to explore if product-specific features shape the incentives for DF use. Our focus on horticultural value chains also allows VC specific considerations; particularly compared to Adong et al. (2025) that considered less perishable value

chains of coffee, soybean, rice and potatoes. Fourth, we contribute to the growing but limited literature on the hidden middle of agrifood value chains in developing regions. As noted earlier, we explore an issue that hitherto remains largely unexplored in the hidden middle: the drivers of DF use.

We highlight four key findings. First, digital DF use is more widespread than previously reported, with between 15% and 70% of respondents reporting using DF. Second, there is substantial heterogeneity in DF use across VC segments and states. Adoption is higher among input suppliers and wholesalers than among processors and retailers. Unexpectedly, DF use is greater among VC actors in Nigeria's relatively poorer northern region (Kaduna) than in the more affluent south (Oyo), all else equal. Third, DF use varies by gender and by nodes. While men are more likely to use DF across most of the nodes, women are more likely to use DF than men significantly only among tomato processors. Finally, the nature of trading relationships strongly influences DF adoption. DF use is more common in sales than in procurement transactions, particularly when dealing with trusted clients or operating through more formal market channels with a higher preference for digital payments.

## 2. Data and study context

This study uses primary survey data from 3,366 MSMEs in two horticultural value chains —tomatoes and green leafy vegetables (GLVs) in Kaduna (northwest) and Oyo (southwest), selected for their production prominence and diverse agro-ecological and socio-economic conditions. These horticulture value chains have expanded recently in response to increased demand from population growth, urbanization and increased incomes (Liverpool-Tasie et al., 2025b). MSMEs operate in four non-farm segments: input supply, wholesale, processing, and retail, and are defined as enterprises with 1–199 employees (NBS & SMEDAN, 2017).

Data collection was preceded by a census of wholesale markets in rural and urban areas of both states to compile comprehensive actor listings.

Input suppliers: Listings of those located within or near the markets were augmented by input suppliers identified by farmers in randomly selected tomato-producing communities. This yielded 236 input suppliers in Oyo and 1,045 in Kaduna. All Oyo input suppliers were surveyed, while a random sample of 400 was drawn from Kaduna.

Tomato processors: All tomato processors identified (317) in the study states were included in the sample. Identification was from combined listings from the markets, the Small and Medium Enterprise Development Agency of Nigeria, the National Association of Small and Medium Enterprises (NASME), and NGOs, along with a snowball sampling approach to identify unlisted processors.

Wholesalers: All wholesalers who served farmers in the main tomato-producing communities in each study state (gotten from a community listing to ensure that non-market wholesalers are captured) were supplemented with randomly selected traders from the wholesale market listings to reach a target of 400 tomato wholesalers per state. For GLV wholesalers, 587 were listed, and the universe surveyed.

Retailers: We surveyed a sample of 500 tomato retailers—372 in Kaduna and 128 in Oyo—drawn from a census of retailers operating in the wholesale markets described above. While this approach excluded retailers in non-market locations (e.g., urban neighborhoods or standalone retail hubs), wholesale markets were confirmed to host extensive retail activity (~80% of sites), and conditions in these markets were found to be broadly reflective of the wider retail environment. For GLV retailers, we surveyed the entire listed population (542 across both states).

Sample sizes across segments were determined using standard formulae for finite population correction (Cochran, 1977; Lohr, 2010), with assumptions of a 95% confidence level, a 5% margin of error, and a conservative population variance of 0.5. Sampling weights were applied where random sampling occurred. The survey instrument included modules on business characteristics, market practices, and digital financial service (DFS) adoption—specifically, the use of mobile money, bank transfers, point-of-sale (POS) terminals, and other non-cash payment methods for buying and selling goods and services.

### 2.1 Conceptual framework and empirical strategy

Our conceptual framework based on the Lancaster theory of demand, posits that DF adoption depends on its bundle of attributes. DF offers functional characteristics (e.g., speed and traceability) and experiential benefits (e.g., security from not carrying cash) but entails cost such as service fees and risks from fraud or poor connectivity (Sands et al., 2017; Simatele & Mbedzi, 2021). We draw on several complementary theoretical perspectives to explain DF adoption among agri-food VC actors.

**Transaction Cost Economics (TCE)**: Firms seek governance structures that minimize transacting costs under uncertainty (Shahzad et al., 2018; Williamson, 1989). In agri-food value chains, intermediary firms may face high ex-post transaction costs and risks due to cash handling, delayed payments, and record-keeping inefficiencies (Adong et al., 2025). DF can reduce these costs by lowering cash-handling risks, automating record-keeping, and improving payment timeliness (Aron, 2018; Dibbern et al., 2024; Khando et al., 2022). DF can improve payment traceability and facilitate faster dispute resolution. Payment traceability can also reduce the transaction costs associated with monitoring where enterprises hire multiple employees (He et al., 2024; Khan et al., 2022; Rahman et al., 2022; Schroeder et al., 2021).

**Social Exchange Theory (SET):** Trust, commitment, and communication shape sustaining inter-firm relationships (Blau, 1964; Dyer & Chu, 2011). In a context where many agrifood MSMEs operate informally, the decision to adopt DF will likely be shaped by relational capital and the mutual confidence that partners will act fairly built on trust and frequent interaction (Shahzad et al., 2018).

**Relational contract theory (RCT)**: Repeated interactions and informal agreements reduce perceived risks of DF in contexts with weak enforcement and low-tech literacy (Levin, 2003; MacLeod & Malcomson, 1989; Michler & Wu, 2020).

**DF use in response to client preferences.** The behavior of farmers and other VC actors have been shown to be influenced by their potential or actual buyers (Barnes et al., 2022; Benitez-Altuna et al., 2024; Bulte et al., 2024; Varyvoda et al., 2025). Certain clients (e.g., importers, processors, and supermarkets) might prefer DF payments over cash while farmers prefer cash, inducing or discouraging DF use among VC actors.

Drawing from these frameworks, we empirically test for three key mechanisms (transactions costs, trust and client preferences) expected to influence DF use among our off-farm VC actors in a context where phone networks and internet connectivity are often weak and VC actor interactions are largely spot transactions and relational contracts.

We estimate a series of discrete choice models to explain the adoption of DF by VC actor $i$ as follows. We define $DF_i \in \{0,1\}$ as denoting whether actor $i$ adopts DF such that $DF_i = 1$ if VC actor $i$ adopts DF and is zero, otherwise. The adoption decision occurs where;

$U_{DF\,i} > U_{cash\,i}$ given:

$$\begin{aligned} U_{DF\,i} &= \zeta_{0\_DFS} + \zeta_1 Z_{TCi\_DFS} + \zeta_2 Z_{TRUSTi\_DFS} + \zeta_3 Z_{CLIENT\_PREFi\_DFS} + \beta' X'_{i\_DFS} + \varepsilon_{i\_DFS} > U_{CASH\,i} \\ &= \zeta_{0\_DFS} + \zeta_1 Z_{TCi\_CASH} + \zeta_2 Z_{TRUSTi\_CASH} + \zeta_3 Z_{CLIENT\_PREFi\_CASH} + \beta' X'_{i\_CASH} + \varepsilon_{i\_CASH} \end{aligned} \quad (1)$$

where: $Z_{TCi}, Z_{TRUSTi}$ and $Z_{CLIENT\_PREFi}$ are the key explanatory variables of interest - transaction costs, trust and client preferences, respectively while $X_i$ is a vector of other firm-level characteristics for enterprise i, $\zeta$ and $\beta'$ are vectors of parameters to be estimated and ε is the stochastic term.

The probability of adoption is estimated as:

$$P(DF_i = 1|Z, X_i) = F(\zeta_1 Z_{TCi} + \zeta_2 Z_{TRUSTi} + \zeta_3 Z_{CONS\_PREFi} + \beta' X'_{i\_} + \varepsilon_i) \quad (2)$$

where $F(.)$ is the cumulative distribution function (CDF): normal for the series of probit models we estimate. For all enterprises, transaction cost is proxied with 4 variables: (1) Whether the enterprise is in a rural vs. non-rural area (urban or peri-urban), (2) Whether the enterprise is in the north (Kaduna) or south (Oyo), and (3) The internet use intensity index at the location of the enterprise, measured by multiplying internet usage at the state level by the relative wealth index obtained from the Facebook data for good following (Chi et al., 2022). (4) Monitoring costs proxied by the number of hired workers in an enterprise and the extent to which an enterprise owner is specialized and thus available to monitor business activities.

For input suppliers and tomato processors, our results reflect the enterprise's reported use of DF in their most recent transaction conducted before their interview. For wholesalers and retailers, DF use is based on the respondents' response to their use of DF during the last trading season. For wholesalers and retailers, trust is measured as the percentage of procurement and sales transactions with regular customers during the last season. For input suppliers and processors, trust is based on whether the most recent transaction was with a regular customer. Client preference is proxied by transaction type; for input suppliers and processors, it distinguishes whether the last transaction was with a farmer/individual customer or a more formal client (e.g., trader, agro-input dealer, restaurant, processor, supermarket). For wholesalers and

retailers, client preference reflects whether most transactions in the last season were with organized clients (e.g., traders, brokers, NGOs, aggregators, hotels) versus farmers or individuals.

Below, we summarize the three key hypotheses associated with DF use among non-farm VC actors along Nigerian horticultural value chains and the proxies used in the empirical analysis:

1. DF adoption is higher where it reduces transaction costs in market interactions. This includes areas with better infrastructure and more financial institutions (lowering the risk and costs from failed financial transactions) or circumstances where DF improves traceability and monitoring. Thus,
    a. DF use is higher in areas with a higher internet usage index or in urban centers than in rural areas, ceteris paribus.
    b. DF use is higher in the more affluent south than the relatively poorer north.
    c. DF use is higher among enterprises with more hired employees.
2. DF use is greater in VC interactions with high trust and where DF complements relational contracts, such as transactions with regular clients versus new or one-time customers.
3. Client preferences for digital payments matter. DF use is more likely with formal clients (e.g., importers, processors, restaurants, supermarkets) than with farmers or consumers.

We include other firm controls following the agricultural technology adoption literature (Barrett et al., 2017; Feder et al., 1985; Sheahan & Barrett, 2017). We expect that DF use is higher among actors with more education and capacity (larger, frequent transactions). Gender differences may also influence DF use due to time, liquidity, attitudes, or preferences (Adeleke, 2024; Choruma et al., 2024; Cuberes & Teignier, 2014; Galindo-Manrique & Rojas-Vargas, 2025; Liu et al., 2024; Martins et al., 2014; Reynolds et al., 2023; UNIDO, 2023).

In estimating the drivers of DF adoption, some explanatory variables may be endogenous to the probability of DF use. For instance, higher ability entrepreneurs might be more inclined to engage with formal market channels (non-farmers in this study) and simultaneously more likely to adopt innovations such as DF. This creates a potential challenge of omitted variable bias in the estimates of such explanatory variables. Moreover, DF use itself could influence entrepreneurs' decisions, such as seeking more modern and formal market channels. This leads to a challenge with reverse causality.

Given that our data is cross-sectional, we minimize endogeneity concerns by focusing on explanatory variables that are not entrepreneur choices but likely to affect the costs, ability and or interest in DF. These include the gender and age of the enterprise owner and the state the enterprise is located in. Additionally, we include a rich set of enterprise characteristics that are unlikely to be determined by DF use but plausibly affect the costs and attractiveness of DF adoption such as whether the business is located in a rural versus non-rural area and the internet connectivity level where the firm is located to proxy for transaction costs. These controls help mitigate omitted variable bias.

Nevertheless, we cannot fully eliminate endogeneity or reverse causality and thus interpret our findings as correlations rather than causal effects. Despite this limitation, we argue that the observed direction, magnitude, and statistical significance of these associations, conditional on other factors, offer meaningful insights into an understudied question on the drivers of DF adoption among VC actors in the hidden middle. Our analysis contributes to a deeper understanding of key correlates of DF use in Nigeria's value chains

We use heteroskedasticity-robust standard errors clustered at the LGA level to account for potential correlation among firms operating within the same local environment, using the lowest level consistently available across all nodes. Because some nodes include a substantial share of actors from markets, we also verify that our main results remain robust when clustering at the market level for that subset of respondents. Additionally, we assess multicollinearity among explanatory variables by examining variance inflation factors (VIFs) and confirm that no artificially high correlations are present.

## 3. Results and discussion

### 3.1 Digital finance use along the tomato and GLV VC

Table 1 presents the use of DF in our study sample and four key findings emerge. First, we find that DF use for business transactions is not uncommon among off-farm agrifood VC actors, used by 44% of the entire sample and by over 70% of

**Table 1.** **Digital finance use among VC actors by node and state (%).**

| Node | Use digital finance at all for any transaction | | | Use digital finance during procurement | | | Use digital finance during sales | | | Total N | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oyo | Kaduna | Pooled | Oyo | Kaduna | Pooled | Oyo | Kaduna | Pooled | Oyo | Kaduna |
| Input suppliers | 61.80 | 50.55 | 54.65 | 61.80 | 50.55 | 54.65 | 26.32 | 4.94 | 16.45 | 233 | 392 |
| Tomato processors | 7.25 | 20.49 | 15.71 | 2.90 | 9.02 | 6.81 | 7.25 | 15.70 | 12.63 | 69 | 121 |
| Tomato Wholesalers | 44.57 | 77.43 | 71.04 | 0.00 | 0.00 | 0.00 | 44.57 | 77.43 | 71.04 | 413 | 390 |
| GLV wholesalers | 25.00 | 48.63 | 35.75 | 0.00 | 0.00 | 0.00 | 25.00 | 48.67 | 35.75 | 316 | 263 |
| Tomato retailers | 37.96 | 40.85 | 40.11 | 0.00 | 0.22 | 0.16 | 37.96 | 40.85 | 40.11 | 130 | 370 |
| GLV retailers | 25.00 | 31.64 | 30.07 | 0.00 | 0.24 | 0.18 | 25.00 | 31.64 | 30.07 | 128 | 414 |

Note: An actor is classified as using DF if the proportion of payments made through non-cash methods is higher than the proportion made using cash for sales transaction, but whether they use any non-cash methods for payment in procurement transactions.

tomato wholesalers and 55% of input suppliers. This means that while cash is still very common, digital payments have become important in the day-to-day running of many businesses. This is also consistent with the 2025 Nigeria Informal Economy Report, which notes that about 50% of informal business owners now use DF methods such as bank transfers or POS for their transactions (Klapper et al., 2025; NCC, 2024). Second, we find that DF finance varies significantly across VC actors. While between 45% and 70% of input suppliers and tomato wholesalers use DF for their transactions, DF use is low among tomato processors, where about 15% of them use DF for any transactions. The low use of DF among tomato processors might be due to the nature of their transactions being less frequent per season and often with farmers (on the procurement side) whose use of DF is generally low, and consumers (on the sales side) whose transactions might be less frequent (Macchiavello & Morjaria, 2021). Third, consistent with Adong et al. (2025), the use of DF is more prevalent for sales transactions than for procurement across all the nodes of the output supply chains (between 30%-70%). However, this contrasts with the input supply node where 55% of input suppliers use DF during procurement but only 16% use it for sales (largely to farmers). Again, these results might imply that DF use might be influenced by client interest in DF which is typically low among farmers but might be more preferable to importers or distributers of agricultural inputs.

Fourth, we find that the use of DF is more prevalent in the north (Kaduna) than in the south (Oyo) across all nodes except among input suppliers. This is contrary to our a priori expectation that digital technology use would be higher in the relatively more affluent south than in the north, due to higher levels of education and economic development. While the World Bank (2016) reports that most economic activities are concentrated in the south (compared to the north) with the exception of Kano and Kaduna States, if doing business in Kaduna is riskier and costlier, this might explain the higher DF use rate to mitigate these risks.

### 3.2 DF use by gender

Technology adoption is often considered gendered (Geng et al., 2024; UNIDO, 2023). The FD literature cites limited access to phones and technologies, different levels of digital literacy as reasons for lower adoption by gender (Adeleke, 2024; Adeleke et al., 2022; Demirgüç-Kunt et al., 2018, 2022; Geng et al., 2024; Reynolds et al., 2023; UNIDO, 2023). Table 2 presents DF use by gender for our study sample and three key points stand out.

First, we find that on average, DF use is higher for men versus women in most nodes, but with some notable exceptions. The share of male input suppliers that utilized DF was approximately 57% compared to 44% for women. While the gender differences are maintained across regions (with larger differences in the north) for purchases, the use of DF for sales is very similar across genders and actually higher among women (compared to men) in the south. Twenty-four percent of women input suppliers used DF in their most recent sales transaction, compared to men (14%). Likewise, we find higher use of DF among women tomato retailers (44%) compared to men (~25%) for sales in the south.

Second, among tomato processors, we find a very similar share of men reporting that they used DF in their last transaction (~16%) compared to women processors (~14%). Breaking it down further by state we find higher DF use among women in both states compared to men in their most recent sales transaction, albeit with very few women in the northern sample.

Third, we observe clear gender differences in reported use of DF for any transaction among wholesalers and retailers in the north. For the south, the shares of enterprises using DF is more similar across gender and not different for procurement, but often higher for males compared to females for sales.

### 3.3 Digital finance use by location (rural/non-rural)

Table 3 presents DF use by geographic location (rural versus non-rural (urban and peri-urban areas). Two key points stand out. First, DF use is quite common among VC actors in rural areas, ranging between a low of 30% (among GLV wholesalers) to more than half (54%) among input suppliers, while no rural tomato processors use DF. Second, as expected, there is more use of DF in non-rural areas for buying and selling transactions across all nodes. One exception is procurement among Tomato and GLV retailers, where it is similar (but narrowly) higher in rural areas in Oyo and Kaduna states. This regional disparity reflects spatially uneven DF diffusion, also observed in Ethiopia and Tanzania (GSMA, 2021; Minten et al., 2013). Adeleke (2024) also noted that DF use varies substantially between urban and rural areas in Nigeria, driven by spatial differences in socio-economic, enabling, and contextual factors.

Table 4 presents the descriptive statistics for the six enterprise samples in this study and reveals significant regional and node-specific differences. In Oyo (South), women constitute more than half of the respondents in most nodes, except among input sellers, where they account for approximately 37%. In contrast, female representation in Kaduna (North) is generally below 10%, with the exception of tomato and GLV retailers (56% and 30% respectively). Respondents in Oyo are slightly older on average (44 years) than those in Kaduna (40 years). More than 20% of respondents in most nodes reside in rural areas, except for tomato processors, where rural representation is less than 10%. In Oyo, rural presence is

**Table 2.** Digital finance use by gender among VC actors by node and state (%).

| | Used digital finance at all | | | Used digital finance during procurement | | | Used digital finance during sales | | | Total N | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gender** | **Oyo** | **Kaduna** | **Pooled** | **Oyo** | **Kaduna** | **Pooled** | **Oyo** | **Kaduna** | **Pooled** | **Oyo** | **Kaduna** |
| **INPUT SUPPLY (% of sample)** | | | | | | | | | | | |
| Male | 69.39 | 51.79 | 56.61 | 69.39 | 51.79 | 56.61 | 27.27 | 5.07 | 14.16 | 147 | 358 |
| Female | 48.84 | 22.12 | 44.42 | 48.84 | 22.12 | 44.42 | 25.00 | 0.00 | 23.78 | 86 | 34 |
| **TOMATO PROCESSORS** | | | | | | | | | | | |
| Male | 5.88 | 19.17 | 16.23 | 2.94 | 7.50 | 6.49 | 5.88 | 15.13 | 11.59 | 34 | 120 |
| Female | 8.57 | 100.00 | 13.51 | 2.86 | 100.00 | 8.11 | 8.57 | 50.00 | 10.81 | 35 | 2 |
| **TOMATO WHOLESALERS** | | | | | | | | | | | |
| Male | 46.40 | 78.16 | 74.92 | 0.00 | 0.00 | 0.00 | 46.40 | 78.16 | 74.92 | 178 | 367 |
| Female | 43.00 | 38.30 | 42.42 | 0.00 | 0.00 | 0.00 | 43.00 | 38.30 | 42.42 | 235 | 23 |
| **GLV WHOLESALERS** | | | | | | | | | | | |
| Male | 29.03 | 51.45 | 45.21 | 0.00 | 0.00 | 0.00 | 29.03 | 51.45 | 45.21 | 93 | 241 |
| Female | 23.32 | 18.18 | 22.86 | 0.00 | 0.00 | 0.00 | 23.32 | 18.18 | 22.86 | 223 | 22 |
| **TOMATO RETAILERS** | | | | | | | | | | | |
| Male | 24.71 | 46.80 | 44.33 | 0.00 | 0.26 | 0.23 | 24.71 | 46.80 | 44.33 | 55 | 220 |
| Female | 43.64 | 13.37 | 30.80 | 0.00 | 0.00 | 0.00 | 43.64 | 13.37 | 30.80 | 75 | 150 |
| **GLV RETAILERS** | | | | | | | | | | | |
| Male | 59.09 | 37.59 | 39.10 | 0.00 | 0.34 | 0.32 | 59.09 | 37.59 | 39.10 | 22 | 290 |
| Female | 17.92 | 17.74 | 17.83 | 0.00 | 0.00 | 0.00 | 17.92 | 17.74 | 17.83 | 106 | 124 |

**Table 3.** **Digital finance use by geographic location (rural versus non-rural) by VC actors (%).**

| | Used digital finance at all | | | Used digital finance during procurement | | | Used digital finance during sales | | | Total N | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location** | **Oyo** | **Kaduna** | **Pooled** | **Oyo** | **Kaduna** | **Pooled** | **Oyo** | **Kaduna** | **Pooled** | **Oyo** | **Kaduna** |
| **INPUT SUPPLY** | | | | | | | | | | | |
| Rural | 57.14 | 51.80 | 53.50 | 57.14 | 51.80 | 53.50 | 0.00 | 0.00 | 0.00 | 42 | 89 |
| Non-rural | 62.83 | 50.20 | 54.94 | 62.83 | 50.20 | 54.94 | 29.41 | 7.15 | 20.54 | 191 | 303 |
| **TOMATO PROCESSORS** | | | | | | | | | | | |
| Rural | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8 | 9 |
| Non-rural | 8.20 | 21.82 | 16.96 | 3.28 | 10.00 | 7.60 | 8.20 | 16.51 | 13.53 | 61 | 110 |
| **TOMATO WHOLESALERS** | | | | | | | | | | | |
| Rural | 31.07 | 35.41 | 32.08 | 0.00 | 0.00 | 0.00 | 31.07 | 35.41 | 32.08 | 108 | 15 |
| Non-rural | 50.21 | 77.64 | 73.47 | 0.00 | 0.00 | 0.00 | 50.21 | 77.64 | 73.47 | 246 | 320 |
| **GLV WHOLESALERS** | | | | | | | | | | | |
| Rural | 22.58 | 46.81 | 30.71 | 0.00 | 0.00 | 0.00 | 22.58 | 46.81 | 30.71 | 93 | 47 |
| Non-rural | 26.40 | 48.80 | 36.64 | 0.00 | 0.00 | 0.00 | 26.40 | 48.80 | 36.64 | 197 | 166 |
| **TOMATO RETAILERS** | | | | | | | | | | | |
| Rural | 37.26 | 36.64 | 36.70 | 0.00 | 0.71 | 0.64 | 37.26 | 36.64 | 36.70 | 13 | 124 |
| Non-rural | 39.24 | 46.31 | 43.97 | 0.00 | 0.00 | 0.00 | 39.28 | 46.31 | 43.97 | 109 | 183 |
| **GLV RETAILERS** | | | | | | | | | | | |
| Rural | 12.50 | 40.71 | 35.77 | 0.00 | 0.00 | 0.00 | 12.50 | 40.71 | 35.77 | 24 | 113 |
| Non-rural | 28.57 | 29.24 | 29.05 | 0.00 | 0.42 | 0.31 | 28.57 | 29.24 | 29.05 | 91 | 236 |

**Table 4.** **Summary statistics of key explanatory variables.**

| Variable | Input sellers | | | Tomato processors | | | Tomato wholesalers | | | GLV wholesaler | | | Tomato retailers | | | GLV retailers | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oyo | Kad | Pool | Oyo | Kad | Pool | Oyo | Kad | Pool | Oyo | Kad | Pool | Oyo | Kad | Pool | Oyo | Kad | Pool |
| Gender % (1 if female; 0 otherwise) | .37 | .11 | .19 | .54 | .01 | .12 | .58 | .05 | .32 | .70 | .08 | .44 | .48 | .56 | .54 | .80 | .30 | .43 |
| Age (years) | 42 | 39 | 40 | 47 | 40 | 42 | 46 | 40 | 43 | 44 | 42 | 43 | 41 | 40 | 40 | 46 | 40 | 41 |
| | (12) | (10) | (10) | (12) | (9) | (10) | (11) | (10) | (11) | (11) | (11) | (11) | (14) | (10) | (11) | (13) | (11) | (12) |
| Rural (1 If rural; 0 otherwise) | .30 | .22 | .24 | .15 | .07 | .08 | .31 | .04 | .18 | .31 | .24 | .28 | .09 | .45 | .36 | .23 | .31 | .29 |
| Internet use intensity | 22 | 16 | 18 | 24 | 20 | 21 | 24 | 19 | 22 | 24 | 19 | 22 | 4 | 3 | 4 | 4 | 4 | 4 |
| | (9) | (7) | (8) | (9) | (4) | (6) | (10) | (10) | (10) | (10) | (8) | (9) | (1) | (1) | (1) | (2) | (1) | (2) |
| Enterprise own specialization | .64 | .79 | .74 | .95 | .91 | .92 | .71 | .30 | .51 | .63 | .61 | .62 | .56 | .61 | .60 | .76 | .71 | .72 |
| Education (1 if at least secondary edu) | .72 | .60 | .64 | .69 | .52 | .55 | .51 | .50 | .51 | .47 | .42 | .45 | .39 | .61 | .56 | .44 | .53 | .51 |
| Buying transaction (0 if farmers/indiv) | .98 | .99 | .99 | .21 | .09 | .11 | .18 | .19 | .18 | .09 | .18 | .13 | .49 | .56 | .54 | .12 | .37 | .31 |
| Selling transaction (0 if farmers/indiv) | .23 | 0.36 | .32 | .95 | .99 | .95 | .98 | .98 | .98 | .99 | .95 | .97 | .85 | .74 | .77 | .88 | .76 | .79 |
| Number of permanent employees | .55 | .34 | .40 | .33 | .76 | .67 | .86 | 5 | 3 | .87 | 1 | 1 | .10 | .75 | .60 | .17 | .60 | .49 |
| | (2) | (1) | (1) | (1) | (2) | (2) | (3) | (9) | (7) | (4) | (3) | (3) | (.60) | (3) | (2) | (2) | (2) | (2) |
| Number of casual employees | .34 | 2 | 1 | 2 | 2 | 2 | 3 | 5 | 4 | 2 | 4 | 3 | .63 | 3 | 2 | .48 | 3 | 3 |
| | (1) | (3) | (3) | (3) | (3) | (3) | (5) | (4) | (5) | (4) | (4) | (4) | (2) | (4) | (3) | (2) | (4) | (4) |
| % Share buy from regular customer | 93 | 89 | 90 | - | - | - | 77 | 68 | 73 | 74 | 70 | 72 | 71 | 65 | 67 | 74 | 67 | 69 |
| | (14) | (18) | (17) | | | | (21) | (24) | (23) | (24) | (22) | (23) | (27) | (23) | (24) | (23) | (23) | (23) |
| % Share sold to regular customer | 75 | 79 | 78 | 78 | 66 | 68 | - | - | - | - | - | - | - | - | - | - | - | - |
| | (20) | (19) | (19) | (24) | (33) | (31) | | | | | | | | | | | | |
| N | 233 | 392 | 625 | 69 | 122 | 191 | 413 | 390 | 803 | 316 | 263 | 579 | 130 | 370 | 500 | 128 | 414 | 542 |

Note: Figure in parenthesis are standard deviation and – denotes missing variables.

higher overall, particularly among input sellers and wholesalers (approximately 30%). Conversely, in Kaduna, tomato and GLV retailers are more frequently located in rural areas. Internet use intensity is generally greater in Oyo than Kaduna across all nodes, though it remains very low in locations where tomato and GLV retailers are located relative to other actors; typically, rural areas.

Occupational diversification is common among off-farm enterprises. Over 90% of tomato processors and more than half of other actors report engaging in additional income-generating activities beyond their primary node roles. Educational attainment is relatively high, with more than half of respondents in most nodes having at least secondary education. Exceptions include tomato processors (31%) and GLV wholesalers (45%). Input sellers are the most educated group, and education levels are higher in Oyo than Kaduna for input sellers, processors, and wholesalers, while the reverse holds for tomato retailers and GLV actors.

Distinct transaction patterns emerge across nodes. Input sellers primarily source from non-farm enterprises such as agro-input manufacturers and distributors or wholesalers, whereas other actors predominantly procure from farmers with the exception of tomato retailers, among whom 54% source a larger share of their products from non-farm actors, largely wholesalers. These sourcing differences may influence digital financial (DF) adoption, given variations in client payment preferences. Input importers or distributors might prefer digital payments than cash while farmers might prefer cash. Consistent with this idea, we see that DF use in procurement is more prevalent among input sellers compared to other actors who transact largely with farmers. During sales, this pattern reverses, with many actors engaging more frequently with non-farm buyers. Repeat transactions are widespread, with nearly two-thirds of purchases and sales involving regular customers. Input sellers, in particular, report buying approximately 90% and selling over 75% of products through repeat relationships, underscoring the importance of trust and relational contracting within these value chains.

Employment characteristics vary across nodes and regions. Wholesalers typically employ more staff than retailers, as expected, and hiring is more prevalent in Kaduna than in Oyo. Although this pattern may seem counterintuitive given relative wealth levels, it aligns with unemployment statistics reported by the Nigerian National Bureau of Statistics (NBS, 2025).

### 3.4 Regression results on factors associated with DF use

Figures 1-6 presents the marginal effects of our explanatory variables from the probit estimation of the drivers of DF use among VC actors for transactions. Our findings generally confirm our a priori hypothesis that transactional costs, trust, and client preferences are crucial important factors associated with DF use among agricultural VC actors, but with some important nuances.

First, we find evidence of a negative association between transaction costs (TC) and DF use with varying level of significance among agri-food VC actors for some VC segments, all else equal as shown in Figures 1A & 1B. More specifically, we find higher DF use in areas with high internet intensity among GLV wholesalers and retailers and tomato retailers. These associations are significant at 5% or 1% respectively and imply that a one unit increase in internet intensity is associated with 1%, 6%, and 6% increase in DF use among GLV wholesalers, tomato retailers, and GLV retailers, respectively. However, being a tomato processor in an area with one unit higher internet intensity is associated with 1% lower probability of DF use, significant at 10%. Being in a rural area does not affect DF use in most cases, ceteris paribus. Two exceptions are lower DF use among tomato wholesalers in rural areas as hypothesized and a positive effect among GLV retailers (where internet use intensity is very low). This is consistent with the descriptive statistics and might reflect the reduced isolation of rural areas, allowing for similar DF use, ceteris paribus. Together, these findings are largely consistent with other studies such as Abate et al. (2023) who emphasized the role of tangible infrastructures including stable internet connectivity, sufficient bandwidth, broad mobile network coverage, secure server access, and reliable electrical power for increasing the adoption of DF among VC actors.

Contrary to our expectation, we find that tomato processors and wholesalers (for both GLV and tomatoes) in Northern Nigeria (Kaduna) are more likely to have used DF for business transactions compared to their counterparts in the south (Oyo) in Figure 1B. However, input suppliers in Oyo were more likely to use DF than those in Kaduna. These results suggest that context matters and conditions vary by region and VC node. Conditional on controlling for infrastructure in rural vs. urban areas, regional differences might reflect variation in business activities (e.g., numerous transactions per day per enterprise that traverse long distances that might encourage DF use) in Kaduna, which is a national supplier of horticultural products, compared to Oyo, which is more of a local and subregional supplier.

Our third measure of TC was amount of labor hired. Our results (Figure 2) confirm that where significant (for input suppliers, tomato processors, and wholesalers for both tomato and GLV), enterprises with higher numbers of hired labor

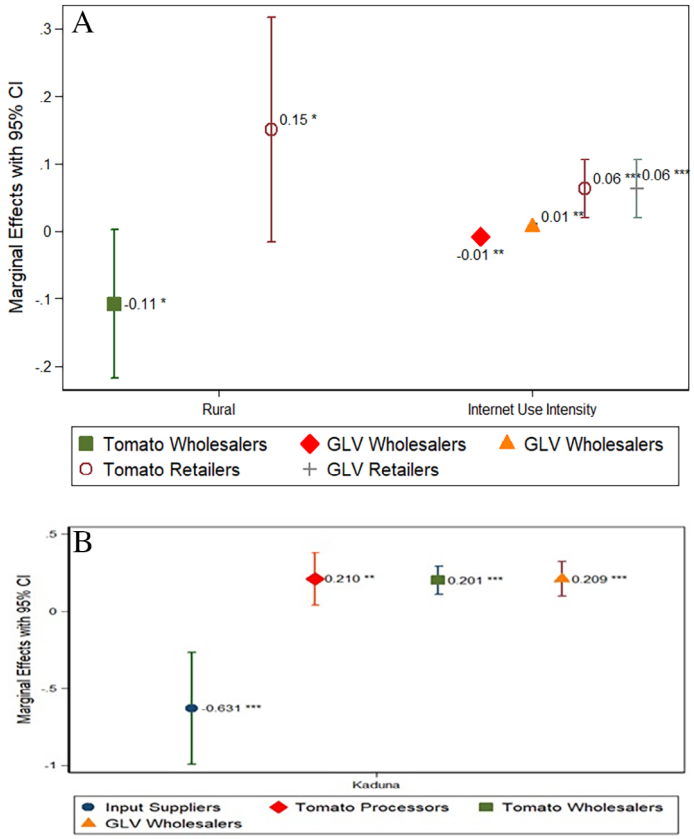


**Figure 1. (A): Effect of infrastructure and location factors on the use of DF. (B) Effect of infrastructure and location factors on the use of DF.** *** p < 0.01, ** p < 0.05, * p < 0.1. The models are estimated with additional covariates. Full models are reported in Table 6.

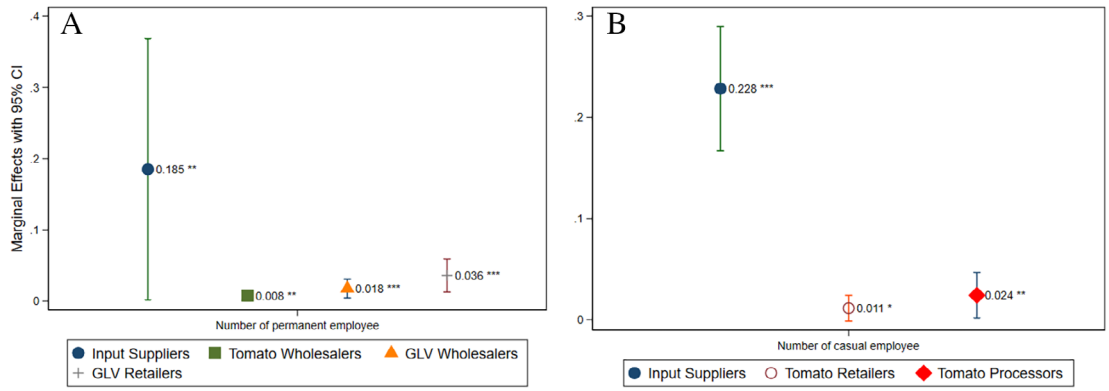


**Figure 2. (A & B): Effect of the number of permanent and casual employee on the use of DF.** *** p < 0.01, ** p < 0.05, * p < 0.1. The models are estimated with additional covariates. Full models are reported in Table 6.

are more likely to use DF. While more employees is also an indication of scale and higher value from DF use for numerous transactions, these findings are consistent with added value for enterprises to use DF to monitor financial payments to and from the firm where multiple non-family members are engaged in business transactions.

Regarding our second hypothesis on trust (see Figure 3), we find that an input supplier whose last sale was to a regular customer was more likely to have received that payment using DF, and this effect is statistically significant at 5%. This is consistent with the study hypothesis (and literature on SET, and RCT) that trust, and repeated interactions can encourage


**Figure 3. Effect of regular customers (trust) on the use of DF.** *** p < 0.01, ** p < 0.05, * p < 0.1. The models are estimated with additional covariates. Full models are reported in Table 6.

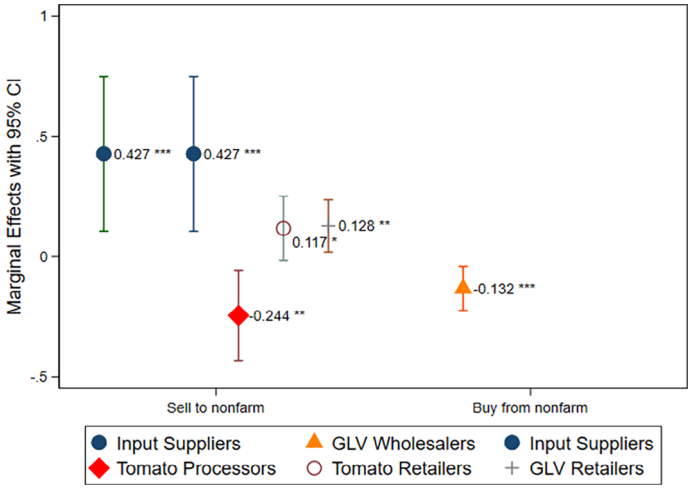


**Figure 4. Effect of client preferences on the use of DF.** *** p < 0.01, ** p < 0.05, * p < 0.1. The models are estimated with additional covariates. Full models are reported in Table 6.

DF use by reducing the risks associated with DF use in context with low contract enforcement (Fafchamps, 2004; Levin, 2003; Michler & Wu, 2020). We do not find any effects of transactions with regular clients at other nodes. The insignificant effect for share of procurement from regular customers is not surprising since the share of respondents using DF for procurement was very low overall. Similarly, for sales to regular customers, this information is only available for the last transaction (and thus for input suppliers and tomato processors).

Third, we find evidence consistent with our hypothesis that client preferences matter. For sales by all VC actors (except tomato processors and GLV wholesalers), we find that sales to non-farmer or consumer clients are more likely to have been done using DF, all else equal. VC actors dealing with other traders or restaurants or processors are much more likely to have used DF in a sales transaction compared to those who sell directly to consumers or farmers. This is consistent with low preference for DF use among farmers due to poor infrastructure, technical know-how and financial literacy (Abate et al., 2023; Benitez-Altuna et al., 2024; Parlasca et al., 2022; Prodhan et al., 2024).

Our empirical analysis also confirms that enterprise characteristics matter for DF use as for other technologies. For example, we find that DF use is generally more common among male VC actors, ceteris paribus. For all nodes except tomato processors, being female is negatively and significantly ($p < 0.05$) associated with the use of DF. However, for tomato processors, being female is positive and statistically significantly associated with DF use at 5%. The magnitudes

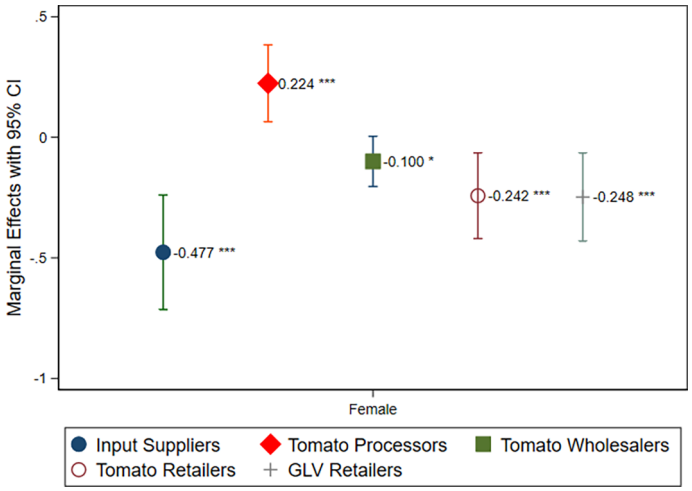


**Figure 5. Effect of gender on the use of DF.** *** p < 0.01, ** p < 0.05, * p < 0.1. The models are estimated with additional covariates. Full models are reported in Table 6.

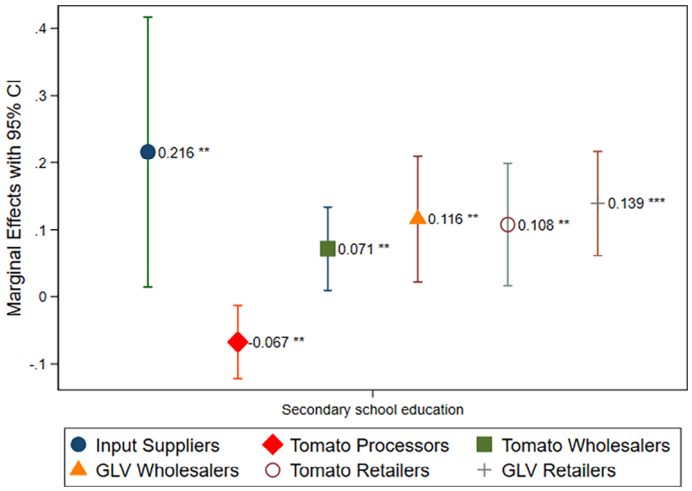


**Figure 6. Effect of education on the use of DF.** *** p < 0.01, ** p < 0.05, * p < 0.1. The models are estimated with additional covariates. Full models are reported in Table 6.

of the negative marginal effects are larger among GLV and tomato retailers relative to other nodes. Women are thought to be more capital-constrained and in Nigeria, often facing cultural norms that limit their access to modern technologies (Adeleke, 2024; Adeleke et al., 2022). However, the converse findings for tomato processors indicate that there are contexts and activities within the horticulture VC where women's use of DF is common and more likely. Understanding the drivers of this phenomenon can be informative for increasing female use of DF in other contexts where it may be lower than desired.

We also find a positive and significant association between entrepreneur education and the use of DF in most cases, particularly for input suppliers, tomato, and GLV wholesalers, and retailers ($p < 0.05$ in most cases) except among tomato processors where the association is negative. This is consistent with literature that has shown that financial literacy and education can boost the use of DF (Achille and Velamuri, 2025; Aker & Mbiti, 2010; Dibbern et al., 2025; Geng et al., 2024; Menberu, 2024; Sam-Abugu et al., 2025; Yang et al., 2023).

## 4. Conclusion and recommendations

This study investigates the extent and drivers of DF use across four off-farm VC actors across culturally and economically distinct locations along two Nigerian VCs. We explore the roles of gender, education, infrastructure, economics,

**Table 5.** **Marginal effect estimates showing the correlates of digital finance adoptions (in any transaction) –– Probit analysis.**

| Variable | Input suppliers | | Tomato processors | | Tomato wholesalers | | GLV wholesalers | | Tomato retailers | | GLV retailers | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | dy/dx | SE | dy/dx | SE | dy/dx | SE | dy/dx | SE | dy/dx | SE | dy/dx | SE |
| State (1 if Kaduna; 0 if Oyo) | -.212*** | .059 | .210** | .086 | .201*** | .047 | .209*** | .058 | .021 | .103 | -.041 | .140 |
| Rural (1 If rural; 0 otherwise) | .025 | .077 | - | | -.107* | .056 | -.005 | .048 | .034 | .104 | .150* | .085 |
| Internet use intensity | .003 | .003 | -.008** | .003 | .003 | .002 | .006** | .002 | .063** | .027 | .063*** | .022 |
| Number of permanent employees | .062** | .031 | .005 | .004 | .008** | .003 | .018*** | .007 | -.007 | .009 | .036*** | .012 |
| Number of casual employees | .077*** | .010 | .024** | .011 | -.002 | .004 | -.003 | .007 | .011* | .007 | .005 | .007 |
| % Share buy from regular customer | .001 | .001 | - | | .001 | .001 | -.002* | .001 | -.001 | .001 | .001 | .001 |
| % Share sold to regular customer | .002*** | .001 | -.001** | .001 | - | | - | | - | | - | |
| Buying transaction with non-farm (0 if farmers/ indiv) | .213* | .128 | .078 | .054 | .057 | .047 | -.132*** | .047 | -.068 | .081 | .058 | .048 |
| Selling transaction to non-farm (0 if farmers/ individuals) | .143*** | .053 | -.244** | .096 | .074 | .188 | .128 | .111 | .117* | .068 | .128** | .055 |
| Gender (1 if female; 0 otherwise) | -.160*** | .039 | .224*** | .081 | -.100* | .053 | -.075 | .065 | -.242*** | .091 | -.248*** | .093 |
| Age (years) | .001 | .002 | -.006** | .001 | -.001 | .002 | .000 | .002 | -.001 | .003 | -.000 | .002 |
| Enterprise own specialization (1 if diversified, 0 if specialized) | -.027 | .037 | .186*** | .064 | -.030 | .047 | .032 | .041 | .007 | .057 | .084 | .062 |
| Education (1 if at least secondary edu) | .072** | .034 | -.067** | .028 | .071** | .032 | .116** | .048 | .108** | .046 | .139*** | .040 |
| Number of obs. | 624 | | 170 | | 616 | | 426 | | 318 | | 367 | |
| Log pseudolikelihood | -366.30 | | -64.32 | | -361.76 | | -253.67 | | -194.60 | | -206.80 | |
| Wald chi2 | 183.59 | | 926.03 | | 225.70 | | 63.17 | | 55.30 | | 173.05 | |
| Prob > chi2 | .000 | | .000 | | .000 | | .000 | | .000 | | .000 | |
| Pseudo R2 | .150 | | .172 | | .119 | | .097 | | .092 | | .129 | |
| Mean of dependent variable | .493 | | .191 | | .588 | | .329 | | .317 | | .291 | |

Note: *, **, and *** denotes significant at 10%, 5%, and 1% p. value respectively. For input sellers and processors, the outcome variable is the use of digital finance for the most recent buying and/or selling transaction while for the wholesalers and retailer is based on the use of digital finance in general buying and/or selling transaction. The robust standard error reported is clustered at the LGA level.

transaction risks, and trust in driving DF use. We utilized a unique and novel dataset covering >3300 input suppliers, processors, wholesalers, and retailers.

Our results reveal that DF use is not as low as generally perceived. More than 40 percent of the agri-food VC actors in our sample used DF in at least one of their most recent and general purchase and sales transactions. However, DF adoption varies significantly by VC segment, region gender, and transaction. While over 70% of tomato wholesalers used DF, only 15% of tomato processors used DF with use in other segments ranging between 30% and 55%. Surprisingly, usage is higher in Nigeria's poorer northern region than in the wealthier south. Gender patterns differ by node: All else equal, men use DF more among input suppliers and retailers but are no more likely than women for GLV wholesale. Women are more likely to use DF among tomato processors. DF is used more for sales than procurement, especially with trusted clients and formal channels.

These findings imply that policies should prioritize affordability, interoperability, and trust-building mechanisms to make DF a reliable and cost-effective alternative to cash. There is a need to tailor interventions around DF use promotion to node and region-specific levers that can scale DF as a driver of productivity, formalization, and welfare in Sub-Saharan Africa. Specifically, we recommend the need for policymakers/donors to:

i. Recognize that DF use is not as uncommon as generally perceived, and that off-farm VC actors appear to use DF where DF provides utility and makes economic sense.

ii. Mainstream gender in the design and implementation of policy to promote the adoption of DF.

iii. Adopt segment-specific and region-tailored efforts to:

   a. Understand reasons for low use among certain segments (e.g. processors) and identify appropriate strategies to close adoption gaps.

   b. Expand DF use for procurement and institutionalize trust mechanisms.

iv. Ensure infrastructural development across the country, including improvements in internet connectivity and other essential services.

## Declaration of competing interests
The authors have no conflicts of interest to declare.

## Data availability statement
Data will be made available on request.

## Acknowledgements
This work was funded in part by the Gates Foundation via the project INV-034790_2021 RSM2SNF, "Actionable research to Support: This African MSMEs to supply affordable, safe, and nutritious foods," at Michigan State University. The findings and conclusions contained within are those of the authors and do not necessarily reflect positions or policies of the Gates Foundation.

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