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Digital Liquidity and Market Segmentation in Agricultural Value Chains: Network Reach and Trader-Level Price Dispersion in Bangladesh

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ABSTRACT

Digital financial services (DFS) are widely presumed to reduce transaction and information frictions and thereby promote market integration in agricultural value chains. However, where exchange is network-embedded and access to differentiated trading tiers depends on reputation, compliance capacity, and rapid verifiable settlement, digitalization may instead be associated with wider within-chain price dispersion. This study examines whether digital liquidity is associated with wider trader-level price dispersion through its interaction with network position. We distinguish digital access (readiness) from digital transaction intensity, measured as the average share of procurement and sales settled digitally. Using the IFPRI enterprise dataset released in 2024, based on survey data collected during June–August 2023 in Bogra and Rangpur districts of Bangladesh through network-based recruitment, we construct selling- and procurement-side price dispersion as the winsorized log difference between each trader's highest and lowest transaction prices. Network position is measured by network reach and diversification-based centrality (1–HHI). OLS estimates with trader-level controls and fixed effects show that digital intensity and network reach are positively associated with price dispersion, and that their interaction is also positive and statistically significant especially in the potato value chain, while the association is not robust in rice.

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Introduction

Digital financial services (DFS) are reshaping how liquidity is mobilized and transactions are organized in agricultural value chains, particularly among midstream micro, small, and medium enterprises. Mobile money, digital wallets, and platform-based payments may reduce transfer costs, improve traceability, and relax spatial and informational frictions, thereby supporting market integration (Fausiyat, 2025; Jouanjean, 2019). Yet these gains are not necessarily uniform. Effective use often depends on complementary capabilities, organizational adjustments and infrastructure, producing uneven adoption (Galperín & Viecens, 2017). This issue is especially relevant in agri-food value chains, where relational exchange and governance structures shape trading terms, market access, and exposure to volatility (Muflikh et al., 2022; Jouanjean, 2019).

This study examines whether digital liquidity is associated with trader-level price dispersion and whether this relationship varies with network position. We define digital liquidity as a trader's capacity to mobilize liquid purchasing power through digital channels in ways that may influence exchange feasibility and trading conditions. Digital access captures infrastructural readiness, including the ability to use digital devices and payment systems, consistent with the view that connectivity and complementary investments underpin potential digital gains (Galperín & Viecens, 2017; Jouanjean, 2019). Digital transaction intensity captures digital payment use in procurement and sales, reflecting evidence that operational use may matter more than access alone (Rani, 2023; Jouanjean, 2019).

Standard arbitrage logic suggests that lower transfer and settlement frictions may support spatial and intertemporal reallocation and narrow price differences when transaction costs are binding (Arimoto et al., 2019; Svanidze et al., 2019). However, reduced frictions may also coincide with wider within trader price dispersion when network-central traders transact across differentiated tiers, such as higher-quality lots, deferred-delivery arrangements, or bundled services. Prices may differ legitimately across these tiers because participation can depend on reputation, compliance capacity, and reliable settlement.

In such settings, digital liquidity may be associated with wider dispersion when it coincides with uneven access to counterparties and contractual arrangements (Muflikh et al., 2022; Galperín & Viecens, 2017; Jouanjean, 2019).

We conceptualize network position in two dimensions. Network reach captures the breadth of a trader's connections across suppliers, buyers, and known enterprises (Muflikh et al., 2022; Arimoto et al., 2019). Diversification-based centrality is measured as one minus the Herfindahl index (1–HHI), capturing the distribution of transactions across partner categories (Casaburi & Reed, 2022; Arimoto et al., 2019). This distinction separates breadth of market access from the spread of transactions across existing partner categories. We examine selling-side and procurement-side dispersion separately because bargaining conditions may differ across output and input markets (Muflikh et al., 2022; Casaburi & Reed, 2022). We also compare potato and rice value chains because crop characteristics and governance structures may shape volatility, coordination requirements, and arbitrage constraints (Muflikh et al., 2022; Arimoto et al., 2019).

Empirically, we analyze midstream traders in Bangladesh's rice and potato value chains using the IFPRI enterprise dataset released in 2024, based on survey data collected between June and August 2023 in Bogra and Rangpur through a network-based recruitment design. Price dispersion is measured separately for selling-side and procurement-side transactions as the winsorized logarithmic difference between each trader's highest and lowest reported prices. We estimate trader-level OLS regressions with interaction terms, trader-level controls, district fixed effects, crop fixed effects in pooled specifications, and heteroskedasticity-robust standard errors.

The findings indicate that network reach and digital transaction intensity are positively associated with price dispersion, and that their interaction is positive and statistically significant in pooled specifications. The relationship is more pronounced in the potato value chain than in the rice value chain, consistent with the possibility that perishability, quality differentiation, and coordination requirements are linked to stronger tiered-market patterns (Muflikh et al., 2022; Arimoto et al., 2019). Similar associations appear on the procurement side, while the interaction between diversification-based centrality and digital intensity is less robust. The study contributes to digital technologies and market integration in developing economies (Jouanjean, 2019; Galperín & Viecens, 2017), network structure and trading behavior (Casaburi & Reed, 2022; Arimoto et al., 2019), and persistent dispersion in agricultural markets (Svanidze et al., 2019; Arimoto et al., 2019; Nzuma & Kirui, 2021; Pandey et al., 2023). Because the data are cross-sectional and observational, the results are interpreted as conditional associations rather than causal effects.

Literature Review

The relationship between digital liquidity and market outcomes in agricultural value chains sits at the intersection of several strands of literature, including digital financial inclusion, payment systems, digital platforms, and agricultural marketing.

Across these fields, digital tools are commonly associated with lower transaction costs, improved information flows, and expanded market access. However, their benefits are rarely distributed evenly. Effective use often depends on infrastructure, skills, organizational capacity, and governance arrangements, which may generate uneven patterns of adoption and differentiated outcomes across market participants (Dudu et al., 2024; Kravchuk & Baula, 2025; TOPPO & Zubairi, 2025; Sille et al., 2024; Molchanova et al., 2020). These issues are particularly important in agri-food value chains, where fragmented supply chains, intermediary influence, and limited transparency may constrain uniform market integration (Fausiyat, 2025; Denashurya & Azizu, 2025; Dugina et al., 2020; Mukherjee, 2025).

A central distinction in this study is between digital access and digital transaction intensity. Digital access refers to the availability of digital financial tools and the basic capacity to use them. Digital transaction intensity, by contrast, reflects the extent to which traders actually rely on digital channels in procurement and sales. This distinction is important because access alone does not necessarily imply meaningful operational use. Digital finance research recognizes that inclusion involves both availability and effective use, although definitions continue to vary across fintech settings (Semenog, 2021; Sille et al., 2024). Payment-system research further emphasizes speed, reliability, security, and ease of settlement, suggesting that transaction depth may be more relevant to exchange outcomes than access alone (Raza, 2025; Sinkala, 2023; Davydenko et al., 2025). From this perspective, digital transaction intensity captures the degree to which digital payments are embedded in day-to-day trading operations rather than merely available as an option (Dudu et al., 2024; Sinkala, 2023; Davydenko et al., 2025; Zaika, 2025).

The literature commonly associates digitalization with stronger market integration. Faster settlement, lower selected transaction costs, improved financial management, and greater security may reduce frictions that limit exchange across locations and counterparties (Dudu et al., 2024; Raza, 2025; Davydenko et al., 2025; Sinkala, 2023; Zaika, 2025). Digital platforms and information systems may also improve matching, coordination, and transparency across agricultural transactions (Cheng et al., 2014; Tang et al., 2023; Mukherjee, 2025; Molchanova et al., 2020). Under this interpretation, digitalization can support arbitrage by making transactions faster and more reliable, potentially narrowing price differences across markets.

At the same time, a growing body of research highlights the limits of this integration perspective. Digital divide research points to affordability, infrastructure, and capability constraints that restrict effective use among smaller or less connected firms (Kravchuk & Baula, 2025; TOPPO & Zubairi, 2025; Sille et al., 2024). Regulatory weaknesses, cybersecurity risks, and informational asymmetries may also introduce new frictions rather than eliminate existing ones (Davydenko et al., 2025; Шлапак, 2022; Molchanova et al., 2020). Embedded-finance and supply-chain-finance models further suggest that digital tools often operate within structured relationships rather than anonymous spot markets.

As a result, digitalization may coincide with differentiated access across transaction tiers instead of producing uniform integration (Aubhi et al., 2025; Denashurya, 2025; Molchanova et al., 2020). This possibility is especially relevant in agricultural value chains, where exchange is frequently network-embedded. Agricultural markets often include a mix of spot transactions, intermediary-mediated trade, contract-linked relationships, and platform-supported transactions (Fausiyat, 2025; Dugina et al., 2020; Mukherjee, 2025). Traders with broader networks may be able to operate across differentiated market nodes, engage with a wider range of counterparties, and access transactions that vary in quality, timing, and service requirements. In this setting, network reach may be associated with exposure to a wider range of prices. The relationship may be particularly pronounced in perishable markets, where rapid coordination, reliable information, and timely settlement are especially important (Cheng et al., 2014; Denashurya, 2025).

A network-embedded perspective also clarifies why digital liquidity may be associated with wider price dispersion in some contexts. Digital market access tools may open new linkages and improve negotiation capacity, but the benefits of these tools may depend on relational connectivity and platform governance (Fausiyat, 2025; Molchanova et al., 2020). Proposals to reduce reliance on intermediaries implicitly recognize the importance of relational power in agricultural trade (Dugina et al., 2020; Mukherjee, 2025). Network reach captures the breadth of a trader's connections across market nodes, while diversification-based centrality captures how transactions are distributed across existing partner categories. These dimensions are related but not identical. A trader may have a broad network without distributing transactions evenly across partners, or may maintain a relatively diversified portfolio within a limited network. Since payment efficiency depends on active throughput rather than passive availability, digital transaction intensity may be more closely associated with market outcomes than digital access alone (Dudu et al., 2024; Sinkala, 2023; Davydenko et al., 2025; Zaika, 2025).

The literature therefore points to two plausible patterns. Digital liquidity may be associated with narrower price dispersion when it supports arbitrage and reduces selected transaction frictions. Alternatively, it may be associated with wider dispersion when network-central traders use digital channels to participate across differentiated transaction tiers, including contract-linked and finance-bundled arrangements (Aubhi et al., 2025; Denashurya, 2025; Molchanova et al., 2020; Fausiyat, 2025). Commodity characteristics may further shape these relationships. Perishable trading places a high value on rapid coordination and verification (Cheng et al., 2014), while capability constraints may generate asymmetric patterns across procurement and selling activities (TOPPO & Zubairi, 2025; Davydenko et al., 2025; Molchanova et al., 2020).

Despite growing attention to digital finance and agricultural platforms, limited empirical evidence examines how digital transaction intensity and network position are jointly associated with trader-level price dispersion. Few studies distinguish network reach from diversification-based centrality or compare these relationships across crop types and transaction sides (Cheng et al., 2014; Denashurya, 2025; Fausiyat, 2025; Molchanova et al., 2020). This study addresses these gaps by examining how digital liquidity and network position are associated with price dispersion among midstream traders in Bangladesh's rice and potato value chains.

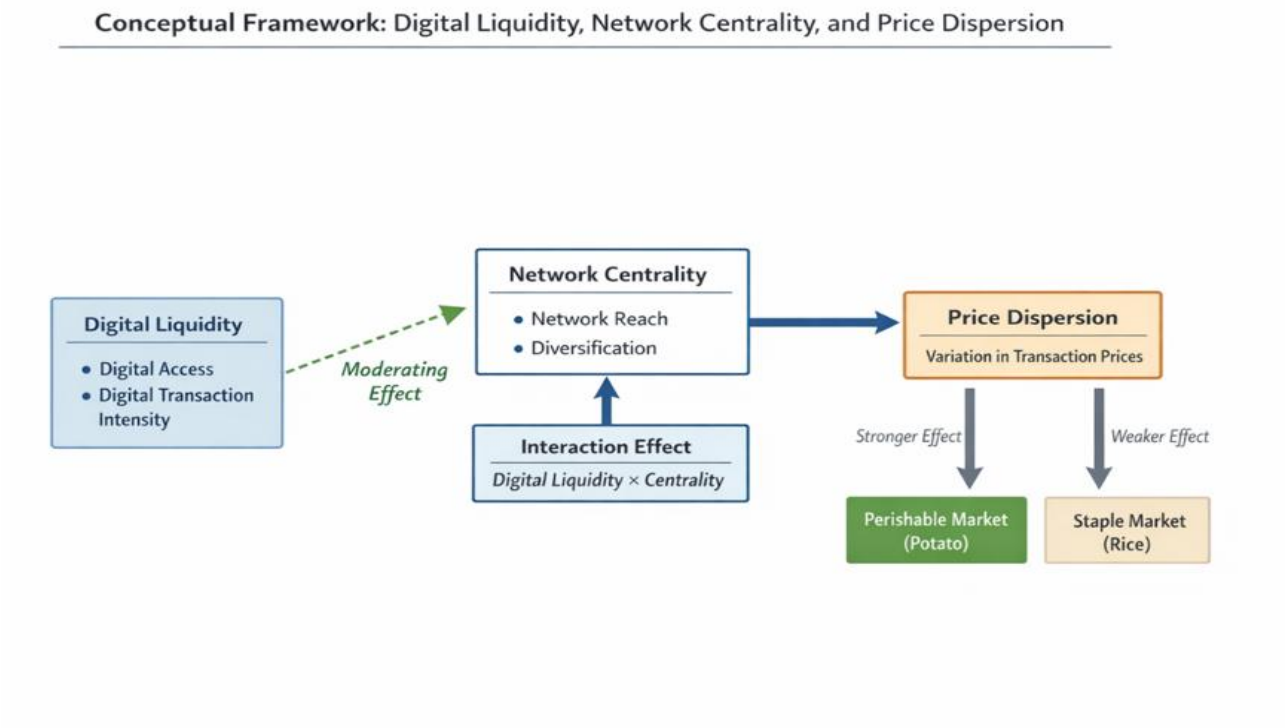

Figure 1. Conceptual Framework Linking Digital Liquidity, Network Centrality, and Price Dispersion

Conceptual Framework

This study develops a conceptual framework linking digital liquidity, network position, and trader-level price dispersion within agricultural value chains. As illustrated in Figure 1, traders with broader relational networks may operate across transaction environments that differ in quality, timing, bargaining conditions, and service requirements. Exposure to differentiated transaction tiers may therefore be associated with wider intra-trader price dispersion.

Network position is conceptualized in two dimensions. Network reach captures the breadth of a trader's connections across buyers, suppliers, and known enterprises. Diversification-based centrality captures the distribution of transactions across partner categories using a one-minus-Herfindahl index (1–HHI). The two measures represent distinct dimensions of network position: reach reflects breadth across market nodes, whereas diversification reflects the distribution of transactions across existing partner categories.

Digital liquidity is incorporated as a conditioning factor. Digital access reflects infrastructural readiness, while digital transaction intensity captures the depth of digital payment use in trading operations. As shown in Figure 1, the framework hypothesizes that the positive association between network reach and price dispersion may be stronger at higher levels of digital transaction intensity. This conditional association may be more pronounced in the potato value chain, where perishability, quality differentiation, storage dynamics, and coordination requirements create greater scope for differentiated transaction conditions than in the relatively standardized rice value chain.

The framework provides the basis for estimating interaction terms between network position and digital transaction intensity. Because the empirical analysis relies on cross-sectional observational data, the estimated relationships are interpreted as conditional associations rather than causal effects.

Methodology

Data Source and Analytical Sample

This study uses the IFPRI dataset titled "Survey of Micro, Small, and Medium Enterprises in Agri-Food Value Chains: Network-Based Recruitment Approach in Bangladesh," released in 2024. The underlying survey data were collected between June and August 2023 in the Bogra and Rangpur districts of Bangladesh. The dataset originates from the second phase of IFPRI's project *"Digital Financial Services Adoption among SMEs in the Midstream of Agricultural Value Chains."* This phase focuses specifically on midstream actors operating in the rice and potato value chains in Bangladesh.

The survey was conducted between June and August 2023 in Bogra and Rangpur districts. The data collection followed a network-based recruitment design intended to capture relational linkages within value chains. In randomly selected villages within the study areas, a short farmer survey was first administered to identify intermediary actors to whom farmers had sold commodities within the previous 30 days.

These identified intermediaries were subsequently contacted and interviewed using a comprehensive enterprise questionnaire. This iterative design improves network validity by tracing actual transaction relationships rather than relying solely on registry-based sampling.

In Bangladesh, 280 rice farmers and 254 potato farmers participated in the farmer listing surveys. The midstream sample includes:

- Rice value chain: 1,066 traders, 456 processors, and 220 wholesalers
- Potato value chain: 1,117 traders, 1 processor, 235 wholesalers, and 1 aggregator

The present analysis focuses on midstream actors in the rice and potato value chains, including traders, processors, wholesalers, and aggregators. These actors play important roles in price formation and intermediation. The contrast between rice, a relatively standardized staple, and potato, a more perishable and quality-differentiated crop, allows an examination of heterogeneity in the relationship between digital liquidity and network position across distinct market structures.

Observations are retained if traders report valid transaction price information necessary to construct price dispersion measures. All variables are constructed at the trader level. Data cleaning includes consistency checks (e.g., ensuring highest prices are not lower than lowest prices) and exclusion of non-positive price observations where logarithmic transformations are required. All data management and econometric estimation are conducted using StataMP14 (64-bit) to ensure reproducibility.

Data citation:

International Food Policy Research Institute (IFPRI). (2024). *Survey of Micro, Small, and Medium Enterprises in Agri-Food Value Chains: Network-Based Recruitment Approach in Bangladesh* [dataset]. Harvard Dataverse. https://doi.org/10.7910/DVN/OBHUQ5

Construction of the Dependent Variable: Price Dispersion

The primary outcome of interest is trader-level price dispersion. Price dispersion is constructed separately for two types of transactions: (i) selling-side transactions in the output market, and (ii) procurement-side transactions in the input market. This dual construction allows the analysis to examine whether dispersion patterns are symmetric across buying and selling activities.

For each trader i, price dispersion is defined as the logarithmic difference between the highest and lowest transaction prices reported within a given period:

$$Dispersion_i = \log(P_i^{high}) - \log(P_i^{low}) \quad (1)$$

where P_i^{high} denotes the highest reported transaction price and P_i^{low} denotes the lowest reported transaction price.

Data Cleaning and Consistency Checks

Several steps are undertaken to ensure data consistency and reliability. First, observations with non-positive price values are excluded to permit a valid logarithmic transformation of prices.

Second, cases in which the reported highest price is lower than the reported lowest price are treated as reporting inconsistencies and removed from the analytical sample. Third, to mitigate the influence of extreme outliers that may disproportionately affect regression estimates, the dispersion variable is winsorized at the 1st and 99th percentiles. Together, these cleaning procedures ensure that the constructed dispersion measure captures meaningful intra-trader price variation rather than reflecting data entry errors, reporting inconsistencies, or extreme noise in the price distribution.

Rationale for the Log-Difference Specification

The log-difference specification is adopted for three methodological reasons. First, it provides scale invariance, allowing price dispersion to be interpreted proportionally rather than in absolute price units. Second, the logarithmic transformation reduces heteroskedasticity that often arises when price levels vary widely across traders, crops, or districts. Third, the measure is consistent with established approaches in the industrial organization and market microstructure literature, where log price differentials are widely used to quantify within-firm price dispersion. As a robustness exercise, an alternative range-based dispersion measure is also estimated to ensure that results are not driven by the logarithmic transformation.

Construction of Network Centrality Measures

To examine how traders' positions within value chain networks shape price dispersion, two distinct measures of network centrality are constructed. The objective is to differentiate between breadth of connections (network reach) and dispersion of transactions across partners (diversification). This distinction is critical for identifying whether digital liquidity is associated with broader market reach or merely broadens transaction portfolios.

Network Reach Centrality

The first measure captures the extent of a trader's relational embeddedness within the trading network. It incorporates three components: the number of suppliers, the number of buyers, and the number of known enterprises within the trader's business network. These variables proxy the breadth of market connections and potential access to differentiated trading opportunities.

To reduce skewness and ensure comparability across dimensions, each component is log-transformed using $\log(1+x)$and subsequently standardized. The network reach index is then constructed as the arithmetic mean of the standardized components:

$$Centrality_i^{Reach} = \frac{1}{3}\left(Z_{\ln Suppliers,i} + Z_{\ln Buyers,i} + Z_{\ln Known,i}\right) \quad (2)$$

Where, Z denotes standardized values. This measure captures how widely connected a trader is across market nodes and reflects exposure to multiple counterparties and potentially segmented sub-markets.

Diversification-Based Centrality (1–HHI)

To distinguish network reach from transaction concentration, we construct a diversification-based centrality measure using a Herfindahl-type index. Let s_{ijq} denote the share of trader(i)'s transaction volume allocated to counterparty category (j) on transaction side (q), where (q) refers to either procurement or selling transactions. The diversification-based centrality measure is defined as:

$$Diversification_{iq} = 1 - HHI_{iq} = 1 - \sum_{j=1}^{J_q} s_{ijq}^2 \quad (3)$$

where (J_q) denotes the number of available counterparty categories on transaction side (q). Higher values indicate that transaction volume is distributed more evenly across counterparty categories, whereas lower values indicate greater concentration. This measure captures diversification across existing transaction categories and is conceptually distinct from network reach, which captures the breadth of a trader's connections.

Construction of Digital Variables

Digitalization within the value chain is conceptualized along two distinct but related dimensions: digital access and digital transaction intensity. This distinction is central to the empirical strategy, as mere access to digital infrastructure may not translate into meaningful changes in trading behavior. Instead, the depth of digital transaction usage is expected to influence liquidity conditions and market participation.

Digital Access

Digital access captures whether traders possess the necessary infrastructure to engage in digital transactions. An index is constructed from binary indicators reflecting:

- Ownership of a business bank account,
- Ownership of a mobile money account,
- Use of mobile-based tools for procurement transactions,
- Use of mobile-based tools for selling transactions.

Each indicator is coded as 1 if the trader reports "Yes" and 0 otherwise. The digital access index is computed as the average of these components, generating a continuous measure ranging between 0 and 1. This measure reflects digital readiness but does not capture transaction depth.

Digital Transaction Intensity

Digital transaction intensity measures the proportion of total transactions conducted through digital channels. Traders report the share of procurement and selling transactions executed digitally. Reported percentages are rescaled to the 0–1 interval where necessary, and the intensity index is computed as the mean of digital shares across buying and selling activities. Formally,

$$DigitalIntensity_i = \frac{Share_i^{DigitalBuy} + Share_i^{DigitalSell}}{2} \quad (4)$$

This variable captures the depth of digital liquidity embedded in trading operations. Unlike access, which measures capability, digital intensity reflects actual integration of digital payment systems into transaction flows. The empirical analysis primarily focuses on digital transaction intensity, as it more directly captures liquidity depth and the potential to facilitate multi-market engagement.

Empirical Model and Estimation Strategy

To evaluate whether digital transaction intensity is associated with a stronger relationship between network centrality and price dispersion, the following baseline model is estimated:

$$Dispersion_i = \beta_1 Centrality_i + \beta_2 DigitalIntensity_i + \beta_3(Centrality_i \times DigitalIntensity_i) + \gamma X_i + \delta_d + \delta_c + \varepsilon_i \quad (5)$$

Where,

- $Dispersion_i$denotes trader-level log price dispersion,
- $Centrality_i$represents either reach-based or diversification-based centrality,
- $DigitalIntensity_i$captures the depth of digital transaction use,
- $Centrality_i \times DigitalIntensity_i$is the interaction term of interest,
- $X_i$is a vector of trader-level control variables,
- $\delta_d$represents district fixed effects,
- $\delta_c$represents crop fixed effects (in pooled specifications),
- $\varepsilon_i$is the idiosyncratic error term.

The interaction coefficient $\beta_3$is central to empirical analysis. A positive and statistically significant coefficient indicates that digital transaction intensity strengthens the association of network centrality on price dispersion, consistent with a market segmentation mechanism.

Control Variables

The vector $X_i$includes controls for trader-level characteristics that may influence price dispersion:

- Years of business experience,
- Log of total sales volume,
- Gender of the trader,
- Role within the value chain.

Including these variables helps mitigate confounding due to firm size, market exposure, managerial experience, and operational scale.

Fixed Effects

To account for unobserved heterogeneity, the model includes district fixed effects to control for location-specific factors such as infrastructure, market integration, and regional demand conditions. In pooled specifications, crop fixed effects are included to account for structural differences between rice and potato markets.

Estimation Procedure

All regressions are estimated using Ordinary Least Squares (OLS) in Stata. Heteroskedasticity-robust standard errors are employed to ensure consistent inference in the presence of potential heteroskedasticity.

In robustness specifications with high-dimensional fixed effects, fixed effects are absorbed using Stata's reghdfe routine where appropriate.

Estimated marginal association of centrality across levels of digital intensity are computed to facilitate interpretation of interaction terms. These estimated marginal association are graphically presented to illustrate how the estimated association of network reach varies with digital liquidity depth.

Heterogeneity Analysis and Robustness Strategy

Crop-Level Heterogeneity

To examine whether the digital–centrality interaction varies across market structures, the baseline model is estimated separately for rice and potato value chains. These crops represent structurally distinct markets: rice is relatively standardized and widely traded, whereas potato is more perishable and often characterized by greater quality differentiation and temporal volatility.

Estimating the model separately for each crop allows identification of whether the interaction between network reach and digital transaction intensity is conditional on market structure This approach provides insight into whether digital liquidity is associated with stronger segmentation patterns primarily in more differentiated or perishable markets.

Procurement-Side Estimation

In addition to selling-side dispersion, the empirical analysis is replicated using procurement-side price dispersion as the dependent variable. This symmetry test assesses whether the digital–centrality interaction operates consistently across output and input markets. Finding similar patterns on both sides strengthens the interpretation that digital liquidity is associated with multi-tier trading rather than affecting only one side of the transaction process.

Alternative Centrality Specification

To assess the robustness of results to the definition of centrality, the diversification-based centrality measure (1–HHI) is used as an alternative to the reach-based index. This test distinguishes whether moderation association are driven specifically by network breadth or by simple dispersion of transactions across partners.

Joint Centrality Specification

To further isolate mechanisms, both centrality measures are included simultaneously in a joint specification:

$$Dispersion_i = \beta_1 Centrality_i^{Reach} + \beta_2 Centrality_i^{Diversification} + \beta_3 DigitalIntensity_i + \beta_4(Centrality_i^{Reach} \times DigitalIntensity_i) + \beta_5(Centrality_i^{Diversification} \times DigitalIntensity_i) + \gamma X_i + \delta + \varepsilon_i \quad (6)$$

This specification allows direct comparison of interaction effect across centrality definitions. If the interaction term remains significant only for network reach but not for diversification, the evidence supports the interpretation that the positive association is stronger at higher levels of digital transaction intensity through expanded market reach rather than portfolio diversification.

Propensity Score Matching Robustness Check

As an additional robustness check, we employ Propensity Score Matching (PSM) to compare traders who report digital transaction use with observationally similar traders who do not report digital transaction use. Because the baseline digital transaction intensity measure is continuous, a binary treatment indicator is constructed. Digital User is coded as 1 if a trader reports a digital transaction intensity greater than zero and 0 otherwise.

Propensity scores are estimated using a logit model that includes network reach centrality, years of business

experience, log sales volume, gender, primary role within the value chain, district, and crop.

Traders are matched using one-to-one nearest-neighbor matching with replacement and a caliper equal to 0.20 standard deviations of the logit of the propensity score. Covariate balance is assessed using standardized mean differences before and after matching.

The PSM analysis is included as a robustness check rather than as a causal identification strategy. Although matching improves comparability between digital users and non-users based on observed characteristics, it cannot eliminate bias arising from unobserved factors. The matched estimates are therefore interpreted as conditional associations.

Marginal Effects and Visualization

To facilitate interpretation of interaction effects, estimated marginal association of centrality across different levels of digital intensity are computed. These effects are graphically presented to illustrate how the estimated association of network reach on price dispersion changes as digital transaction intensity increases.

Identification Considerations

The empirical analysis relies on cross-sectional observational data. While the network-based recruitment design improves relational validity and captures embeddedness within value chains, it does not provide exogenous variation in digital usage or network position. Therefore, the results are interpreted as conditional associations rather than causal effects.

The inclusion of district and crop fixed effects, along with detailed trader-level controls, mitigates observable heterogeneity. Nevertheless, unobserved factors such as entrepreneurial ability or local competitive conditions may remain. The robustness exercises and joint specifications are designed to reduce concerns about mechanical correlations between centrality and price dispersion.

The empirical strategy combines network-based measures, digital liquidity indicators, interaction modeling, fixed effects estimation, and multiple robustness checks. By distinguishing between network reach and diversification, and between digital access and digital intensity, the methodology enables a precise test of whether digital liquidity reduces price dispersion or instead with market segmentation among network-central traders. All estimations are implemented in Stata, ensuring transparency and reproducibility. We considered an instrumental variable (IV) approach to address potential endogeneity concerns. However, the dataset does not contain any variable that satisfies the exclusion restriction required for a valid instrument. Therefore, we rely on OLS estimates with extensive control variables and fixed effects to reduce observable confounding. In addition, we use Propensity Score Matching as a robustness check to improve comparability between digital users and non-users based on observed characteristics. Nevertheless, neither approach fully eliminates bias from unobserved heterogeneity, and therefore all results are interpreted as conditional associations rather than causal effects.

Results

Overview of Empirical Findings

This section presents empirical evidence on how network position and digital transaction intensity shape trader-level price dispersion. The central hypothesis is that digital transaction intensity is associated with a stronger positive relationship between network reach and price dispersion, consistent with a market segmentation mechanism rather than price compression.

The analysis proceeds in five steps. First, baseline results for selling-side dispersion are presented. Second, symmetry is assessed using procurement-side prices. Third, heterogeneity across rice and potato markets is examined. Fourth, alternative centrality measures are evaluated. Finally, joint specifications and estimated marginal associations are used to isolate mechanisms. All regressions are estimated using OLS in Stata with heteroskedasticity-robust standard errors. Fixed effects are included as specified in the methodology section.

Baseline Results: Selling-Side Price Dispersion

Table 1 reports the baseline results for selling-side log price dispersion. The dependent variable is the winsorized log-difference between the highest and lowest selling prices reported by each trader. Column (1) indicates that network reach centrality is positively associated with price dispersion. Traders with broader buyer–supplier connections exhibit significantly higher intra-trader price variation. This suggests that more centrally positioned traders operate across differentiated transaction contexts. Digital transaction intensity is also positively and statistically significant. Higher integration of digital payment systems is associated with wider price dispersion.

Column (2) introduces the interaction term. The coefficient on the interaction between network reach and digital intensity is positive and statistically significant at the 1 percent level. This implies that the estimated marginal association of network reach on dispersion increases with digital transaction intensity. Substantively, the result suggests that digital liquidity does not compress price dispersion. Instead, the positive association between network reach and price dispersion is stronger among traders with higher digital transaction intensity, consistent with a segmentation mechanism whereby digital transactions facilitate participation in multiple differentiated trading tiers.

Table 1. Baseline Estimates: Selling-Side Log Price Dispersion

Variables	(1) Baseline	(2) +Interaction
Network Reach Centrality	0.0131**	0.0156**
	(0.0057)	(0.0061)
Digital Transaction Intensity	0.1680***	0.1724***
	(0.0537)	(0.0561)
Centrality × Digital Intensity	—	0.1798***
		(0.0559)
Controls	Yes	Yes
District FE	Yes	Yes
Crop FE	Yes	Yes
Observations	2,099	2,099
R^2	0.110	0.113

Note: Robust standard errors in parentheses

*** p < 0.01, ** p < 0.05, * p < 0.10

Procurement-Side Price Dispersion

To assess whether the digital–centrality relationship operates symmetrically across trading activities, the baseline specification is re-estimated using procurement-side log price dispersion as the dependent variable. This symmetry test is important because if digital liquidity merely affects selling behavior but not input purchasing, the mechanism would be incomplete. The results are presented in Table 2.

The specification mirrors the selling-side model and includes trader-level controls and district fixed effects. The key parameter of interest remains the interaction between network reach and digital transaction intensity. The results indicate that network reach centrality is positively associated with procurement-side price dispersion.

Traders with broader supplier networks report significantly greater dispersion in input purchase prices. Digital transaction intensity is also positively and statistically significant, suggesting that higher digital integration correlates with wider variation in procurement prices.

Most importantly, the interaction between network reach and digital transaction intensity remains positive and statistically significant at conventional levels.

This finding is consistent with a similar positive conditional association on the procurement side, although the results should not be interpreted as evidence of a causal mechanism. In other words, digitally intensive and network-central traders appear to transact across multiple differentiated supplier tiers, consistent with a multi-market participation mechanism. The similarity of magnitude and statistical significance between selling- and procurement-side interactions strengthens the interpretation that digital liquidity is associated with wider price dispersion, consistent with a segmented-market pattern rather than reducing price dispersion.

Table 2. Procurement-Side Log Price Dispersion

Variables	(1) Baseline	(2)+Interaction
Network Reach Centrality	0.0115**	0.0132**
	(0.0051)	(0.0058)
Digital Transaction Intensity	0.1473***	0.1526***
	(0.0548)	(0.0574)
Centrality × Digital Intensity	—	0.1794***
		(0.0508)
Controls	Yes	Yes
District FE	Yes	Yes
Observations	2,460	2,460
R^2	0.112	0.115

Note: Robust standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.10

Crop-Level Heterogeneity: Perishable vs Staple Markets

To examine whether the digital–centrality interaction differs across market structures, the baseline model is estimated separately for rice and potato value chains. This comparison is critical because the two crops represent structurally distinct trading environments.

Rice markets are relatively standardized and integrated, whereas potato markets are more perishable and potentially characterized by greater quality segmentation and temporal arbitrage opportunities. The results are reported in Table 3.

The estimates reveal a striking contrast. In the rice value chain, the interaction between network reach and digital transaction intensity is statistically insignificant. Although digital intensity is weakly associated with dispersion, the moderating role of network reach does not appear to operate in this market. This suggests that in relatively standardized staple markets, digital liquidity is not meaningfully associated with stronger network-driven price dispersion.

In contrast, the potato value chain exhibits a strong and statistically significant interaction effect. Network reach is positively associated with dispersion, and this estimated association becomes stronger as digital transaction intensity increases. The magnitude of the interaction coefficient is economically meaningful and highly statistically significant. These findings in Table 3 suggest that the digital–centrality mechanism is conditional on market structure. In more segmented and perishable markets such as potato, digital liquidity is associated with participation in differentiated transaction tiers, which is consistent with wider price dispersion among network-central traders. In standardized markets such as rice, this mechanism is muted.

Table 3. Crop-Level Heterogeneity: Selling-Side Log Price Dispersion

Variables	***Rice***	***Potato***
Network Reach Centrality	0.0120	0.0245***
	(0.0088)	(0.0079)
Digital Transaction Intensity	0.1850*	0.1798***
	(0.1021)	(0.0602)
Centrality × Digital Intensity	-0.0090	0.1945***
	(0.1184)	(0.0615)
Controls	Yes	Yes
Observations	1,042	1,057
R^2	0.022	0.061

Note: Robust standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.10

Alternative Centrality Measures and Joint Specification

To assess whether the interaction between digital intensity and network position is sensitive to how centrality is defined, the baseline model is re-estimated using a diversification-based centrality measure (1–HHI). Subsequently, both reach-based and diversification-based centrality measures are included simultaneously in a joint specification. The results are reported in Table 4.

When diversification-based centrality is used alone, it is positively associated with price dispersion. Traders whose transactions are more evenly distributed across partners tend to exhibit greater dispersion. However, the interaction between diversification-based centrality and digital intensity is statistically insignificant. This suggests that digital liquidity is not associated with wider dispersion through simple portfolio diversification.

The joint specification provides sharper identification.

When both centrality measures are included simultaneously, network reach remains positively and significantly associated with price dispersion. More importantly, the interaction between network reach and digital intensity remains positive and statistically significant. In contrast, the interaction between diversification-based centrality and digital intensity remains statistically insignificant.

This pattern is consistent with the interpretation that the relationship between digital transaction intensity and price dispersion is more closely associated with network reach than with the distribution of transactions across existing counterparty categories. In other words, digital intensity appears to facilitate participation in multiple market nodes, not merely redistribution of transactions among current partners.

This strengthens the interpretation that the mechanism is associated with market segmentation linked to network breadth.

Table 4. Alternative Centrality and Joint Specification (Potato Chain, Selling-Side Log Dispersion)

Variables	(1)Diversification Only	(2) Joint Model
Reach Centrality	—	0.0180**
		(0.0089)
Diversification Centrality	0.0308**	0.0333***
	(0.0120)	(0.0091)
Digital Transaction Intensity	0.1096*	0.1670***
	(0.0662)	(0.0604)
Reach × Digital Intensity	—	0.2105***
		(0.0748)
Diversification × Digital Intensity	0.0169	-0.0690
	(0.1110)	(0.0625)
Controls	Yes	Yes
Observations	1,057	1,057
R^2	0.031	0.073

Note: Robust standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.10

Propensity Score Matching Robustness Check

To assess whether the baseline findings are sensitive to observable differences between traders who report digital transaction use and those who do not, we conduct an additional Propensity Score Matching analysis. The analysis focuses on selling-side log price dispersion, which is the primary outcome in the baseline specification. Digital users are matched with observationally similar non-users based on network reach, business experience, log sales volume, gender, primary role, district, and crop.

Table 5 reports the matching results. The analytical sample includes 2,099 traders, of whom 532 report a positive digital transaction intensity. All 532 digital users are matched successfully with observationally similar non-users. The matched mean selling-side log price dispersion is 0.1282 among digital users and 0.1102 among matched non-users. The estimated matched difference is positive and statistically significant at the 5 percent level (0.0180; standard error = 0.0075; p = 0.016).

The PSM result is consistent with a positive association between digital transaction use and selling-side price dispersion after balancing observed characteristics. However, PSM cannot address bias arising from unobserved factors. The matched estimate is therefore interpreted as a conditional association rather than a causal effects.

Table 5. Propensity Score Matching Robustness Check: Selling-Side Log Price Dispersion

Indicator	Value
Analytical sample	2,099
Digital users before matching	532
Non-user traders before matching	1,567
Successfully matched digital users	532
Unique matched non-user traders	382
Mean dispersion: digital users	0.1282
Mean dispersion: matched non-users	0.1102
Matched mean difference	0.0180
Standard error	0.0075
p-value	0.016

Note: Digital User is coded as 1 if digital transaction intensity is greater than zero and 0 otherwise. Propensity scores are estimated using network reach centrality, years of business experience, log sales volume, gender, primary role, district, and crop. One-to-one nearest-neighbor matching with replacement and a 0.20-standard-deviation caliper is applied. The matched estimate is interpreted as a conditional association rather than a causal effect.

Marginal Associations and Interaction Interpretation

To facilitate interpretation of the interaction between network reach and digital transaction intensity, marginal association of network centrality are computed across the observed range of digital intensity. The results are illustrated in Figure 2 for the potato value chain, where the estimated conditional association is strongest.

The marginal association of network reach on price dispersion is defined as:

$$\frac{\partial Dispersion_i}{\partial Centrality_i} = \beta_1 + \beta_3 \times DigitalIntensity_i \qquad (7)$$

where $\beta_1$is the coefficient on network reach and $\beta_3$is the coefficient on the interaction term.

The marginal association reveal a clear upward-sloping relationship. At low levels of digital transaction intensity, the estimated association with network reach on dispersion is modest but positive. As digital intensity increases, the marginal association of network reach increases substantially in magnitude. At the upper end of the digital intensity distribution, the estimated association of network reach on price dispersion is several times larger than at the lower end.

This pattern provides evidence consistent with a stronger positive association between network reach and price dispersion among traders with higher digital transaction intensity.. Importantly, the confidence intervals remain above zero for higher levels of digital intensity, indicating statistically meaningful stronger positive association. The figure confirms that the estimated

interaction is not merely statistical but economically significant.

Traders who combine extensive network reach with high digital transaction intensity exhibit the greatest levels of intra-trader price dispersion. This supports the interpretation that digital liquidity may coincide with participation across differentiated transaction tiers, deepening market segmentation rather than compressing prices.

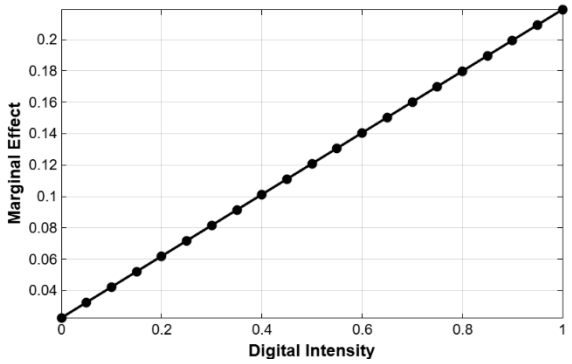

Figure 2. Marginal Association of Network Reach on Log Price Dispersion Across Levels of Digital Intensity (Potato Chain)

Note: The figure plots the marginal association of network reach centrality on log price dispersion as digital transaction intensity increases from its minimum to maximum observed values. The solid line represents the estimated marginal association, and shaded areas (if applicable) represent 95 percent confidence intervals.

Discussion

This study examines how digital liquidity, measured through digital access and digital transaction intensity, is associated with price dispersion among midstream MSMEs in Bangladesh's rice and potato value chains. The findings indicate that network reach and digital transaction intensity are positively associated with price dispersion on both the selling and procurement sides. The estimated interaction between network reach and digital transaction intensity is also positive and statistically significant, suggesting that the positive association between network reach and price dispersion is stronger among traders with higher digital transaction intensity. This pattern is more pronounced in the potato value chain than in the rice value chain. Diversification-based centrality (1–HHI) shows weaker and less robust interaction estimates, suggesting that network breadth may be more relevant than the distribution of transactions across existing counterparty categories.

The estimated relationships are relevant to the common expectation that digital technologies are associated with stronger market integration. One possible interpretation is that digital liquidity may coincide with participation across differentiated transaction tiers involving variations in quality, timing, service levels, and settlement arrangements. Previous studies suggest that digital transactions may be related to tiered exchange relationships across quality segments and service levels (Kamal et al., 2023; Su et al., 2023), temporal arbitrage through rapid verification and settlement (Srouji, 2020), reputation-based positioning through digital records (Shi & Sun, 2020), and coordination of differentiated quality lots (Rojers, 2018).

Digital platforms may also be associated with lower coordination costs when traders manage multiple counterparties (Ozili, 2022; Kirobo et al., 2024), potentially reinforcing the advantages associated with stronger network positions (Kitamura, 2022).

The findings are also consistent with research emphasizing that the outcomes associated with digital adoption may vary with trader capabilities and market structure (Balakrishnan, 2017; Nasyati et al., 2024; Jiang, 2024), as well as with literature on intermediary power and network position (Cong et al., 2024; Burugulla, 2025; Bhattacharya & Karnad, 2024). Evidence of persistent segmentation alongside technological change (Christodorescu et al., 2020; Veronika, 2025), commodity-specific integration patterns (Figorilli et al., 2018), tiered value-chain governance (Masiha, 2022; Zebua & Jamaluddin, 2024; Marjohan et al., 2025), and uneven outcomes associated with digital finance (Biswas & Burman, 2009; Wachira & Wachira, 2021; Megersa et al., 2023; Sreekantha et al., 2021) further contextualizes the results. The comparatively stronger relationship in the potato value chain is consistent with the possibility that perishability, quality differentiation, and storage dynamics create greater scope for timing-related strategies and differentiated transaction conditions (Sugathadasa et al., 2016).

Overall, the results are consistent with a stronger positive association between network reach and price dispersion among traders with higher digital transaction intensity, particularly in the potato value chain. Rather than assuming that digitalization is uniformly associated with price convergence, the findings suggest that its relationship with market outcomes may vary with existing network structures and trader capabilities. Policy discussions should therefore consider competition, inclusion, and transparency alongside the expansion of digital financial services. The findings must be interpreted cautiously because the study relies on cross-sectional observational data, self-reported measures, and a geographically concentrated sample. The estimated relationships represent conditional associations rather than causal effects.

Conclusion

This study examines whether digital liquidity is associated with trader-level price dispersion within agricultural value chains and whether this relationship varies with network position. Using trader-level data from Bangladesh's rice and potato value chains, the analysis finds that digital transaction intensity and network reach are positively associated with price dispersion. Their estimated interaction is also positive, indicating that the association between network reach and dispersion is stronger among traders with higher digital transaction intensity.

The estimated relationship is more pronounced in the potato value chain than in the relatively standardized rice value chain. This pattern is consistent with the possibility that perishability, quality differentiation, storage dynamics, and coordination requirements are related to greater variation across transaction tiers.

The interaction between diversification-based centrality and digital transaction intensity is less robust, suggesting that network breadth may be more relevant than the distribution of transactions across existing counterparty categories.

The findings challenge the assumption that digital payment expansion is necessarily associated with uniform market integration and price convergence. Instead, the relationship between digital liquidity and market outcomes may vary with network structure and market organization. Because the study uses cross-sectional observational data, the estimates should be interpreted as conditional associations rather than causal effects.

Future research should examine these relationships using panel data, quasi-experimental designs, or other identification strategies that can provide stronger evidence regarding causal mechanisms. Further research should also investigate whether complementary policies can support broader market participation while limiting exclusionary outcomes.

Declarations

AI Usage Declaration

Generative Artificial Intelligence (AI) tools including ChatGPT were used only for language refinement and writing assistance during the preparation of this manuscript. All research ideas, experimental design, data analysis, interpretations and scientific conclusions were fully developed by the authors without AI involvement. The authors have carefully reviewed and verified all AI-assisted text to ensure accuracy, originality and academic integrity. The full responsibility for the content of this manuscript lies solely with the authors.

Author Contribution Statement

Tanvir Ahmed: Data curation, investigation, formal analysis, and writing the original draft.

Nure Jannat Arpa: Project administration, supervision, conceptualization, methodology, review and editing.

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Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this article.

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