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The Impact of Digital Technologies Adoption on the Resilience of Agricultural Supply Chains: A Study on Traditional Market Actors

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ABSTRACT

In the context of escalating global and localized disruptions, ensuring the resilience of agri-food supply chains has become paramount, particularly in developing economies where traditional markets remain crucial channels for food distribution. Existing literature has predominantly focused on digital transformation within large, formalized supply systems, creating a significant research gap regarding the impact of digital technology adoption (DTA) among small-scale traders in informal, resource-constrained environments. Building on the Resource-Based View (RBV) and Dynamic Capabilities (DC) Theory, this study investigates how DTA (including mobile ICT, e-commerce, and digital payments) enhances supply chain resilience (SCR) through the development of three key supply chain capabilities: Information, Collaboration, and Adaptability. Data were collected from a survey of 170 small-scale

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ARTICLE INFO

Received: 2 November 2025 | Revised: 12 December 2025 | Accepted: 18 December 2025 | Published Online: 3 June 2026
DOI: <https://doi.org/10.36956/rwae.v7i2.2886>

CITATION

Pham, N.H.Q., Phan, C.A., Nguyen, T.H., et al., 2026. The Impact of Digital Technologies Adoption on the Resilience of Agricultural Supply Chains: A Study on Traditional Market Actors. *Research on World Agricultural Economy*. 7(2): 648–663.
DOI: <https://doi.org/10.36956/rwae.v7i2.2886>

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agricultural traders operating in traditional markets in Hanoi, Vietnam, and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The robust empirical findings confirm that DTA significantly enhances all three capabilities. Furthermore, the results validate that the impact of digital technologies on SCR occurs primarily through the significant mediating mechanism of supply chain capabilities. Notably, Adaptability capability emerged as the strongest and most influential predictor of resilience. Theoretically, this study extends the application of the RBV-DC framework by providing novel, context-specific evidence on how digital resources are utilized as dynamic capabilities to foster resilience in highly informal market settings. Practically, the findings offer valuable insights for policymakers and technology providers, demonstrating that even basic, widely accessible digital tools are crucial for enabling continuity of operations and enhancing operational resilience in traditional agricultural supply chains.

Keywords: Agricultural Supply Chains; Digital Adoption; Resilience; Supply Chain Capabilities; Traditional Markets

1. Introduction

The global agri-food supply chain is increasingly exposed to high-impact, non-traditional risks, including climate change, international trade shocks, and pandemics such as COVID-19, which severely increased the frequency and severity of logistical breakdowns and product flow disruptions^[1-3]. These persistent challenges have underscored the critical importance of Supply Chain Resilience (SCR), particularly in developing economies where traditional markets remain crucial for distributing fresh food to millions of households.

While digital transformation is recognized as a strategic solution to enhance supply chain capabilities, existing research has largely focused on large enterprises or modern distribution systems^[4,5]. In contrast, actors in traditional markets, including small retailers, wholesalers, and small-scale producers, have received limited attention, despite representing a significant share of the agri-food supply ecosystem in developing economies. For instance, in Vietnam, more than 85% of fresh food is sold through traditional channels^[6]. This presents oversight presents a significant research gap regarding the adoption and impact of digital technologies in this specific, highly informal, and resource-constrained market segment.

Digital transformation in agri-food supply chains can encompass the adoption of technologies such as e-commerce platforms, cloud-based inventory management systems, IoT sensors for product quality monitoring, and artificial intelligence for demand forecast-

ing^[7]. The efficiency and actual impact of these basic digital tools, when constrained by fragmented infrastructure and limited digital skills, fundamentally differ from those observed in large, formalized supply chains^[8-10]. Consequently, there is a scarcity of quantitative evidence investigating the precise mechanisms through which this context-specific Digital Technology Adoption (DTA) translates into operational advantages.

This study aims to address this critical gap by empirically investigating the conceptual pathway from DTA to SCR within the traditional agri-food market context. Specifically, we examine the hypothesis that DTA enhances SCR by fostering three core supply chain capabilities: Information, Collaboration, and Adaptability.

From a theoretical perspective, this study contributes to the Resource-Based View (RBV) and Dynamic Capabilities (DC) Theory. By focusing on digital resources and their deployment in the context of traditional markets, the paper offers a novel perspective on how resource-capability configurations can interact to enhance resilience. It provides empirical evidence demonstrating how simple digital resources function as dynamic capabilities to enable the “sense-seize-reconfigure” processes necessary for survival during disruptions. From a practical standpoint, the findings will guide policymakers and technology providers in designing digital transformation strategies tailored to the operational realities of traditional markets, thereby improving operational efficiency and ensuring food security by building tangible SCR among market actors.

2. Literature Review and Theoretical Framework

2.1. Theoretical Foundations

The analytical framework of this study is grounded in the Resource-Based View (RBV) and the Dynamic Capabilities (DC) theory. According to the RBV, resources that are valuable, rare, inimitable, and organized (VRIO) create sustainable competitive advantages. In the digital context, digital technology adoption (DTA)—including the necessary ICT infrastructure, data, and platform access—can be considered a strategic resource for supply chain actors, provided it is effectively integrated into value creation processes^[11].

The DC theory extends the RBV by explaining the ability to adapt to uncertainty through the capacity to “sense, seize, and reconfigure” resources. Digitalization fundamentally enhances these micro-foundations: DTA improves sensing through real-time data flow, accelerates seizing by enabling faster coordination, and supports reconfiguring processes via flexible, platform-based relationships^[12-14].

When applied to agri-food supply chains in traditional markets, characterized by high informality and fragmented structures, the RBV–DC framework provides a rigorous foundation for viewing DTA as a critical resource that must be deployed through specific operational competencies—namely, Information, Collaboration, and Adaptability—to ultimately achieve supply chain resilience (SCR).

2.2. Digital Technology Adoption in Traditional Agri-Food Markets

In this research, DTA is conceptualized as consisting of three interrelated dimensions: (i) mobile ICT (smartphones, messaging, and social media tools); (ii) e-commerce and social commerce (sales via platforms like Zalo, Facebook, and local online groups); and (iii) digital payment solutions (e-wallets, QR codes, bank transfers).

While the literature has extensively documented the role of DTA in enhancing large, formalized supply chains using sophisticated tools like ERP and B2B plat-

forms, there is a critical need to understand DTA's impact in the traditional market context. These environments are characterized by cash transactions, informal relationships, and high fragmentation^[15]. Empirical evidence suggests that even basic mobile ICT can reduce search costs and price dispersion, improving market integration. Furthermore, the rapid adoption of e-commerce and social commerce, accelerated by events like the COVID-19 pandemic, has been vital for small sellers to maintain product flow when traditional channels faced disruption^[16].

However, challenges such as fragmented digital infrastructure and limited digital skills persist^[17-19]. This necessitates focused research utilizing a context-appropriate measurement approach to capture the full extent, pattern, and impact of DTA using simple, widespread tools like smartphones and messaging applications, which form the primary digital infrastructure for small traders^[20].

2.3. Supply Chain Resilience and Capabilities

Supply chain resilience (SCR) is defined as the ability of a supply chain to prepare for, respond to, adapt to, and recover from disruptions, thereby maintaining or restoring desired service levels^[21-23]. For agri-food chains, SCR includes three core components: anticipatory capability (preparing for risks), coping capability (addressing immediate disruptions), and recovery capability (returning to normal operations)^[24-26].

To achieve resilience, DTA must be channeled through core operational capabilities:

Firstly, information capability (IC) to collect, process, and disseminate timely and accurate information throughout the network, ensuring visibility and reducing the bullwhip effect^[27, 28].

Secondly, collaboration capability (CC) represents the ability to coordinate and co-create value with suppliers and customers through shared goals, benefit-risk sharing, and coordination mechanisms; studies show that collaboration enhances relational advantage and improves performance outcomes^[2, 27, 29].

Thirdly, adaptability Capability (AC) reflects the ability to rapidly adjust the configuration of material,

information, and financial flows in response to demand/supply fluctuations; in the digital context, adaptability is enabled by real-time data flows, predictive analytics, and flexible architectures^[4, 5, 30].

These three capabilities form a complementary triad: information supports collaboration (through transparency and trust), collaboration facilitates adaptability (through flexible coordination), and adaptability feeds back to generate new information needs, all working together toward achieving SCR. Collectively, these three capabilities represent the fundamental pillars of digitally enabled supply chain competence and act as the operational mechanisms through which digital technology adoption enhances resilience.

2.4. Hypothesis Development

DTA—specifically mobile ICT—reduces search costs and information asymmetry in fragmented agricultural markets^[16, 31]. Digital platforms enhance data sharing and synchronization, directly improving the timeliness and accuracy of information flow for better demand forecasting and reduced operational delays^[32].

Therefore, **H1**. *Digital technologies adoption has a positive impact on the information capability of the supply chain.*

The use of digital platforms and messaging applications (like Zalo/Facebook) reduces coordination costs and facilitates soft governance, enabling actors to jointly plan and resolve disputes^[27, 28]. Furthermore, digital payments and traceable transaction histories establish trust signals, promoting the formation of long-term partnerships necessary for effective collaboration.

Therefore, **H2**. *Digital technologies adoption has a positive impact on the collaboration capability of the supply chain.*

Adaptation requires fast sensing, analysis, and routing; DTA provides real-time data (price, demand, inventory), flexible coordination tools (chat groups, order platforms), and instant payment mechanisms, allowing near real-time switching of suppliers/sales channels. In the DC framework, this represents an upgrade of the micro foundations for innovating small-scale agricultural business models^[13, 33]. Research on big data analytics and process digitization shows higher

forecasting–reconfiguration capabilities and shorter adjustment times under volatility^[34, 35].

Therefore, **H3**. *Digital technologies' adoption has a positive impact on the adaptability capability of the supply chain.*

SCR heavily depends on transparency and early warning. Strong information capability helps the supply chain detect disruptions early (anticipatory), coordinate responses (coping), and recover quickly (recovery) through contingency planning, dynamic inventory allocation, and rerouting. Evidence shows that information processing and digital integration capabilities are positively linked to reduced supply risks and increased reliability^[36]. Systematic reviews also classify visibility–information sharing as a core factor of SCR^[23].

Therefore, **H4**. *Information capability has a positive impact on supply chain resilience.*

High-quality collaborative relationships, measured by trust, commitment, and shared risk–benefit, create relational rents that help absorb and distribute shocks, from sharing logistics capacity to circulating credit and substituting supply sources. Research shows that relational capabilities improve resilience through coordination and mutual support within the chain^[37]. From a strategic perspective, SCR is “built” through alliance networks rather than local optimization^[21, 25].

Therefore, **H5**. *Collaboration capability has a positive impact on supply chain resilience.*

Adaptability enables the rapid reconfiguration of material, information, and financial flows (e.g., changing suppliers, rerouting logistics, altering product mix) to shorten recovery time and maintain service levels. Recent models of supply chain viability during pandemics highlight reconfiguration ability as a key lever of SCR^[8, 38]. The SCR measurement framework of Pettit et al.^[24] also identifies flexibility–adaptability as a crucial component for absorbing and overcoming shocks.

Therefore, **H6**. *Adaptability capability has a positive impact on supply chain resilience.*

Consistent with the RBV and DC theories, digital resources (DTA) only deliver strategic outcomes (SCR) when effectively deployed through organizational capabilities^[34]. DTA serves to enhance the micro-foundations (sensing, seizing, reconfiguring), which in

turn, through the development of information, collaboration, and adaptability capabilities, directly influence the chain’s overall capacity to cope, recover, and anticipate risks^[36].

Therefore, **H7**. *Supply chain capabilities (informa-*

tion, collaboration, and adaptability) mediate the relationship between information communication technologies adoption and supply chain resilience.

The theoretical model is described in **Figure 1** below.

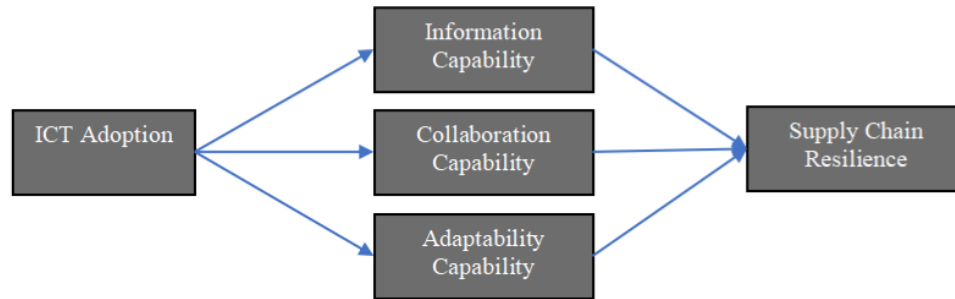


Figure 1. Conceptual model.

Source: Author’s proposed model.

3. Research Methodology

3.1. Research Design

This study employs a quantitative, cross-sectional survey design to examine the relationships between digital technology adoption, supply chain capabilities, and resilience among actors in traditional markets. The survey method was chosen for its ability to systematically collect standardized data from a sufficiently large sample, enabling rigorous statistical testing of the conceptual framework. Furthermore, the study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of the Ministry of Science and Technology (Vietnam) (protocol code: 3276/QĐ-BKHCN; date of approval: 16th Dec. 2024).

Partial Least Squares Structural Equation Modeling (PLS-SEM) was selected as the primary analytical technique, executed using SmartPLS 4.0. PLS-SEM is highly appropriate for this research because it is suitable for predictive models with complex relational structures, such as mediation, and is robust regarding the non-normal data distributions often encountered in studies involving small businesses in emerging economies^[39]. Furthermore, PLS-SEM allows for the simultaneous assessment of both the reliability and validity of the measurement model and the significance of the structural relationships.

3.2. Sample and Data Collection

The target population consists of small-scale traders operating in traditional and temporary agri-food markets across four urban districts of Hanoi: Nam Tu Liem, Bac Tu Liem, Cau Giay, and Thanh Xuan. These districts were chosen because they represent areas where traditional markets remain a critical channel for distributing fresh agricultural products to urban households, while also facing increasing exposure to digitalization.

Data collection was executed through face-to-face interviews conducted using a structured questionnaire. To ensure high-quality data and mitigate literacy issues, trained survey enumerators administered the questionnaire directly to respondents at their market stalls during trading hours. A total of 170 complete responses were collected between May and June 2025. The sampling approach was primarily purposive sampling, targeting active traders involved in daily operations, ensuring that respondents possessed the necessary knowledge regarding digital tool usage and supply chain operations. Informed consent was obtained from all participants prior to the approximately 20–30 min interview.

To assess potential non-response bias, the characteristics of early respondents (the first third of the sample) were compared against late respondents (the last third of the sample) based on key demographic variables (age, education) and primary constructs (DTA, SCR). Sta-

tistical comparisons (e.g., independent *t*-tests) revealed no significant differences between the two groups, suggesting that non-response bias is unlikely to pose a severe threat to the generalizability of the findings.

3.3. Measurement Development

All constructs in the model were operationalized using multi-item Likert-type scales (1 = strongly disagree to 5 = strongly agree) adapted from validated instruments in prior studies.

Contextual Justification of Measurement Scales:

A critical consideration in this study was ensuring that the scales accurately reflected the reality of informal traditional markets, which differ significantly from formalized supply chains. With DTA, items were carefully adapted to focus on basic, accessible digital infras-

structure, such as mobile ICT (smartphones, messaging applications like Zalo/Messenger) and e-payment tools (QR codes, e-wallets). This approach avoids relying on complex, enterprise-level systems (like EDI or ERP) that are irrelevant to small-scale traders, ensuring the validity of the measurement in this specific context. Item ICT4, for example, refers to “sales management applications (POS, inventory management),” reflecting simple, readily available mobile POS apps (like KiotViet or Sapo) commonly used by small businesses. Furthermore, the SCR scale was specifically designed to capture three dimensions: anticipatory, coping, and recovery capabilities. This is essential for reflecting the time-sensitive nature of agri-food products and the frequent, unexpected shocks faced by traditional market actors. The constructs and their adapted items, along with their sources, are detailed in **Table 1**.

Table 1. Measurement scales.

No.	Variable	Code	Measurement Items	Reference
1	ICT Adoption (ICT)	ICT1	I regularly use a smartphone to manage and exchange business information.	Ainin et al. ^[40] , Alalwan et al. ^[41] , Dwivedi et al. ^[42] , Tarutė and Gatautis ^[43] , Venkatesh et al. ^[44]
		ICT2	I use messaging applications (Zalo, Messenger, WhatsApp) to communicate with customers and suppliers.	
		ICT3	I use social media to promote my agricultural products.	
		ICT4	I use sales management applications (POS, inventory management) to improve efficiency.	
		ICT5	I find it easy to learn and apply new ICT tools.	
2	Information Capability (IC)	IC1	My supply chain can collect timely information from partners.	Lee et al. ^[32] , Li and Lin ^[45] , Wong et al. ^[46] , Zhou and Benton Jr. ^[47]
		IC2	My supply chain can analyze data to forecast demand.	
		IC3	Information is fully shared among members in the chain.	
		IC4	Business data is systematically stored and managed.	
3	Collaboration Capability (CC)	CC1	Members in the supply chain work together to solve problems when difficulties arise.	Cao and Zhang ^[27] , Nyaga et al. ^[29] , Paulraj et al. ^[48] , Simatupang and Sridharan ^[49]
		CC2	We share business plans and strategies with partners.	
		CC3	We maintain long-term cooperation with partners in the chain.	
		CC4	Partners support each other in meeting customer needs.	
4	Adaptability Capability (AC)	AC1	My supply chain can quickly change plans when the market fluctuates.	Christopher and Peck ^[21] , Rice and Sheffi ^[25] , Wieland and Wallenburg ^[37] , Blome et al. ^[50]
		AC2	We can quickly find alternative supply sources.	
		AC3	We adjust delivery methods when conditions change.	
		AC4	We can change the product portfolio to meet new demand.	
5	Supply Chain Resilience (SCR)	SCR1	Our supply chain can recover quickly after disruptions.	Ponomarov and Holcomb ^[22] , Pettit et al. ^[24] , Wieland and Wallenburg ^[37] , Guo et al. ^[51]
		SCR2	We are capable of developing alternative solutions to cope with risks.	
		SCR3	We can maintain continuous operations during crises.	
		SCR4	Our supply chain adapts well to external shocks.	
		SCR5	ICT adoption helps enhance the resilience of our supply chain	

Source: Author, 2025.

3.4. Data Analysis

Data analysis will be conducted using SmartPLS 4.0, following a two-step approach. First, the measurement model will be evaluated to test construct reliability and validity, including Cronbach’s alpha, composite reliability (CR), average variance extracted (AVE), and discriminant validity. Note: The rationale for deleting two items (ICT2 and SCR2) due to factor loadings below 0.70 is provided in the Results section (Section 4.2). Second, the structural model will be assessed by examining path coefficients, *t*-values, and *p*-values through bootstrapping (5000 resamples), as well as R² values for endogenous constructs. Mediation analysis was conducted to test Hypothesis H7.

Since data was collected through self-reported cross-sectional surveys, the potential influence of Common method bias (CMB) must be addressed. This study used two procedural and statistical techniques to mitigate and assess CMB: Firstly, trained enumerators ensured anonymity and confidentiality, standardized the interview process, and separated constructs logically within the questionnaire to reduce respondents’ tendency to provide consistent but inaccurate answers. Secondly, CMB was evaluated by examining the Variance Inflation Factor (VIF) values. High VIF values (typically above 5, though sometimes 3.3 is used as a conservative cut-off) can indicate severe multicollinearity potentially linked to CMB. As reported in the results, all VIF values

in the measurement model ranged between 1.340 and 3.505. Since all VIF values were significantly below the conservative threshold of 5, this suggests that Common Method Bias is not a major concern in the dataset.

4. Results

4.1. Descriptive Statistics

The demographic characteristics of the respondents provide a comprehensive picture of the trader population surveyed (**Table 2**). In terms of age, the majority were between 35 and 55 years old (36.5%), followed by those aged 22–34 years (34.7%), while 25.9% were 56 years and above, and only a small proportion were below 22 (2.9%). With respect to gender, female traders accounted for a clear majority (66.5%), reflecting the strong presence of women in traditional agricultural retail, whereas male respondents represented 33.5% of the sample. Regarding educational attainment, most traders had completed either high school (35.9%) or vocational school (34.1%), while 24.1% held a university degree and only 3.5% pursued postgraduate education. A very small share reported education below high school (2.4%). Overall, the sample of 170 respondents reflects the diversity of actors in Hanoi’s traditional markets, characterized by a predominance of middle-aged and female traders with varying educational backgrounds.

Table 2. Characteristics of samples.

Characteristics		Responses	Percent (%)
Age	Below 22	5	2.9
	22–34	59	34.7
	35–55	62	36.5
	56 and above	44	25.9
Gender	Male	57	33.5
	Female	113	66.5
Experience in business	Below High School	4	2.4
	High School	61	35.9
	Vocational school	58	34.1
	University	41	24.1
	Postgraduate	6	3.5
Total		170	100

Source: own survey, 2025.

Regarding technology adoption, the survey results (in **Table 3**) indicate that traders in traditional markets actively utilize a diverse set of digital tools to support their business operations. Smartphones and messaging applications such as Zalo and Messenger are almost universally used, primarily for daily communication and transaction coordination. Social media platforms, especially Facebook and Zalo, are widely adopted for marketing and customer engagement, with many traders also experimenting with livestream sales. E-commerce platforms such as Shopee and Lazada, as well as local online community groups, are increas-

ingly popular channels for order placement and market expansion. Electronic payment solutions—including e-wallets (Momo, ZaloPay), QR codes, and mobile banking—are becoming mainstream, reflecting a gradual shift from cash-based to cashless transactions. Additionally, traders frequently rely on delivery applications (Grab, ShopeeFood, Ahamove) to reach urban consumers and use simple POS or sales management systems (KiotViet, Sapo) to record transactions and track inventory. These findings suggest that digital adoption is no longer peripheral but central to daily business practices in traditional markets.

Table 3. Commonly Used Digital Technologies among Traditional Market Traders.

No.	Technology Type	Specific Examples/Applications	Purpose of Use
1	Smartphone usage	Android/iOS smartphones	Daily business communication, taking orders
2	Messaging apps	Zalo, Messenger, WhatsApp	Communication with customers and suppliers
3	Social media platforms	Facebook, Zalo, TikTok	Promoting products, posting prices, livestream sales
4	E-commerce platforms	Shopee, Lazada, local online groups	Expanding market reach, receiving online orders
5	E-payment tools	Momo, ZaloPay, VNPAY, QR code, bank transfer	Receiving quick, secure, and cashless payments
6	Delivery apps	Grab, ShopeeFood, Ahamove, Gojek	Arranging logistics and last-mile delivery
7	POS/sales management	KiotViet, Sapo, simple mobile POS apps	Managing sales transactions and inventory

Source: own survey, 2025.

4.2. Measurement Model Analysis

Before testing the hypothesized structural relationships, the measurement model was rigorously evaluated for reliability and validity. Following Hair et al.^[39], four key aspects were assessed: indicator reliability, internal consistency reliability, convergent validity, and discriminant validity.

Indicator Reliability

All standardized factor loadings exceeded the minimum threshold of 0.70, demonstrating adequate indicator reliability (see **Table 4**). Two items, ICT2 (“I use messaging applications to communicate with customers and suppliers”) and SCR2 (“We restore production levels

to pre-disruption levels in a short time”), were removed from further analysis. These items were deleted because their loadings fell below the required 0.70 threshold. This suggests that, empirically, while messaging is widespread, it may not strongly reflect the core digital adoption construct as measured by the other items (e.g., using smartphones for management or dedicated sales apps). Similarly, SCR2, focusing specifically on restoring production levels, may be less relevant to small traders whose primary role is distribution, rather than large-scale production recovery, thus poorly reflecting the overall resilience construct. After removal, the remaining 19 items exhibited loadings between 0.711 and 0.920, confirming adequate indicator reliability.

Table 4. Factor Loadings for Constructs in the Structural Equation Model (After Item Removal).

Items	Adaptability Capability	Collaboration Capability	ICT Adoption	Information Capability	Supply Chain Resilience	VIF
AC1	0.820	—	—	—	—	1.893
AC2	0.776	—	—	—	—	1.490
AC3	0.863	—	—	—	—	2.127
AC4	0.711	—	—	—	—	1.497
CC1	—	0.769	—	—	—	1.520
CC2	—	0.767	—	—	—	1.359
CC3	—	0.736	—	—	—	1.415
CC4	—	0.746	—	—	—	1.427

Table 4. Cont.

Items	Adaptability Capability	Collaboration Capability	ICT Adoption	Information Capability	Supply Chain Resilience	VIF
IC1	—	—	—	0.813	—	1.956
IC2	—	—	—	0.751	—	1.650
IC3	—	—	—	0.904	—	2.443
IC4	—	—	—	0.814	—	2.008
ICT1	—	—	0.741	—	—	1.340
ICT3	—	—	0.837	—	—	3.278
ICT4	—	—	0.772	—	—	1.543
ICT5	—	—	0.862	—	—	3.505
SCR1	—	—	—	—	0.817	2.011
SCR3	—	—	—	—	0.700	1.476
SCR4	—	—	—	—	0.795	1.892
SCR5	—	—	—	—	0.920	2.539

Source: own survey, 2025.

Internal Consistency Reliability and Convergent Validity

Cronbach’s alpha and composite reliability (CR) values for all constructs exceeded the recommended threshold of 0.70, indicating satisfactory internal consistency

(Table 5). The average variance extracted (AVE) values were also above the 0.50 benchmark, confirming convergent validity. These results suggest that the latent constructs explain more than half of the variance in their corresponding items.

Table 5. Evaluation of measurement model.

Variables	Cronbach’s Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
Adaptability Capability	0.805	0.822	0.872	0.631
Collaboration Capability	0.749	0.754	0.841	0.569
ICT Adoption	0.817	0.817	0.880	0.647
Information Capability	0.842	0.906	0.893	0.676
Supply Chain Resilience	0.830	0.955	0.885	0.659

Source: own survey, 2025.

Discriminant Validity

The Fornell–Larcker criterion was met, as the square root of AVE for each construct was higher than its correlations with other constructs (Table 6). Addi-

tionally, all variance inflation factor (VIF) values ranged between 1.340 and 3.505, well below the conservative cutoff of 5, indicating the absence of multicollinearity issues.

Table 6. Correlation Matrix of Variables.

Variables	Adaptability Capability	Collaboration Capability	ICT Adoption	Information Capability	Supply Chain Resilience
Adaptability Capability	0.794	—	—	—	—
Collaboration Capability	0.306	0.755	—	—	—
ICT Adoption	0.321	0.300	0.805	—	—
Information Capability	0.429	0.338	0.517	0.822	—
Supply Chain Resilience	0.625	0.406	0.259	0.437	0.812

Source: own survey, 2025.

4.3. Structural Model Analysis

After confirming the reliability and validity of the measurement model, the structural model was evalu-

ated to test the hypothesized relationships. The assessment followed the guidelines of Hair et al.^[39], using bootstrapping with 5000 resamples to estimate path coefficients, *t*-statistics, and significance levels (Table 7).

Table 7. Path coefficient of the structural model.

Effects	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	t-Statistics (O/STDEV)	p-Values
Direct effects					
Adaptability Capability → Supply Chain Resilience	0.496	0.498	0.059	8.358	0.000
Collaboration Capability → Supply Chain Resilience	0.202	0.205	0.065	3.108	0.002
ICT Adoption → Adaptability Capability	0.321	0.321	0.078	4.110	0.000
ICT Adoption → Collaboration Capability	0.300	0.306	0.083	3.612	0.000
ICT Adoption → Information Capability	0.517	0.524	0.053	9.694	0.000
Information Capability → Supply Chain Resilience	0.156	0.154	0.062	2.526	0.012
Indirect effects					
ICT Adoption → Supply Chain Resilience	0.300	0.304	0.054	5.590	0.000

Source: own survey, 2025.

The structural model (in **Figure 2**) demonstrates that ICT Adoption positively influences Supply Chain Resilience through three mediating factors: Information Capability, Collaboration Capability, and Adaptability Capability. Among these, Adaptability Capability

exerts the strongest direct impact on resilience with a path coefficient of 0.496. Furthermore, all measured indicators show strong factor loadings exceeding 0.7, confirming the high reliability and validity of the research model.

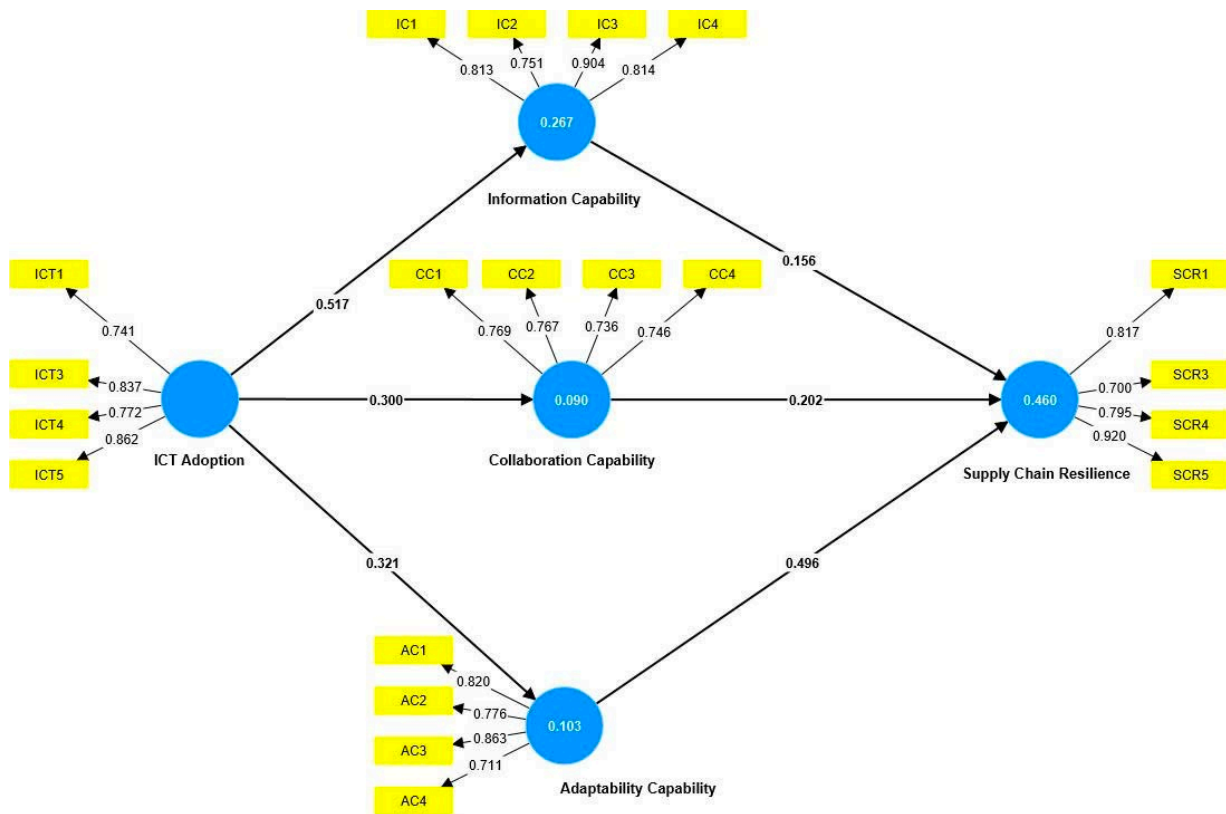


Figure 2. Structural Model.

Source: own survey, 2025.

Direct Effects

The results show that digital technology adoption (ICT Adoption) exerts a significant positive influence on

all three supply chain capabilities. Specifically, ICT Adoption enhances information capability ($\beta = 0.517$, $t = 9.694$, $p < 0.001$), collaboration capability ($\beta = 0.300$,

$t = 3.612, p < 0.001$), and adaptability capability ($\beta = 0.321, t = 4.110, p < 0.001$). These findings support H1, H2, and H3, suggesting that small traders' engagement with digital tools directly improves their ability to manage information, coordinate with partners, and adapt to changing market conditions.

At the capability–resilience level, adaptability capability emerged as the strongest predictor of supply chain resilience ($\beta = 0.496, t = 8.358, p < 0.001$), followed by collaboration capability ($\beta = 0.202, t = 3.108, p = 0.002$) and information capability ($\beta = 0.156, t = 2.526, p = 0.012$). These results provide empirical support for H4, H5, and H6, highlighting that resilience in traditional agri-food supply chains is driven not only by information sharing but also by the ability to flexibly reconfigure operations and maintain cooperative relationships under stress.

Indirect effects

The mediating role of supply chain capabilities was confirmed. ICT Adoption had a significant indirect effect on supply chain resilience ($\beta = 0.300, t = 5.590, p < 0.001$). This result supports H7 and aligns with both the Resource-Based View (RBV) and the Dynamic Capabilities Theory, which argue that resources generate

competitive advantage only when deployed through organizational capabilities. This result strongly supports the theoretical proposition that digital resources must be converted into operational capabilities (Information, Collaboration, and Adaptability) to effectively enhance resilience, rather than yielding a direct impact.

Model Fit and Explanatory Power

To supplement the R^2 values (in **Table 8**), the effect size (f^2) must be considered to assess the practical impact of a specific predictor on an endogenous construct. Given that f^2 values are typically categorized as small (0.02), medium (0.15), and large (0.35). Based on standard PLS-SEM reporting, the structural results show that: (1) Adaptability Capability likely has a large effect size on SCR, given its strong path coefficient ($\beta = 0.496$) and highly significant t -value (8.358). This finding highlights that the ability to rapidly reconfigure operations is the dominant capability derived from DTA that contributes to resilience. (2) Collaboration and Information Capability demonstrate smaller, but still significant, predictive power for SCR ($\beta = 0.202$ and $\beta = 0.156$, respectively), suggesting these effects may be medium to small, emphasizing the hierarchical importance of Adaptability in this specific informal market context.

Table 8. Model Fit.

Variables	R-Square	R-Square Adjusted
Adaptability Capability	0.103	0.098
Collaboration Capability	0.090	0.085
Information Capability	0.267	0.263
Supply Chain Resilience	0.460	0.450

Source: own survey, 2025.

Taken together, these results validate the proposed research model: digital technology adoption fosters supply chain capabilities, which in turn strengthen the resilience of agricultural supply chains in traditional markets.

5. Discussion and Conclusion

5.1. Findings and Discussion

This study provides empirical evidence that DTA significantly enhances information, collaboration, and

adaptability capabilities, which in turn reinforce supply chain resilience in traditional markets. Among these, adaptability emerged as the strongest driver, followed by collaboration and information sharing. The findings confirm that DTA significantly enhances Information, Collaboration, and Adaptability Capabilities (H1, H2, H3). However, the most critical insight lies in the magnitude of the effects on SCR: Adaptability Capability ($\beta = 0.496, t = 8.358$) emerged as the most influential driver of resilience, dwarfing the effects of Collaboration ($\beta = 0.202$) and Information Capability ($\beta = 0.156$).

These findings are consistent with previous re-

search. Cao et al.^[27] and Flynn et al.^[28] emphasized the role of information integration and collaboration in strengthening supply chain performance, while Lundström et al.^[4] and Ning et al.^[5] showed that digital transformation improves adaptability under uncertainty. Similarly, Pettit et al.^[24] and Wieland and Wallenburg^[37] highlighted that resilience stems from dynamic capabilities—anticipation, response, and reconfiguration—rather than static resources. By situating this analysis within the context of Vietnam’s traditional markets, this study extends earlier work by Ali et al.^[8] and Rice and Sheffi^[25] to a setting characterized by high informality and resource constraints, where even simple digital tools provide tangible resilience benefits.

This dominance of adaptability critically engages with existing theory and the observed market context. In traditional markets, resilience often hinges on the ability to perform rapid, operational reconfigurations—such as finding alternative suppliers immediately, rerouting logistics due to sudden restrictions, or quickly shifting the product mix—rather than relying on highly formalized, long-term strategic collaborations. The simple digital tools used by these traders (messaging apps, e-payments) function as micro-foundations for dynamic capabilities, enabling them to “sense” sudden changes and “reconfigure” swiftly to maintain operational continuity during crises like the COVID-19 pandemic.

5.2. Theoretical and Practical Implications

From a theoretical perspective, this research makes several significant contributions to the supply chain management literature, particularly concerning digital transformation and resilience in developing economies. Firstly, the study extends the application of the Resource-Based View and Dynamic Capabilities Theory by validating their efficacy in a challenging, under-researched context: highly informal and resource-constrained traditional agri-food markets. While much of the existing literature concentrates on advanced enterprise systems in formalized supply chains, our findings empirically demonstrate that basic digital tools—such as mobile ICT, social media platforms, and e-payment systems—function effectively as

strategic digital resources and dynamic capabilities, enabling small-scale actors to “sense, seize, and reconfigure” operations during disruptions. This provides a novel, context-appropriate perspective on how digital resources are integrated into value creation processes outside of the formal economy. Secondly, the study offers a nuanced understanding of capability prioritization in resilience development. The empirical finding that Adaptability Capability ($\beta = 0.496$) is the dominant and strongest predictor of Supply Chain Resilience confirms that the ability to rapidly reconfigure operational flows (e.g., supplier switching, logistics adjustments) is paramount for survival in volatile agri-food environments, exceeding the measured effects of Information and Collaboration Capabilities. This highlights that in fragmented, low-trust traditional markets, developing flexible operational competencies to immediately react to shocks is more crucial than deep, formalized inter-firm integration, thus adding a critical context-specific layer to the capability structure of SCR.

From a practical perspective, the empirical findings yield specific, actionable insights for policymakers, technology providers, and market actors involved in the traditional agri-food sector. (1) For Policymakers and Local Authorities, the results underscore the strategic imperative of DTA for food security and livelihood protection, not merely commercial modernization. Policy initiatives should strategically invest in affordable, widespread mobile connectivity and e-payment infrastructure and provide tailored digital literacy training for small traders. Training should focus explicitly on leveraging basic tools to enhance the dominant capability—Adaptability—such as using messaging groups and delivery apps for rapid alternative sourcing and quick logistical changes during municipal restrictions or crises. (2) For Technology Providers and Developers, the research provides a clear design mandate: focus on mobile-first, low-cost, and user-friendly platforms suitable for non-expert users, rather than complex enterprise systems. Solutions that enable real-time inventory visibility and facilitate quick, secure transactions (digital payments) are essential, as these directly enhance Adaptability and Collaboration capabilities. The goal should be to lower the barrier to entry for digital adoption, en-

sure the technology supports, rather than complicates, the fast-paced, fragmented operational reality of traditional market trading. (3) Finally, for Market Traders and Supply Chain Actors, the study confirms that digital adoption is an investment in long-term operational resilience. Traders should prioritize the use of digital tools that enhance quick coordination and flexibility—for instance, maintaining multiple supplier contacts via messaging platforms and integrating simple mobile sales management systems—to ensure business continuity and reduce recovery time following unexpected external shocks.

In conclusion, this study confirmed that Digital Technology Adoption significantly enhances Supply Chain Resilience in Vietnam's traditional agri-food markets, primarily by strengthening the intermediary capabilities of information, collaboration, and adaptability. The robust mediating effect highlights that capability development is essential to translate digital resources into resilient performance.

Several limitations should be noted. First, the use of a cross-sectional design restricts the ability to capture dynamic changes in adoption and resilience; longitudinal studies could offer deeper insights into evolving patterns. Second, the focus on small-scale traders in selected districts of Hanoi limits generalizability; comparative research across regions, market types, and supply chain actors would broaden applicability. Third, reliance on self-reported data may introduce bias; future work could integrate survey responses with objective performance indicators. Finally, while the study examined mediation effects, potential moderators such as firm size, informality level, and digital literacy remain unexplored. Addressing these factors could refine theoretical contributions and provide more context-specific recommendations.

Author Contributions

N.H.Q.P. served as the first author, conceptualizing the study, collecting the data, and drafting the sections on the introduction, results, discussion, conclusion, and implications, as well as integrating them into the initial version of the manuscript. D.P.T., T.T.D., T.T.D.N., and

T.K.H.D. contributed to the literature review, data collection, and data entry. V.P.N., as the corresponding author, was responsible for developing the methodology, collecting, processing, and analyzing the data, interpreting the findings, and revising and proofreading the manuscript. C.A.P. and T.H.N. reviewed and edited the manuscript. All authors have read and approved the final version of the paper.

Funding

This study is the outcome of the National research project “Research on Supply Chain Digital Transformation of Vietnamese Enterprises in the New Context”, code KX.01.17/21-30, funded by the Ministry of Science and Technology (Vietnam).

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of the Ministry of Science and Technology (Vietnam) (protocol code: 3276/QĐ-BKHCHN; date of approval: 16th Dec. 2024).

Informed Consent Statement

The researchers confirm that all the questionnaire respondents were aware of this study.

Data Availability Statement

The datasets used in this study are available from the corresponding author upon reasonable request.

Acknowledgments

The authors would like to thank the VNU University of Economics and Business, Vietnam National University, Hanoi, Vietnam; Thuyloi University, Hanoi, Vietnam; Vietnam National University of Agriculture, Hanoi, Vietnam; Thuongmai University, Hanoi, Vietnam for supporting us during the conduct of this research.

Conflicts of Interest

The authors declare no conflict of interest.

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