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How digital empowerment enhances rural supply chain performance: evidence from Taobao villages in China

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In the era of digital transformation, rural small and medium-sized enterprises (SMEs) face challenges such as weak supplier integration, ineffective information transmission, and limited digital capabilities in supply chain management. These issues underscore the critical role of digital empowerment in enhancing rural supply chain performance. This study constructs and empirically tests a conceptual framework "digital empowerment–collaborative mechanism–performance enhancement" to explain how digital empowerment improves the performance and competitiveness of rural supply chains through supply chain collaboration. Using partial least squares structural equation modeling (PLS-SEM), the study analyzes 263 valid survey responses collected from e-commerce supply chains in Zhejiang Province's "Taobao Villages" and surrounding rural areas. The findings reveal that digital empowerment through structural empowerment, trust empowerment, and resource empowerment significantly enhances rural supply chain collaboration and performance, with policy support amplifying these effects. Moreover, supply chain collaboration is a key mediating variable in the relationship between digital empowerment and performance. While policy support significantly moderates the effects of structural development and resource acquisition, its moderating role in trust-based empowerment is insignificant. These findings offer practical insights for managers developing digital strategies and collaborative mechanisms and provide theoretical and policy implications for improving rural supply chain performance and promoting rural economic development.

KEYWORDS

digital empowerment, PLS-SEM, policy support, rural supply chain performance, supply chain collaboration

1 Introduction

With the rapid advancement of digital technologies, agricultural supply chains are undergoing a profound transformation. Traditionally, these supply chains were characterized by linear and decentralized vertical transaction structures, encompassing agricultural input supply, production, processing, and distribution stages (Lu et al., 2024). However, the rise of digital technologies has facilitated the evolution of agricultural supply chains into data-driven systems supported by e-commerce platforms, enabling the digital integration of procurement, logistics, and market activities (Zeng et al., 2017). This transformation has become a vital pathway for improving farmers' market access, promoting rural employment, and advancing industrial upgrading globally (Liu et al., 2023). Conventional rural supply chains often exhibit over-extended and multi-tier structures, fragmented distribution channels, and high systemic vulnerability. Weak digital infrastructure further reduces resource allocation efficiency and

constrains market expansion (Ashley and Maxwell, 2001; Liu, 2022), making these supply chains ill-equipped to respond to rapidly changing market environments and thereby hindering the sustainable development of rural economies (Zhang, 2024). Digital empowerment generally refers to the process through which platform enterprises leverage data resources, digital technologies, and analytical capabilities to enhance SMEs' information acquisition, market responsiveness, and operational decision-making by providing low-cost and scalable digital tools and services (Jiang et al., 2023; Leong et al., 2016). In the context of digitalization and rural supply chains, this study defines digital empowerment as a process through which digital platforms systematically enhance the collaborative capabilities and performance of rural supply chains by providing structural support, fostering trust mechanisms, and facilitating resource provision. Accordingly, analyzing the mechanisms of digital empowerment in rural supply chains clarifies the pathways linking digitalization to rural economic structural transformation and upgrading, generating valuable theoretical and practical insights for global rural revitalization (Zhang et al., 2026).

The "rural supply chain" discussed in this paper primarily refers to agricultural and food supply chains in rural areas. These chains are typically characterized by small-scale family operations, weak digital infrastructure, and loose organizational structures, which differ substantially from supply chains in urban or industrialized contexts (Kosec and Wantchekon, 2020). This highly fragmented, atomized, and spatially dispersed structure, characterized by limited market access and restricted capacity for resource integration, makes rural supply chains an ideal context for examining the effects of digital empowerment. In this context, although existing studies indicate that digital technologies such as e-commerce platforms, the Internet of Things (IoT), and cloud computing have been widely applied in rural supply chains and play an important role in coordinating information, logistics, and capital flows (Jiang et al., 2023; Palmer-Abbs et al., 2021; Wang et al., 2023), most research has concentrated on the evolutionary mechanisms, influencing factors, or efficiency improvements of rural e-commerce within agricultural and food supply chains (Liu et al., 2022; Ramirez et al., 2021). Systematic research on how digital empowerment drives collaboration in rural supply chains and enhances overall performance remains limited. Moreover, studies that explore the pathways and mechanisms of digital empowerment from a supply chain systems perspective and incorporate evidence from representative cases are still lacking.

As a distinctive and representative form of rural e-commerce, "Taobao Villages" offer a suitable empirical context for examining the digitalization of rural supply chains. On the one hand, they are defined as clusters of rural online merchants that meet specific thresholds for sales volume and the number of e-shops, thereby reducing traditional distribution links and enhancing supply chain competitiveness through disintermediation (Wang et al., 2021). On the other hand, their development demonstrates how digital platforms can overcome spatial barriers, integrate regional resources, and expand market reach for rural products (Keefe et al., 2024; Zhang et al., 2023). Supported by both digital platforms and government policies, Taobao Villages have achieved notable progress in employment generation, poverty reduction, and industrial upgrading (Song et al., 2023; Zhang J. et al., 2025; Zhang Q. et al., 2025). Moreover, through the integration of digital technologies and e-commerce platforms, Taobao Villages have realized efficient coordination between commerce and logistics, greatly improving the operational efficiency and responsiveness of rural supply chains (AliResearch, 2023). This transformation illustrates the core value of digital empowerment in optimizing supply chain structures, enhancing collaborative efficiency and resource integration, and improving overall performance. Structural empowerment refers to the improvement of organizational structures and institutional conditions through digital platforms, which reduces structural barriers to enterprises' access to information, opportunities, and resources, thereby providing institutional and organizational support for supply chain collaboration (Nambisan et al., 2017). However, systematic empirical research on these mechanisms remains limited—particularly regarding structural empowerment, trust-building processes, resource integration pathways, and the enabling role of policy support—which still lack a comprehensive explanation.

While digital technologies have demonstrated substantial benefits in rural supply chains, existing studies primarily examine application models (e.g., channel optimization, digital finance, O2O models), collaborative mechanisms (such as resource integration and operational agility), and overall benefits, including farmer income, poverty reduction, employment creation, and industrial upgrading (Chen et al., 2023; Liu et al., 2021; Lu and Reardon, 2018). In other words, this body of research largely concentrates on isolated technological or managerial dimensions, while overlooking a systematic examination of how digital empowerment enhances supply chain performance and thereby supports the efficient, flexible, and sustainable development of rural supply chains. In rural contexts, supply chain efficiency determines the market accessibility of agricultural and consumer goods, flexibility reflects the capacity to respond to demand fluctuations and external shocks, and sustainability underpins the long-term stability and inclusiveness of rural economic development (Li et al., 2025). These dimensions are also central to global rural revitalization strategies, which emphasize improving operational efficiency, strengthening system resilience, and promoting sustainable development in rural areas (Li and Gan, 2025).

Addressing this gap, this study aims to investigate digital empowerment pathways, collaborative mechanisms, and the role of policy support in enhancing rural supply chain performance (Chen et al., 2024; Wang and Xu, 2025). Specifically, this paper addresses three core questions: (1) How does digital empowerment influence rural supply chain performance? (2) Does supply chain collaboration mediate the relationship between digital empowerment and supply chain performance? (3) Does policy support moderate this relationship? In this study, policy support refers to the institutional and instrumental support provided by local governments during rural digital transformation, including digital infrastructure development, fiscal incentives, training services, and institutional safeguards. Its role lies in shaping the external institutional environment of rural supply chains rather than directly determining firms' behaviors. To answer these questions, this study proposes a conceptual framework—"digital empowerment–collaboration mechanism–performance improvement"—and employs partial least squares structural equation modeling (PLS-SEM) to conduct empirical analysis based on data collected from 263 respondents in Taobao Villages across Zhejiang Province.

The structure of this paper is as follows: Section 2 reviews the relevant literature and proposes the research hypotheses; Section 3 explains the conceptual model and describes the research design;

Section 4 analyzes and discusses the research results; and Section 5 discusses the main findings and conclusions.

2 Theory and hypotheses

2.1 Digital empowerment in rural supply chains

Digital empowerment, driven by advancements in digital technology, enhances the self-efficacy and coordination capabilities of enterprises within supply chains by leveraging digital platforms and tools (Fang and Liu, 2024; Sun et al., 2018). Its core function lies not only in the adoption of digital platforms and technical tools but also in promoting resource sharing and information exchange among organizations, thereby strengthening overall supply chain collaboration (Chang et al., 2025). Although prior studies have confirmed that digital empowerment positively influences supply chain responsiveness and resource integration in rural enterprises, its underlying mechanisms within rural supply chain contexts remain insufficiently explored. This study investigates these mechanisms through the three dimensions of structure, trust, and resource empowerment.

With the deepening of research, the concept of digital empowerment has been progressively expanded. Leong C. et al. (2015), Leong C. M. L. et al. (2015), and Leong et al. (2016) emphasized its role at the business ecosystem level, particularly in offering low-cost, high-efficiency support for small and medium-sized enterprises (SMEs) operating on e-commerce platforms (Min and Kim, 2021). Compared with traditional operational management, such platforms demonstrate distinct advantages in empowering rural SMEs through data sharing and market insight (Zhu et al., 2020). Sun et al. (2018) categorized digital empowerment into three dimensions: structural empowerment, psychological empowerment, and resource empowerment—corresponding, respectively, to the optimization of external institutional conditions, enhancement of collaborative trust, and reinforcement of resource integration capabilities. This classification provides a systematic framework for understanding how rural enterprises can enhance their capabilities and improve performance through digitalization. Therefore, structural empowerment, trust empowerment, and resource empowerment do not directly influence rural supply chain performance; rather, they exert their effects through supply chain collaboration by shaping coordination mechanisms, resource integration processes, and relational linkages among supply chain members. In this process, supply chain collaboration serves as a key transmission mechanism through which digital empowerment is transformed into performance outcomes and functions as a critical mediating link between digital empowerment and rural supply chain performance (Cao and Zhang, 2011). Moreover, digital empowerment and its synergistic effects do not operate in isolation but are conditioned by the external institutional environment (Mei et al., 2020). Accordingly, policy support is incorporated as a contextual institutional moderator to explain variations in the strength of different digital empowerment pathways. This study conceptualizes structural empowerment, trust empowerment, and resource empowerment as three digitalization-driven mechanisms of capability generation. These mechanisms, respectively, enable enterprises to sense changes in demand, seize opportunities through cross-stakeholder collaboration, and reconfigure resource allocation, thereby enhancing supply chain collaboration and performance (Li Z. et al., 2022; Li Z. B. et al., 2022; Teece, 2007). Dynamic capability theory thus provides the theoretical foundation for the three-dimensional empowerment framework adopted in the conceptual model and guides subsequent hypothesis development.

To further elucidate the impact mechanisms of digital empowerment on rural supply chains, this paper draws on dynamic capability theory (Teece, 2007). This theory posits that organizational capabilities consist of three core functions: sensing, seizing, and transforming. Empowerment, in this context, is not merely about delegation of authority, but also about capability creation (Li Z. et al., 2022; Li Z. B. et al., 2022). In rural digital transformation, enterprises utilize digital tools to rapidly sense market demands (Wu et al., 2022), integrate resources via digital platforms to optimize operations (Jiang et al., 2022), and continually adapt business models and organizational structures to address environmental uncertainty (Ellström et al., 2021). Furthermore, institutional theory highlights how formal and informal institutional arrangements constrain and guide firm behaviors (North, 1990; Scott, 1995), which is essential for explaining the external institutional foundations that enable digital empowerment in the digitalization of rural supply chains. As a result, digital empowerment enhances rural enterprises' agility and responsiveness, ultimately promoting both coordinated rural supply chain optimization and performance improvement.

2.2 Supply chain collaboration

Supply chain collaboration (SCC) refers to the coordination and cooperation among multiple enterprises to achieve mutually beneficial objectives, particularly under conditions of resource constraints. Supply chain collaboration enhances firms' capacity to access resources and improve market competitiveness (Simatupang and Sridharan, 2002). It involves not only the sharing of information and resources but also the alignment of interests and synchronization of decision-making processes to boost overall operational efficiency and profitability (Soosay and Hyland, 2015). As Cao and Zhang (2011) emphasized, Supply chain collaboration highlights the importance of mutual benefit and shared goals among independent entities within the supply chain. Given the increasing complexity of supply chain structures, collaboration has become an essential driver for improving responsiveness and operational performance (Acquah et al., 2021; Wu et al., 2014), and is recognized as a critical source of competitive advantage (Liao et al., 2017).

In the digital era, Supply chain collaboration has gained heightened strategic importance. The emergence of digital platforms and the widespread use of data analytics tools have significantly enhanced upstream and downstream interactions, facilitating improved supply–demand alignment and more effective resource integration (Ikram et al., 2018). Particularly within industrial agglomeration contexts, geographical proximity further amplifies the efficiency of collaboration among rural enterprises, leading to shorter response times and reduced communication costs (Merrell et al., 2022). Effective collaborative mechanisms not only improve the operational performance of rural supply chains but also increase their adaptability and competitiveness in dynamic market environments.

Although existing studies affirm the positive impact of supply chain collaboration on rural enterprises' responsiveness and resource allocation, its mechanisms in the rural e-commerce context remain underexplored. This paper investigates how digital empowerment enhances the supply chain performance and competitiveness of rural enterprises through collaborative mechanisms. Central to this process is the development of dynamic capabilities—enterprises' abilities to respond to environmental uncertainties by fostering coordination, engaging in interactive learning, and reorganizing resources through cooperative complementarities (Al-Omoush et al., 2023; Eslami et al., 2021; Yang and Ren, 2021). From an institutional perspective, improvements in the institutional environment reduce uncertainty and reinforce cooperative expectations among members of rural supply chains. Such enhancements provide more stable institutional support for the digital empowerment–driven collaboration mechanisms in rural supply chains (Liu et al., 2024).

2.3 Rural supply chain performance

Rural supply chain performance (SCP) encompasses multiple dimensions, including resource utilization, output effectiveness, and operational flexibility (Belhadi et al., 2024; Khan et al., 2009). SCP refers to improvements in operational outcomes achieved through collaborative engagement among supply chain members (Molnár et al., 2010; Odongo et al., 2016). Prior research highlights that SCP is influenced by various factors, with the interplay between internal and external collaboration recognized as a critical driver of enhanced performance (Zhong et al., 2023).

In the context of digital empowerment, technologies such as big data analytics, artificial intelligence, and digital performance management systems have been shown to optimize decision-making processes and enable supply chain transformation, thereby significantly improving e-commerce supply chain performance (Balakrishnan and Ramanathan, 2021). Furthermore, digital tools foster information sharing and collaborative mechanisms—particularly in supplier-customer interactions—which are essential for enhancing delivery speed, product quality, service responsiveness, and flexibility (Zhang et al., 2016). From the perspective of performance formation mechanisms, supply chain performance is not only reflected in outcome-based results but also depends on firms' continuously enhanced capabilities in coordination, adaptation, and resource integration during collaborative processes. These capabilities, in turn, drive improvements in innovation, operational efficiency, and strategic collaborative performance (Zhan and Tan, 2020).

For rural e-commerce enterprises, SCP is typically assessed using five key indicators: profit growth, cost reduction, business expansion, product upgrading, and improved partnerships (Odongo et al., 2016; Abd Rahman et al., 2023; Zeng et al., 2018). Profit growth reflects the net income generated through business activities, while cost reduction refers to the minimization of operational and opportunity costs through management optimization and collaboration (Odongo et al., 2016). Business expansion is evident in increased product sales resulting from investments in digital platforms (Zeng et al., 2018). Product upgrades involve improvements in product structure, function, or value to meet evolving market demands. Improved partnerships are reflected in heightened trust and collaboration with upstream and downstream supply chain partners. Collectively, these indicators provide a comprehensive evaluation of performance within rural e-commerce supply chains.

Although existing literature emphasizes the roles of collaboration, capability development, and technology adoption in enhancing SCP, the mechanisms through which digital empowerment contributes to SCP improvement in rural contexts remain insufficiently examined. This study investigates how digital empowerment facilitates rural supply chain performance by fostering collaborative supply chain mechanisms.

2.4 Research hypotheses

Digital technologies have created new opportunities for economic development and social interaction in rural areas, particularly in the field of e-commerce (Freeman and Park, 2015). Their application facilitates online collaborative environments and business network activities, offering rural enterprises enhanced access to cooperation and knowledge exchange (Merrell et al., 2022). The use of digital tools to engage in online business networks also enables enterprises to rapidly establish credibility, thereby fostering cooperation and accelerating problem-solving (Quinton and Wilson, 2016; Tiwasing et al., 2022). Digital empowerment comprises three dimensions—resource empowerment, structural empowerment, and trust empowerment—each of which plays a vital role in promoting rural supply chain collaboration and performance. Digital empowerment comprises three dimensions—resource empowerment, structural empowerment, and trust empowerment—each exerting significant influence on the collaborative mechanisms and performance outcomes of rural supply chains. Meanwhile, policy support, as part of the external institutional environment, further strengthens the effects of digital empowerment by improving infrastructure, reducing environmental uncertainty, and expanding channels for resource access. Based on these insights, we develop the conceptual model illustrated in Figure 1. Drawing on dynamic capability theory and institutional theory, this study argues that digital empowerment strengthens rural supply chains' sensing, seizing, and reconfiguring capabilities through three interrelated pathways: structural empowerment improves institutional and organizational conditions, trust empowerment reinforces relational governance, and resource empowerment enhances resource acquisition and restructuring capabilities. These capability enhancements are primarily translated into performance outcomes through supply chain collaboration as a key mediating mechanism. Policy support, as a contextual institutional condition, is introduced to explain differences in the strength of these empowerment pathways.

2.4.1 Structural empowerment

Structural empowerment emphasizes the removal of barriers to information, opportunities, and resources for enterprises by improving external objective conditions, including organizational, institutional, social, economic, political, and cultural factors. Specifically, according to dynamic capabilities theory, enterprises must reshape processes and break down traditional organizational boundaries in uncertain environments to respond agilely to market changes (Nambisan et al., 2017). In rural supply chains, platforms integrate multiple stakeholders through structural mechanisms such as route planning and cost sharing, thereby promoting efficient

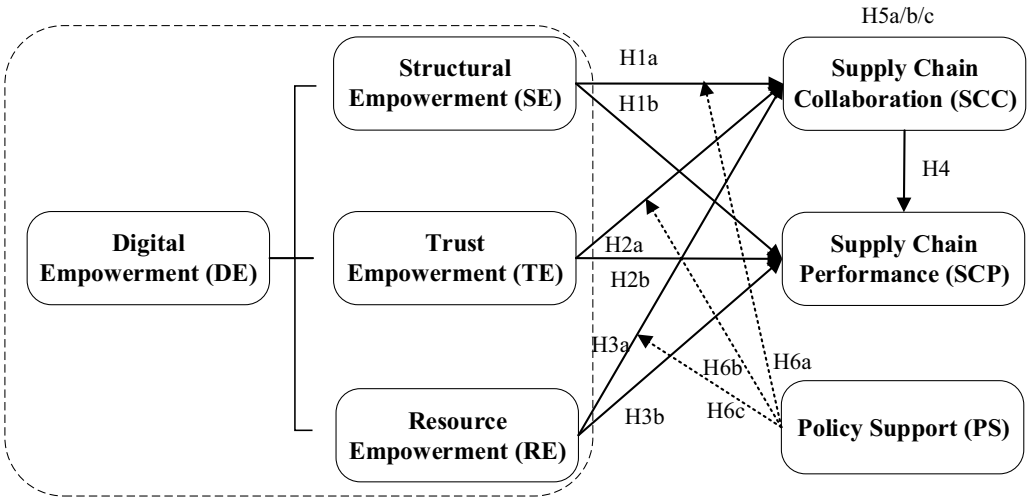


FIGURE 1
Conceptual model.

collaboration in platform-driven delivery models. They also facilitate information sharing through structured data recording and traceability platforms, such as blockchain, RFID, and barcode technologies, significantly enhancing coordination among stakeholders (Petrillo et al., 2025; Rao et al., 2025). The development of smart villages depends on the structural allocation of human and administrative resources within socio-technical infrastructure and highlights the importance of multi-party collaboration and institutional arrangements, including tools, rules, and division of labor. This further illustrates that structural empowerment can foster rural collaborative mechanisms (Stein et al., 2025; Wagg and Simeonova, 2022). In the case of Taobao Villages, platform-based cluster development expands production chains and leverages close actor connections, directly demonstrating that structural empowerment promotes collaboration among regional actors (Chu et al., 2023).

Similarly, by providing access to information, support, resources, and decision-making authority, structural empowerment optimizes the organizational environment and enhances rural supply chain performance (Laschinger et al., 2000; Su and Yu, 2022). According to dynamic capabilities theory, structural empowerment enables process reshaping through platform-enabled optimization of transportation, inventory, and production efficiency. It also improves last-mile logistics via route optimization and structured collaboration, yielding cost savings and increased output, thereby exerting a significant positive impact on rural supply chain performance (Petrillo et al., 2025; Rao et al., 2025). Therefore, this study proposes the following hypotheses:

> *H1a*: Structural empowerment has a positive effect on rural supply chain collaboration.
>
> *H1b*: Structural empowerment has a positive effect on rural supply chain performance.

2.4.2 Trust empowerment

Trust empowerment emphasizes the psychological perceptions and relationship-building processes that shape collaborative interactions among supply chain members. Specifically, it enhances members' collaborative motivation and adaptability by increasing information transparency, reducing uncertainty, and strengthening commitment to cooperation (Maynard et al., 2012). At the same time, it reinforces intrinsic work motivation and cooperative relationships within teams by improving members' sense of efficacy and autonomy (Su and Yu, 2022). According to dynamic capabilities theory, organizations operating in uncertain environments rely on trust mechanisms to rapidly coordinate internal and external resources and maintain agile responses. In rural supply chains, digital literacy, platform governance, and multi-stakeholder collaboration all underscore the centrality of trust. Trust and interaction among diverse actors can promote collaborative cooperation (Choudhary, 2025), whereas insufficient trust impedes inter-organizational knowledge sharing (Wagg and Simeonova, 2022). Moreover, farmers' trust in technology and digital financial applications directly shapes multi-stakeholder interactions and collaborative behavior (Nova and Gonzalez, 2023). Additionally, online marketing platforms support seller credibility through rating and monitoring mechanisms (Bruckermann, 2021), cluster expansion depends on interpersonal and inter-organizational trust (Chu et al., 2023), and micro-business communities strengthen collective action through online mutual assistance and trust (Zhou et al., 2023). Collectively, these findings highlight the pivotal role of trust empowerment in facilitating rural supply chain collaboration.

Digital technologies further amplify the impact of trust empowerment in rural supply chains. E-commerce platforms and digital tools enhance collaboration mechanisms and resource-sharing opportunities for upstream and downstream enterprises, while simultaneously improving operational efficiency and profitability by strengthening trust relationships among members (Mawutor and Hajjar, 2024). According to dynamic capabilities theory, organizations leverage trust mechanisms to coordinate resources swiftly and maintain agility in uncertain environments. Improved transparency and traceability not only reinforce trust but also directly promote fair trade and profitability, demonstrating that trust empowerment can translate effectively into enhanced supply chain performance (Petrillo et al., 2025). For instance, rural e-commerce enterprises experience

notable gains in perceived trust empowerment through expanded information sharing and collaborative opportunities, leading to higher operational efficiency and profitability (Chu et al., 2023). Therefore, this study proposes the following hypotheses:

> *H2a*: Trust empowerment positively influences rural supply chain collaboration.
>
> *H2b*: Trust empowerment positively influences rural supply chain performance.

2.4.3 Resource empowerment

Resource empowerment emphasizes enhancing enterprises' capacity to acquire, integrate, and manage resources to strengthen market competitiveness (Sun et al., 2018). Specifically, digital technologies facilitate effective communication and collaboration among enterprises in rural supply chains by optimizing resource utilization and management processes, reducing information gaps and asymmetries, and improving data accuracy and sharing (Lin and Kunnathur, 2019; Shu et al., 2023). Evidence suggests that human and administrative resources play a core role in digital participation, and multi-stakeholder collaboration is essential, indicating that resource empowerment can foster collaborative activities in rural areas (Stein et al., 2025). Conversely, resource constraints, including limited infrastructure, funding, and technological capacity, hinder multi-party collaboration, highlighting resource empowerment as a key prerequisite for enhancing rural supply chain collaboration (Choudhary, 2025; Nxumalo and Chauke, 2025). Moreover, technical support and safeguarding resources improve multi-party collaborative implementation, while financial and technological investments facilitate the establishment of formal cooperative relationships, thereby strengthening collaborative operations (Utama et al., 2025; Xing and Yao, 2022). During the COVID-19 pandemic, smallholder farmers achieved supply chain collaboration through adaptive strategies such as resource reallocation, market diversification, direct sales, and e-markets, demonstrating the practical relevance of resource empowerment (Maren et al., 2022).

From a performance perspective, resource empowerment enhances the information environment and improves resource allocation efficiency, thereby promoting overall supply chain performance (Shu et al., 2023). According to dynamic capabilities theory, digital resources not only strengthen enterprises' ability to sense and respond to external changes but also facilitate supply chain collaboration by improving data processing and resource integration capabilities. Specifically, digital tools enable rural enterprises to integrate and analyze data in real time, yielding more accurate supply–demand matching (Kumar, 2017), which in turn reduces costs and increases profitability. Furthermore, existing studies provide multi-dimensional evidence supporting the performance effects of resource empowerment. For example, shared transportation resources have generated significant cost savings across multiple regional cases, demonstrating the substantial role of resource empowerment in improving rural supply chain performance (Rao et al., 2025). Resource-based digital empowerment has also been shown to enhance farmers' production efficiency, resource management capability, and market performance (Nxumalo and Chauke, 2025). Likewise, resource-oriented initiatives—such as infrastructure investment—strengthen digital capabilities and improve performance outcomes in rural areas (Choudhary, 2025). Meanwhile, resource-based interventions, including financial inclusion tools and digital platforms, help enhance connectivity within the supply chain, thereby improving overall value chain performance (Utama et al., 2025). Based on these insights, this study proposes the following hypotheses:

> *H3a*: Resource empowerment positively influences rural supply chain collaboration.
>
> *H3b*: Resource empowerment positively influences rural supply chain performance.

2.4.4 Supply chain collaboration

Supply chain collaboration establishes networks among enterprises through information sharing, resource integration, and close communication, thereby enhancing overall efficiency and performance (Cao and Zhang, 2011; Zhang and Cao, 2018). In rural e-commerce supply chains, collaboration not only reduces operating costs but also integrates dispersed resources to expand market share and mitigate the bullwhip effect, ultimately improving supply chain transparency and responsiveness (Panahifar et al., 2018; Ramjaun et al., 2024). According to dynamic capabilities theory, organizations must continuously reshape collaborative mechanisms to sense external changes and respond rapidly, thereby sustaining performance improvements. Prior research indicates that organizational innovation and inclusiveness, as key agent collaboration characteristics, are strongly associated with regional development awareness, highlighting the empirical link between enhanced organizational collaboration, innovative practices, and supply chain performance (Utama et al., 2025). During the pandemic, collaborative innovation between e-commerce firms and delivery intermediaries substantially improved supply chain resilience and capacity, demonstrating the effectiveness of collaborative mechanisms in enhancing performance (Reardon et al., 2021). Moreover, local collaboration capabilities and connections with external networks significantly facilitate enterprise product updates (Zhang et al., 2023). Evidence from Taobao Villages further shows that close collaboration with local and external networks enhances technological innovation and value addition, confirming that rural supply chain collaboration can significantly improve overall supply chain performance (Wei et al., 2020). Therefore, the following hypothesis is proposed:

> *H4*: Rural supply chain collaboration positively influences supply chain performance.

Structural empowerment provides organizational and institutional support for supply chain collaboration by optimizing process boundaries and improving information systems and logistics infrastructure (Nambisan et al., 2017). In digital environments, structural empowerment blurs industry, organizational, and product boundaries, facilitating the restructuring of enterprise operating models and cooperative relationships, thereby enhancing the collaborative capabilities of rural supply chains (Li Z. et al., 2022; Li Z. B. et al., 2022). Adequate structural resources further enable real-time communication and synchronized decision-making among enterprises, improving collaborative efficiency and overall performance (Laschinger et al., 2000). According to dynamic

capabilities theory, enterprises rely on structural resources to dynamically reshape collaborative mechanisms and enhance responsiveness to market changes. Empirical evidence shows that improvements in production processes, through e-commerce integration of material, information, and capital flows combined with cross-regional collaboration, significantly enhance product quality and variety, thereby boosting supply chain performance (Zhang et al., 2023). Additionally, e-commerce integration across stages captures and shares key information, strengthens communication and coordination, and effectively integrates local and non-local resources, supporting product updates (Zhang et al., 2023).

Trust empowerment enhances members' willingness to collaborate and stabilizes cooperative relationships by increasing information transparency, reducing uncertainty, and strengthening commitment (Maynard et al., 2012; Su and Yu, 2022). Digital empowerment also improves transactional trust between enterprises (Liu et al., 2022). This trust-based mechanism not only improves collaboration efficiency but also stimulates cross-organizational innovation, thereby driving performance gains (Lu et al., 2024). Dynamic capabilities theory suggests that organizations rely on trust mechanisms to quickly coordinate internal and external resources under uncertainty. Research shows that trust increases participation, which is closely linked to the economic effectiveness of poverty alleviation projects (Chen et al., 2021). Moreover, e-commerce platform mechanisms, including user review trust and institutional trust, reduce uncertainty in new product decisions by promoting knowledge exchange and supply–demand matching across regions, thereby indirectly driving product updates and enhancing supply chain performance (Zhang et al., 2023).

Resource empowerment emphasizes enhancing enterprises' ability to acquire, integrate, and manage key resources (Sun et al., 2018). Digital technologies optimize data transmission and resource sharing, reducing information asymmetry and improving resource flow efficiency across the supply chain (Shu et al., 2023). In resource-constrained contexts, supply chain collaboration compensates for internal resource shortages, integrates external advantages, and mediates the relationship between digital transformation and supply chain resilience (Wu et al., 2023; Zhang J. et al., 2025; Zhang Q. et al., 2025). According to dynamic capabilities theory, enterprises rely on resource awareness and reallocation capabilities to adjust collaborative mechanisms and improve performance. Empirical evidence demonstrates that e-commerce provides rural merchants with external market information and cross-regional resources, which, through collaborative supply chain mechanisms integrating local and extensive market networks, directly enhance product quality and category expansion, thereby improving rural supply chain performance (Zhang et al., 2023). Accordingly, the following hypotheses are proposed:

> *H5a*: Supply chain collaboration mediates the relationship between structural empowerment and supply chain performance.
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> *H5b*: Supply chain collaboration mediates the relationship between trust empowerment and supply chain performance.
>
> *H5c*: Supply chain collaboration mediates the relationship between resource empowerment and supply chain performance.

2.4.5 Policy support

Policy support plays a crucial moderating role in the relationship between structural empowerment and rural supply chain collaboration. Institutional theory argues that formal institutions reduce institutional gaps and transaction uncertainty, thereby providing the institutional foundation needed for transforming structural empowerment into collaboration (Parmigiani and Rivera-Santos, 2015). Within this framework, policy support represents a key external institutional condition shaping how structural empowerment influences the collaborative behavior of supply chain actors through formal and informal institutional arrangements (North, 1990). Furthermore, policy support is conceptualized as a contextual institutional condition perceived by rural enterprises. Rather than directly driving collaborative behavior, its primary role lies in moderating the strength of the relationship between different dimensions of digital empowerment and rural supply chain collaboration, thereby shaping the transformation of structural empowerment into collaborative outcomes (Mei et al., 2020). In China, the government has alleviated capacity, resource, and risk constraints faced by rural enterprises by offering funding, technology, and training (Yin and Choi, 2022). It has also strengthened logistics, information, and capital flows through infrastructure construction, e-commerce loans, and broadband networks (Mei et al., 2020; Zhang J. et al., 2025; Zhang Q. et al., 2025), thereby improving the collaborative environment of rural supply chains. Studies further show that the development of smart villages depends on policy-driven socio-technical infrastructure, indicating that policy support can reinforce the positive influence of structural empowerment on collaboration (Stein et al., 2025). Policy design and institutional intervention enhance the synergistic effect of structural institutional arrangements (Wagg and Simeonova, 2022), while subsidies and fault-tolerance mechanisms significantly increase the cooperative willingness of village-level organizations, highlighting the role of policy as an exogenous institutional force strengthening structural empowerment (Yin et al., 2024).

Policy support may also be an important moderating factor in the relationship between trust empowerment, and rural supply chain collaboration. Institutional theory emphasizes that informal institutions—such as social norms and mutual trust mechanisms—are essential for cooperative relationships; thus, policy support can reinforce the institutional environment that trust empowerment relies upon (Cai et al., 2010). By improving institutional legitimacy and optimizing the business environment, policies help enhance trust among supply chain entities (Avgerou and Li, 2013; Mei et al., 2020). In Taobao village development, government support in entrepreneurship, coordination mechanisms, and training programs has boosted farmers' willingness to cooperate and increased mutual trust (Cui et al., 2019). The political and institutional environment also exerts a decisive influence on the collaborative atmosphere of rural e-commerce clusters (Nguyen et al., 2023). Policy and practical interventions can strengthen trust and collaboration among stakeholders, thereby amplifying the positive effects of trust empowerment (Choudhary, 2025). Policy mechanisms may also mitigate trust conflicts and promote multi-party cooperation (Wagg and Simeonova, 2022). The crucial role of institutional trust in promoting farmer participation suggests that policy support can alter the transformation path from trust

empowerment to collaboration (Chen et al., 2021). Government involvement in regulating platform credibility further shows that policy can shape the functioning of trust mechanisms (Bruckermann, 2021).

Policy support can also exert a significant moderating effect on the relationship between resource empowerment and rural supply chain collaboration. Institutional theory suggests that policy incentives and institutional arrangements can alleviate rural resource constraints and enhance factor mobility, thereby offering institutional support for transforming resource empowerment into collaboration (Wu et al., 2022). Governments promote industrial resource integration and cross-regional flow through fiscal subsidies, improved logistics systems, and knowledge-sharing platforms (Guihang et al., 2014). Local investment in transportation and digital infrastructure creates the resource base for rural e-commerce development and facilitates resource aggregation and optimal allocation through e-commerce industrial parks (Lin et al., 2022). Research shows the critical role of policy intervention in strengthening resource enhancement and collaboration, indicating that government support can reinforce the relationship between resource empowerment and synergy (Nxumalo and Chauke, 2025). The combined effect of policies, financial tools, and digital platforms can amplify both resource-related and structural interventions, suggesting that policy support actively shapes the pathway from resource empowerment to supply chain synergy and performance improvement (Utama et al., 2025). Government support also helps relieve resource bottlenecks for rural enterprises and improves their collaborative capability (Herold et al., 2021). Therefore, the following hypotheses are proposed:

> *H6a*: Government policy support positively moderates the relationship between structural empowerment and supply chain collaboration.
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> *H6b*: Government policy support positively moderates the relationship between trust empowerment and supply chain collaboration.
>
> *H6c*: Government policy support positively moderates the relationship between resource empowerment and supply chain collaboration.

3 Methodology

In this study, the research subjects mainly include the "Taobao Village" in Zhejiang Province and the key participants of its related rural e-commerce supply chain. Specifically, the study focuses on the interaction and collaboration of multiple parties engaged in rural e-commerce, including farmers, suppliers, retailers, service providers, and e-commerce platforms. Digital empowerment breaks through the traditional one-way process of "supply → demand" by optimizing supply chain collaboration and reconstructing it into an efficient model of "supply → platform → demand" (Xu et al., 2020), thereby improving the overall performance and competitiveness of the rural supply chain. To facilitate understanding of the differences between traditional rural supply chains and digitally empowered rural supply chains, see the structural diagram of traditional rural supply chains and "Taobao Village" rural e-commerce supply chains in Appendix.

3.1 Questionnaire design

Based on the literature review and the conceptual framework described above, a survey tool was designed to measure digital empowerment, policy support, supply chain collaboration, and supply chain performance. The specific items are shown in Table 1.

Specifically, digital empowerment is measured through three dimensions: structural empowerment, trust empowerment, and resource empowerment, each of which contains 3, 3, and 4 measurement items, respectively. These items are adapted from the studies of Leong C. et al. (2015), Leong C. M. L. et al. (2015), and Lee and Koh (2001). The measurement of policy support includes policy planning, e-commerce talent training, infrastructure construction, and market supervision, referring to the studies of Dania et al. (2018) and Mei et al. (2020). The measurement of supply chain collaboration performance is based on the studies of Cao and Zhang (2012) and Acquah et al. (2021), covering four dimensions: information sharing, resource sharing, collaborative communication, and co-creation of knowledge. Supply chain performance is evaluated using five items, including profit growth, cost reduction, business expansion, product upgrades, and improved partnerships, which are adapted from the studies of Zeng et al. (2018) and Odongo et al. (2016).

To ensure theoretical consistency, this study draws primarily on dynamic capability theory to define and operationalize the constructs, allowing them to capture processes of capability formation and transformation. Institutional theory is additionally incorporated to explain the moderating role of policy support. Structural empowerment reflects enterprises' perceptions of improvements in institutional and structural conditions, indicating their ease of access to information, opportunities, and market connections. Trust empowerment captures confidence and relational support under conditions of uncertainty, facilitating cross-stakeholder collaboration. Resource empowerment represents enterprises' ability to share, control, and reconfigure key resources with partners. Supply chain collaboration characterizes cross-organizational coordination and joint knowledge activities, serving as a central mechanism through which empowerment is translated into performance outcomes. Performance indicators capture observable outcomes in rural e-commerce contexts, including profitability, cost efficiency, market expansion, and upgrading. Measures of policy support reflect enterprises' perceptions of the external institutional environment and policy instrument provision; their role is to moderate the extent to which different empowerment mechanisms are transformed into collaborative behavior rather than to directly determine performance outcomes (North, 1990; Scott, 2014).

Respondents were asked to select a partner they were most familiar with and, based on the actual situation of inter-enterprise cooperation, indicate their agreement with the statements about the relationship between digital empowerment, policy support, supply chain collaboration, and supply chain performance. We used a 5-point Likert scale, where "1" means "completely disagree" and "5" means "completely agree."

Before the formal survey, the study conducted a preliminary survey of 5 companies in a "Taobao Village." After the managers filled out the questionnaire, the researchers discussed the survey questions with them face to face, clarified the meaning of some

TABLE 1 Constructs and indicators.

Constructs	Items	Indicator	Adapted from
Structural Empowerment (SE)	SE1	I can easily engage in e-commerce activities with my partners (such as platforms like Taobao and Douyin, as well as social media).	Leong C. et al. (2015), Leong C. M. L. et al. (2015), and Lee and Koh (2001)
	SE2	New sales channels allow my partners and me to access new markets and customer segments.	
	SE3	Digital policy support and resources enhance our operational and management effectiveness.	
Trust Empowerment (TE)	TE1	I feel capable of improving living conditions for myself and my family.	
	TE2	I feel supported by the government, neighbors, family, and partners.	
	TE3	I believe my self-confidence has improved through collaboration with my partners.	
Resource Empowerment (RE)	RE1	I can easily share essential resources with my partners.	
	RE2	I can effectively control and manage business resources alongside my partners.	
	RE3	Together, we can sell products or services more efficiently.	
	RE4	We can communicate with suppliers and customers more effectively.	
Policy Support (PS)	PS1	Government-provided infrastructure facilitates cooperation between our company and supply chain partners.	Dania et al. (2018) and Mei et al. (2020)
	PS2	E-commerce talent introduced and developed by the government enhances collaboration between our company and supply chain partners.	
	PS3	Low-interest loans from the government improve our company's ability to cooperate effectively with supply chain partners.	
	PS4	Strengthened market supervision and quality safety measures by the government enhance trust in cooperation between our company and supply chain partners.	
Supply Chain Collaboration (SCC)	SCC1	Our company and supply chain partners exchange complete and accurate information in a timely manner.	Acquah et al. (2021) and Zhang and Cao (2018)
	SCC2	Our company and supply chain partners share various resources, including technical support, equipment, and both financial and non-financial resources (such as time, money, and training).	
	SCC3	Our company and supply chain partners maintain frequent and regular contact through diverse communication channels, ensuring open and two-way communication.	
	SCC4	Our company and supply chain partners collaboratively search for, acquire, and apply relevant knowledge, jointly identify customer needs, and explore new markets.	
Supply Chain Performance (SCP)	SCP1	Collaboration with supply chain partners has increased the company's revenue and profits.	Odongo et al. (2016) and Zeng et al. (2018)
	SCP2	Collaboration with supply chain partners has reduced operating costs.	
	SCP3	Collaboration with supply chain partners has increased market share.	
	SCP4	Collaboration with supply chain partners has driven product upgrades and innovation.	
	SCP5	Our cooperative relationship with supply chain partners has improved the overall efficiency of the supply chain.	

questions, and revised and optimized the items that caused ambiguity.

3.2 Sampling and data collection

This study collected data from April to May 2024. The formal survey lasted for 2 months, aiming to obtain the opinions of upstream and downstream participants in the rural e-commerce supply chain. The survey subjects included government departments, e-commerce associations, e-commerce public service centers, suppliers (farmers), producers (processors), rural e-commerce retailers, operating companies, e-commerce platform companies, logistics companies, and related service providers (such as packaging, printing, training, etc.).

To ensure the smooth progress of the formal survey, the research team first conducted a pre-survey. 20 paper questionnaires were distributed to verify the scientificity and rationality of the questionnaire. Based on the feedback collected in the pre-survey, the research team discussed and revised, and finally determined the formal questionnaire. Before the survey, the researchers received special training, focusing on the business scenarios and questionnaire items of rural e-commerce supply chain collaboration to ensure that they could provide accurate interpretations to the respondents so that they could answer according to the actual situation of the enterprise.

The questionnaires were administered in Chinese, and all respondents were native speakers. For scale items adapted from English literature, a translation–backtranslation procedure was employed, conducted by two bilingual experts to ensure conceptual equivalence. Any discrepancies identified during backtranslation were discussed and resolved. To minimize respondent bias, all investigators received standardized training to maintain neutrality in interpreting questions and emphasized the principles of anonymity and the absence of correct answers (see Table 2).

After revising the questionnaire, the data collection work of the formal survey adopted a combination of on-site and online methods. On the one hand, the team members visited 10 "Taobao villages" in Zhejiang Province, including Bainiu Village, Beishan Village, Qingyanliu Village, Changdai Village, Jiangchuan Village, Xinze Village, Shenjia Village, Hanbu Village, Xi'ao Village and Shuangyi Village. These sample villages have a relatively mature e-commerce operation foundation and strong supply chain linkage characteristics, and the survey subjects are representative. The questionnaire was distributed through the online platform "Wenjuxing" and forwarded with the help of key informants (such as enterprise managers, platform leaders, government policymakers, etc.) established during the field investigation, covering more rural e-commerce enterprises of different types and development stages, and improving the diversity of the sample. On the other hand, to alleviate the selection bias that may be caused by exclusive dependence on a few sample villages, the research team further distributed online questionnaires in Taobao town where the sample village is located, and the nearby rural e-commerce industrial park based on the above-mentioned field visits, to expand the scope of sample sources and improve the external generalizability of the research conclusions (see Figure 2).

With the strong support of the e-commerce platform (Ali Research Institute), local governments, and e-commerce associations, a total of 400 questionnaires were distributed, 350 were collected, and the collection rate was 87.5%. After eliminating the questionnaires that did not understand the cooperative relationship, had incomplete information, or had obvious problems, 263 valid questionnaires were finally obtained, with an effective collection rate of 75.14%, which met the requirements of the subsequent model empirical analysis. The descriptive analysis of the sample characteristics showed that the sample distribution was reasonable and representative. The specific statistical results are shown in Table 3.

Based on the statistical survey results, the following conclusions can be drawn: The typical age of rural e-commerce practitioners is between 20 and 40 years old, which is related to the use of the Internet. Since there are certain barriers to entry in Taobao store operations, most managers have a high school degree or above. Although Taobao Village has been in operation for about fifteen years, most entrepreneurs have only opened online stores in the past 5 to 15 years, and they started inter-enterprise cooperation after the development of rural e-commerce.

Although the proportion of raw material suppliers and processing/manufacturing enterprises is relatively low, this distribution reflects the actual structure of rural e-commerce supply chains in "Taobao Villages," where downstream e-commerce retailers and logistics providers serve as core entities. These villages typically exhibit "production–sales integration" in a family-based operational model, with farmers naturally assuming dual roles as both product suppliers and online retailers (AliResearch, 2019; Mei et al., 2020). Moreover, the sample spans "Taobao Villages" across different regions and developmental models, encompassing key actors such as suppliers, processing enterprises, e-commerce platforms, government agencies, and related service providers. This diversity ensures sufficient structural representation, thereby enhancing the external generalizability of the research findings.

4 Results

This study employed SmartPLS 4 software to perform partial least squares-based structural equation modeling (PLS-SEM). PLS-SEM was selected due to its status as a variance-based SEM method and its reputation as one of the most established and widely utilized tools for data analysis. It is particularly well-suited for predictive and exploratory research that has not been extensively tested (Hair et al., 2011; Henseler et al., 2014). Furthermore, PLS-SEM effectively accommodates small sample sizes and non-normally distributed data (Hair et al., 2017) and has been extensively applied in supply chain management research (Hazen et al., 2017).

Given that this study utilized a self-report survey, there is a potential risk of common method bias (CMB). Both dependent and independent variables were collected using the same procedure (Jordan and Troth, 2020; Podsakoff and Organ, 1986). To evaluate whether the model was affected by CMB, we employed the full collinearity variance inflation factor (VIF) criterion for detection. The results indicated that the maximum VIF value was 2.365, which is below the 3.3 threshold recommended in the literature (Kock, 2015). Additionally, Harman's single-factor test results revealed that the total variance explained by a single factor did not exceed 50% (Podsakoff et al., 2003), suggesting that there is no significant collinearity issue in the data and that the impact of CMB on the model is minimal.

4.1 Measurement model evaluation

This study evaluated the measurement model through three key aspects: internal consistency, indicator reliability, and convergent validity (Hair et al., 2020). The main results are presented in Table 3. First, item reliability was assessed using factor loading, with a recommended threshold of 0.7, indicating that the construct explained at least 50% of the variance and thus ensuring item reliability (Hair et al., 2019). Second, Cronbach's alpha and composite reliability (CR) were employed to evaluate internal consistency. The results demonstrated that both Cronbach's alpha and CR for all constructs exceeded the 0.7 threshold, meeting the required reliability standards (Hair et al., 2019). Additionally, convergent validity was assessed using the average variance extracted (AVE). The AVE values for all constructs surpassed the 0.50 threshold, indicating strong convergent validity of the model (Hair et al., 2019). Although the Average Variance Extracted (AVE) primarily assesses convergent validity, its square root is also used to evaluate discriminant validity between constructs according to the Fornell–Larcker criterion (Al-Omoush et al., 2023; Fornell and Larcker, 1981). Furthermore, the model exhibited good discriminant validity, as all factor loadings for their respective dimensions were higher than those for other dimensions, thereby further validating the measurement model.

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TABLE 2 Characteristics of the sample.

Descriptive	*N* = 263	Percentage of respondents
Select your age		
Under 20 years	16	6.08
21–30 years	131	49.81
31–40 years	71	27.00
41–50 years	25	9.51
Over 50 years	20	7.60
Education level		
Junior high school or below	3	1.14
Technical secondary school or high school	28	10.65
College or undergraduate degree	215	81.75
Graduate degree or above	17	6.46
E-commerce industry position		
Raw materials supply	18	6.84
Processing and manufacturing	38	14.45
E-commerce retail	90	34.22
E-commerce platform	36	13.69
Express logistics	29	11.03
Financial institutions	6	2.28
Government and e-commerce associations	22	8.37
Other e-commerce-related industries	24	9.12
Size of your company/organization		
Fewer than 10 employees	31	11.79
10–50 employees	114	43.35
50–100 employees	81	30.79
More than 100 employees	37	14.07
Level of understanding of the partner enterprise		
No understanding	0	0.00
Limited understanding	0	0.00
Unsure	12	4.56
Moderate understanding	179	68.06
Complete understanding	72	27.38
Participation in the cooperation process with the enterprise		
No participation	0	0.00
Minimal participation	6	2.28
Unsure	17	6.46
Moderate participation	198	75.29
Full participation	42	15.97
Duration of contact with the partner enterprise		
≤1 year	12	4.56
1–3 years	72	27.38
3–5 years	123	46.77
5–10 years	45	17.11
More than 10 years	11	4.18

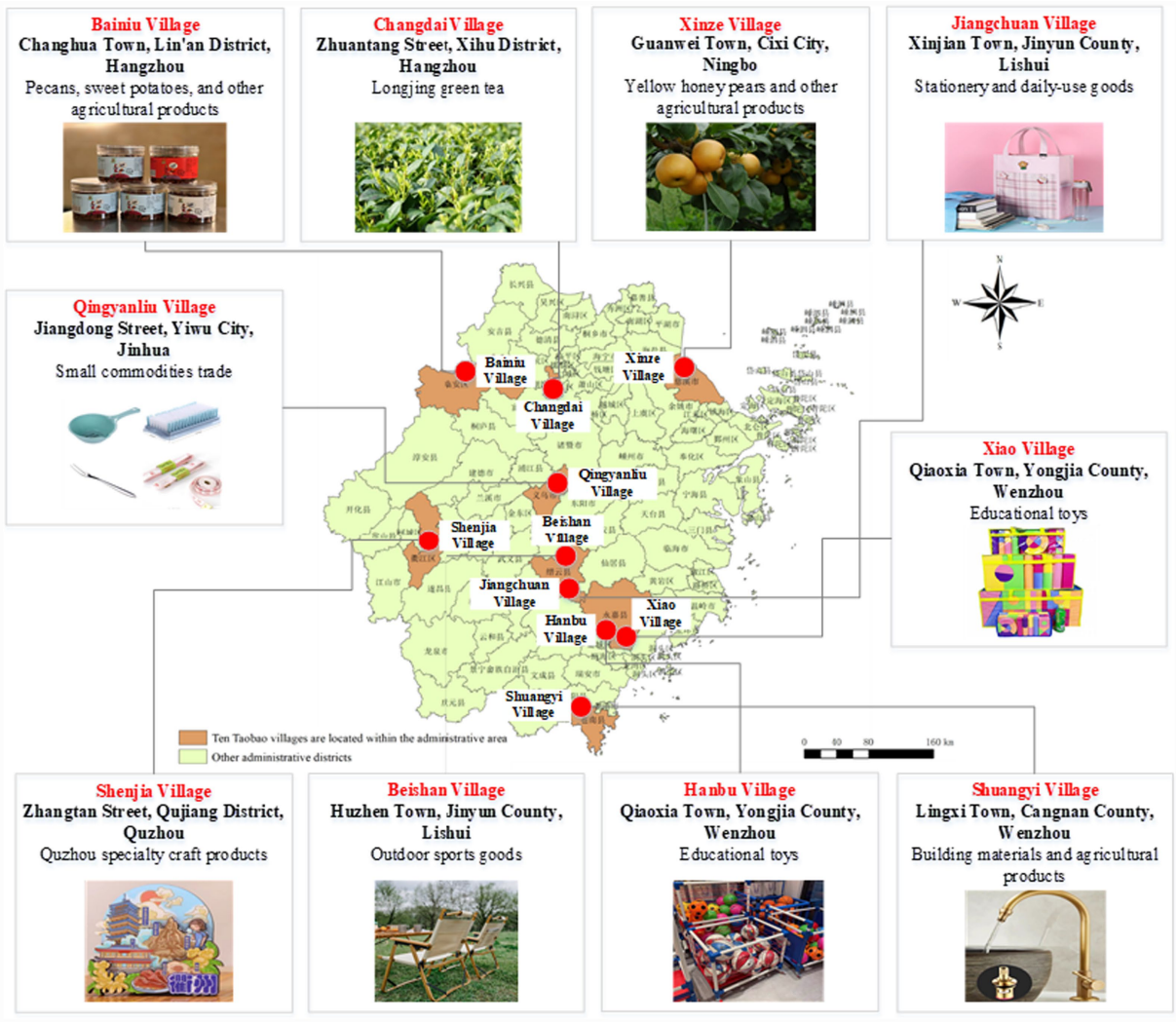


FIGURE 2
Basic information of case samples.

In Table 4, we assessed the discriminant validity of each construct in the model using the Fornell-Larcker criterion. This criterion evaluates discriminant validity by comparing the average variance extracted (AVE) of each construct with its squared correlation coefficients with other constructs (Fornell and Larcker, 1981). The diagonal values in the table, highlighted in bold, represent the square root of the AVE for each construct and are contrasted with the correlations of the remaining constructs. According to this criterion, the square root of the AVE should exceed the correlation with other constructs, indicating significant differences among them. Thus, the model is considered to exhibit good discriminant validity. Furthermore, following the standard established by Chin (1998), the AVE value must exceed 0.5 to ensure convergent validity in reflective models. Additionally, according to Fornell and Larcker (1981), the square root of the AVE must be higher than the correlations between the construct and other latent variables, further reinforcing the discriminant validity of the model.

In the assessment of the measurement model, we further verified discriminant validity by employing the heterotrait-monotrait ratio (HTMT) as a supplementary evaluation method alongside the Fornell-Larcker criterion. Table 5 presents the HTMT results, which measure the correlation between different constructs, specifically assessing the average correlation between each construct and its items (Hair et al., 2019; Henseler et al., 2015). All HTMT values in this study were below the threshold of 0.85, indicating that the model exhibits good discriminant validity. The values reported in Table 5 align with literature recommendations (Hair et al., 2019; Henseler et al., 2015), further confirming that the constructs can be effectively distinguished statistically.

4.2 Structural model evaluation

In evaluating the structural model, we employed the Stone-Geisser Q^2 test (Mitrega et al., 2017; Stone, 1974) to assess the model's predictive relevance. This test calculates samples iteratively using the Monte Carlo algorithm (Ringle et al., 2015). A Q^2 value greater than zero indicates that the model possesses predictive capability (Hair et al., 2019). Specifically, the Q^2 value assesses the predictive relevance of the model for a particular dependent variable; a Q^2 greater than zero

TABLE 3 Measures of internal consistency reliability and convergent validity.

Construct	Items	Loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
SE	SE1	0.860	0.849	0.908	0.768
	SE2	0.873			
	SE3	0.896			
TE	TE1	0.871	0.858	0.914	0.779
	TE2	0.891			
	TE3	0.886			
RE	RE1	0.864	0.884	0.920	0.741
	RE2	0.850			
	RE3	0.855			
	RE4	0.874			
PS	PS1	0.886	0.919	0.942	0.804
	PS2	0.884			
	PS3	0.911			
	PS4	0.905			
SCC	SCC1	0.867	0.894	0.927	0.759
	SCC2	0.859			
	SCC3	0.878			
	SCC4	0.882			
SCP	SCP1	0.864	0.923	0.942	0.765
	SCP2	0.878			
	SCP3	0.889			
	SCP4	0.869			
	SCP5	0.875			

TABLE 4 Discriminant validity using average variance extracted (AVE).

Constructs	SE	TE	RE	PS	SCC	SCP
SE	**0.876**					
TE	0.39	**0.883**				
RE	0.445	0.468	**0.861**			
PS	0.358	0.302	0.32	**0.897**		
SCC	0.478	0.45	0.513	0.394	**0.871**	
SCP	0.453	0.484	0.477	0.381	0.543	**0.875**

Bold values on the diagonal represent the square roots of the average variances extracted (AVEs).

TABLE 5 Discriminant validity using heterotrait-monotrait ratio (HTMT).

Construction	SE	TE	RE	PS	SCC	SCP
SE						
TE	0.456					
RE	0.514	0.538				
PS	0.405	0.336	0.352			
SCC	0.548	0.514	0.576	0.428		
SCP	0.511	0.543	0.526	0.412	0.596	

HTMT ratios (good if < 0.90, best if < 0.85).

signifies predictive relevance, whereas a value less than or equal to zero indicates a lack of predictive relevance.

In this study, the overall model achieved a Q^2 value of 0.306, which aligns with established standards in the literature (Hair et al., 2019). A higher Q^2 value reflects stronger predictive ability. Additionally, the explained variance for the endogenous variables was as follows: supply chain collaboration (SCC, 0.456) and supply chain performance (SCP, 0.400). Table 6 presents the specific values of Q^2 and R^2, further elucidating the model's explanatory and predictive power.

The results of the PLS path analysis for the research model are illustrated in Figure 3. The analysis reveals that digital empowerment accounts for 47.0% of the variance in supply chain collaboration. Furthermore, digital empowerment and supply chain collaboration jointly explain 40.9% of the variance in supply chain performance.

In Table 7, the standardized path coefficients of the hypotheses (H1–H4) are listed. The findings indicate that structural empowerment has a significant positive effect on both supply chain collaboration (H1a; $\beta = 0.216$, $p = 0.001$) and supply chain performance (H1b; $\beta = 0.160$, $p = 0.016$), with corresponding t-values exceeding 2. Trust empowerment significantly influences supply chain collaboration (H2a; $\beta = 0.193$, $p = 0.002$) and supply chain performance (H2b; $\beta = 0.220$, $p = 0.001$), with t-values greater than 3. Resource empowerment also exerts a significant impact on supply chain collaboration (H3a; $\beta = 0.263$, $p = 0.000$) and supply chain performance (H3b; $\beta = 0.154$, $p = 0.015$), both with t-values exceeding

TABLE 6 Values for Stone-Geisser's Q^2 and adjusted R^2.

Dependent variable	Q^2	R^2 (adjusted)
SCC	0.338	0.456
SCP	0.306	0.400

2. In addition, supply chain collaboration significantly contributes to supply chain performance (H4; $\beta = 0.288$, $p = 0.000$), with a t-value above 3.

Following the procedure outlined by Preacher and Hayes (2008), the mediating role of supply chain collaboration was further assessed. The analysis confirms that supply chain collaboration significantly mediates the relationships between structural empowerment, trust empowerment, resource empowerment, and supply chain performance, thereby supporting hypotheses H5a, H5b, and H5c. The corresponding indirect effects are $\beta = 0.062$ ($p = 0.017$), $\beta = 0.056$ ($p = 0.027$), and $\beta = 0.076$ ($p = 0.008$), respectively, with all t-values greater than 2.

Moreover, the results demonstrate that policy support significantly moderates the relationships between structural empowerment and supply chain collaboration (H6a; $\beta = 0.131$, $p = 0.025$) and between resource empowerment and supply chain collaboration (H6c; $\beta = 0.160$, $p = 0.006$), with t-values exceeding 2 in both cases. However, the moderating effect of policy support between trust empowerment and supply chain collaboration is not significant (H6b; $\beta = 0.016$, $p = 0.796$), as the p-value exceeds 0.05 and the t-value is below 2. Detailed results are presented in Table 8.

5 Conclusion

5.1 Discussion

This study develops and validates a theoretical model linking digital empowerment, collaboration mechanisms, and performance improvement, using "Taobao Villages" in Zhejiang Province as the empirical context. It elucidates how digital empowerment enhances supply chain collaboration through multi-dimensional empowerment mechanisms, thereby ultimately improving the performance of rural supply chains. The findings demonstrate that collaboration mechanisms serve as key mediators in this process. Furthermore, policy support strengthens structural and resource empowerment, although its moderating effect on trust empowerment appears limited. This research contributes theoretically by the advancing understanding of how digitalization enhances rural supply chain competitiveness and sustainability. Practically, it offers valuable guidance for rural managers and policymakers in designing digital strategies, strengthening collaborative mechanisms, and optimizing resource allocation to achieve improved supply chain performance.

First, digital empowerment significantly fosters supply chain collaboration and improves rural supply chain performance, consistent with prior research (Jiang et al., 2023; Li Z. et al., 2022; Li Z. B. et al., 2022). Structural empowerment enhances information-sharing infrastructure; trust empowerment strengthens cooperative intentions; and resource empowerment improves the efficiency of factor acquisition. These mechanisms broaden upstream and downstream collaboration, providing rural enterprises with advantages in customer responsiveness, cost control, and relationship management (Zhang et al., 2023). Thus, digital empowerment enhances collaborative capabilities by reducing information asymmetry and transaction friction, ultimately leading to stable improvements in supply chain performance.

Second, supply chain collaboration plays a significant mediating role between digital empowerment and rural supply chain performance. This finding underscores that collaborative mechanisms are critical for translating digital capabilities into measurable performance outcomes, aligning with studies on e-commerce cluster models (Yue, 2022). In "Taobao Villages," digital infrastructure enables dispersed rural supply entities to establish stable collaborative networks, minimizing redundant investments and improving resource utilization. The effectiveness of these collaborative mechanisms explains why the influence of digital empowerment on performance emerges indirectly, gradually materializing through the collaborative process rather than instantaneously.

Finally, policy support significantly moderates certain empowerment pathways, though its influence on trust empowerment is limited. Results indicate that policy support strengthens structural and resource-based empowerment pathways, consistent with previous studies (Ramjaun et al., 2024). Government initiatives, including training, infrastructure investment, and policy incentives, provide exogenous capabilities for resource-constrained rural enterprises, thereby enhancing their collaborative engagement. However, trust empowerment primarily arises from long-term interactions and endogenous relationships among enterprises; consequently, policy support has only an indirect effect, and its moderating role is not significant. This suggests that the external institutional environment is more likely to influence structural and resource-based empowerment than to replace the endogenous trust-building mechanisms among rural enterprises.

5.2 Theoretical significance

This study makes several theoretical contributions to the field of rural e-commerce supply chain management (SCM). First, it addresses a significant gap in the literature by focusing on supply chain collaboration (SCC) in rural contexts, an area that has received limited scholarly attention. Existing studies often overlook the distinct characteristics and challenges of rural supply chains, particularly under the pressures of sustainable competition (Duan et al., 2022). By conducting empirical research in this setting, the study highlights the pivotal role of supply chain collaboration in rural environments and extends the applicability of SCM theory. The findings not only offer practical insights for developing countries with similar rural supply chain structures but also expose the fragmented and underdeveloped nature of SCM in these regions (Ramirez et al., 2021).

Second, this study contributes to the extension of dynamic capability theory and institutional theory by proposing an explanatory framework of "digital empowerment–synergy mechanism–performance improvement." It elucidates how the external institutional environment moderates the development of dynamic capabilities and the process of supply chain collaboration in rural enterprises through digital empowerment. Digital empowerment enhances rural enterprises' abilities to capture production data, distribute benefits more equitably, and adopt new technologies across three dimensions:

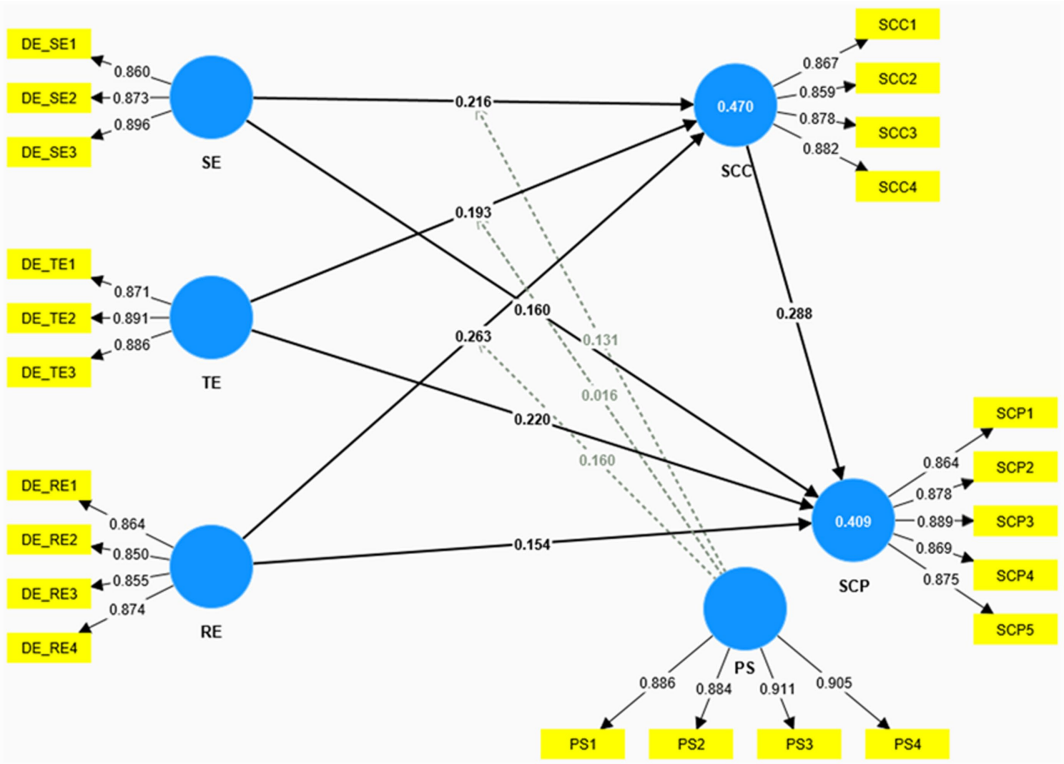


FIGURE 3
Path coefficient analysis.

TABLE 7 Direct path analysis.

Hypotheses	Path	Beta	Standard deviation	T statistics	*p* values	Decision
H1a	SE → SCC	0.216	0.067	3.242	0.001	Accepted
H1b	SE → SCP	0.160	0.066	2.417	0.016	Accepted
H2a	TE → SCC	0.193	0.063	3.089	0.002	Accepted
H2b	TE → SCP	0.220	0.065	3.367	0.001	Accepted
H3a	RE → SCC	0.263	0.065	4.050	0.000	Accepted
H3b	RE → SCP	0.154	0.064	2.426	0.015	Accepted
H4	SCC → SCP	0.288	0.082	3.513	0.000	Accepted

TABLE 8 Indirect path analysis.

Hypotheses	Path	Beta	Standard deviation	T statistics	*P* values	Decision
H5a	SE → SCC → SCP	0.062	0.026	2.383	0.017	Accepted
H5b	TE → SCC → SCP	0.056	0.025	2.216	0.027	Accepted
H5c	RE → SCC → SCP	0.076	0.028	2.672	0.008	Accepted
H6a	PS x SE → SCC	0.131	0.058	2.245	0.025	Accepted
H6b	PS x TE → SCC	0.016	0.060	0.258	0.796	Rejected
H6c	PS x RE → SCC	0.160	0.058	2.757	0.006	Accepted

structural, trust-based, and resource-based empowerment. These improvements, in turn, strengthen supply chain synergy. Additionally, policy support, as an external moderating factor, further enhances supply chain performance by facilitating the synergy enabled by digital empowerment. This theoretical framework thus provides a robust foundation for understanding how rural enterprises can build dynamic capabilities and improve supply chain collaboration in the context of digital transformation.

5.3 Practical significance

First, implications for rural enterprise managers are discussed. The findings indicate that digital empowerment significantly enhances supply chain collaboration and performance, suggesting that rural enterprises should approach digitalization as a gradual and staged strategic process rather than a one-off investment. When promoting technologies such as high-speed networks, cloud computing, the Internet of Things, and data analytics, managers should carefully assess implementation costs, infrastructure readiness, and the alignment with existing digital skills, and adopt phased implementation strategies aligned with firm size and development stage. In contexts characterized by fragmented processes and resource constraints, digital tools should not aim for comprehensive technological substitution. Instead, they should be leveraged to incrementally improve information accessibility, strengthen inter-firm collaboration, and enhance operational visibility, thereby enabling steady improvements in rural supply chain performance.

Second, implications for rural supply chain practitioners and platform operators. Given that supply chain collaboration is central to performance gains driven by digital empowerment, practitioners should proactively strengthen coordination across nodes—for example, by sharing demand information and synchronizing inventory and logistics—to reduce operational uncertainty and enhance value co-creation efficiency. Platforms, as digital ecosystem hubs, should offer low-barrier digital tools, trust-building mechanisms, and collaborative systems that enable rural stakeholders to seamlessly integrate into digital supply chains and achieve performance improvements.

Finally, implications for policymakers. The results suggest that policy support reinforces the effects of structural and resource empowerment, underscoring the critical role of the institutional environment in promoting rural digitalization. Governments should continue investing in digital and logistics infrastructure and reduce the costs of digital transformation for enterprises through subsidies, tax incentives, and targeted training programs. Simultaneously, improving data governance and security mechanisms can enhance stakeholder trust in digital platforms. A supportive policy environment can effectively alleviate resource and capability constraints for rural enterprises, thereby systematically strengthening supply chain collaboration and performance.

5.4 Limitations and future research

First, this study is based on the context of "Taobao Villages" in Zhejiang Province, China, where the digital ecosystem and policy support mechanisms exhibit distinctive local characteristics. This may limit the generalizability of the findings to other institutional and cultural contexts. In particular, the mechanisms of policy support depend on the development stage of rural supply chain digitalization and the governmental role in China. In other countries or regions, such as Southeast Asia, South Asia, or Latin America, policy design, implementation logic, and social perceptions may differ. Future research should conduct cross-contextual validation across different countries and rural digitalization models to clarify boundary conditions.

Second, this study employs cross-sectional data, which cannot capture the dynamic interactions among digital empowerment, collaboration mechanisms, and rural supply chain performance. Given the ongoing adjustments in policy environments and digital infrastructure, the pathways of influence may vary over time. Future studies could adopt longitudinal designs or multi-wave data to capture the temporal evolution of policy interventions and digital collaboration capabilities.

Finally, this research focuses on digital empowerment, collaboration mechanisms, and policy support, but does not incorporate other potential influencing factors, such as relational governance, institutional voids, organizational culture (Mei et al., 2020), leadership (Zang et al., 2023), or resource sharing (Ye et al., 2020). Structural elements of rural supply chains and socio-cultural forces, such as community norms, also shape trust and collaborative mechanisms. Future studies should integrate a broader set of institutional and organizational behavior variables to provide a more comprehensive explanation of the mechanisms underlying rural supply chain collaboration and performance.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

This study involved surveys and interviews with participants who provided informed consent. All data were anonymized and used solely for research purposes, in accordance with relevant ethical guidelines.

Author contributions

JW: Conceptualization, Investigation, Software, Writing – original draft, Writing – review & editing. ND: Data curation, Formal analysis, Methodology, Writing – review & editing. HN: Formal analysis, Project administration, Resources, Visualization, Writing – review & editing.

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Conflict of interest

ND was employed by the Qingdao Qingtie Commercial Development Co., Ltd.

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Appendix

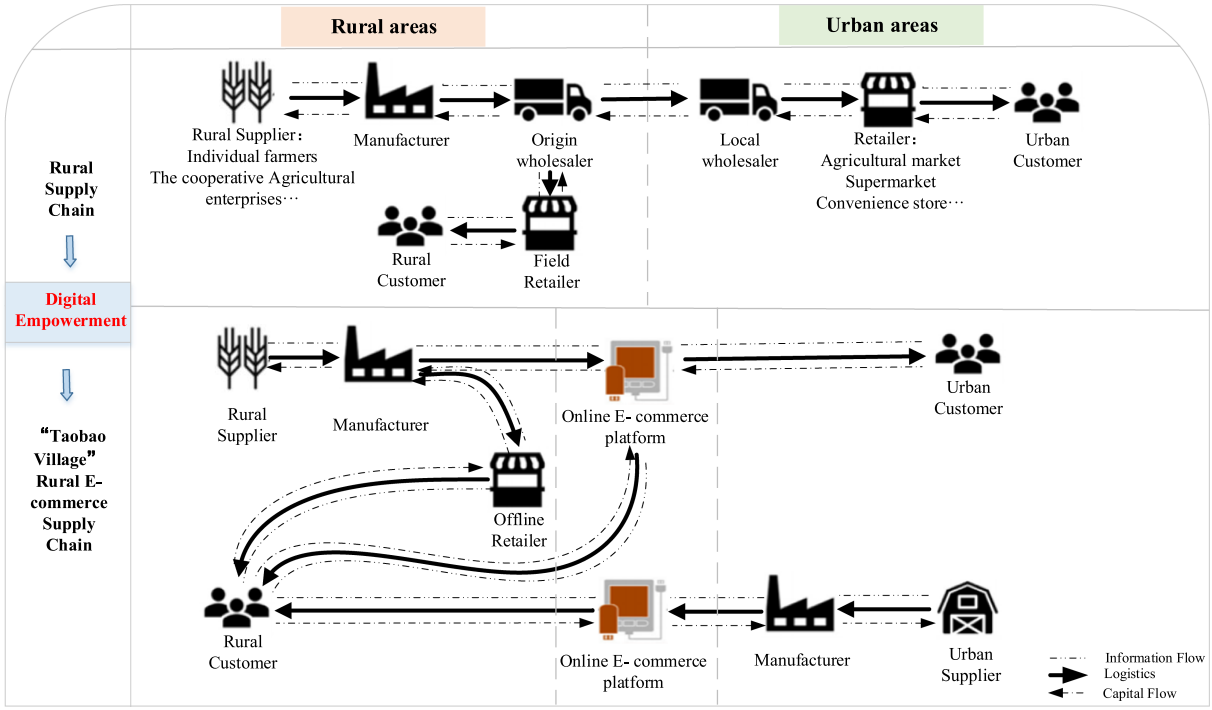


FIGURE A1
Structure of traditional rural supply chain and rural e-commerce supply chain.