



Evolution of Resilience in Cross-Border Agri-Food Supply Chains Under Institutional Friction: A Literature Review

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Abstract. In the era of "fragmented globalization," multinational enterprises face escalating trade policy uncertainties and systemic disruptions. While institutional friction—encompassing asymmetric tariff shocks, soft infrastructure bottlenecks, and digital trade barriers—affects all sectors, cross-border agri-food supply chains are uniquely vulnerable due to their high perishability and strict geographic dependencies. This paper systematically reviews the multidimensional disruption mechanisms of institutional friction and synthesizes the evolutionary paths of supply chain resilience. Moving beyond static buffering, we highlight proactive mitigation strategies, including network reconfiguration, digital empowerment via "Smart Borders," ESG integration, and strategic adaptation to Local Content Requirements (LCRs). Furthermore, we identify critical research gaps, particularly the lack of hybrid macro-micro simulation frameworks (such as GTAP-SD models) capable of translating macroeconomic policy shocks into micro-operational disruptions. This review provides a foundational theoretical framework for cross-border agri-food suppliers and policymakers to navigate a friction-heavy trade order.

Keywords: Cross-Border Trade, Agri-food Supply Chain, Institutional Friction, Evolutionary Resilience, Smart Borders

1 Introduction

In recent years, the paradigm of global trade has experienced a profound structural shift, transitioning from hyper-globalization toward what is increasingly recognized as "fragmented globalization" [1]. Escalating geopolitical tensions—coupled with the resurgence of trade protectionism, have severely disrupted the stability of global supply networks. Within this new trade order, multinational enterprises and cross-border suppliers are constantly exposed to unpredictable trade policy uncertainties (TPU) and systemic disruptions, necessitating a critical re-evaluation of supply chain resilience [2], [3].

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D. Magni et al. (eds.), *Proceedings of the 2026 3rd International Conference on Applied Economics, Management Science and Social Development (AEMSS 2026)*, Advances in Economics, Business and Management Research 389,

https://doi.org/10.2991/978-94-6239-672-2_43

Central to these disruptions is the concept of "institutional friction." Unlike traditional transportation or production costs, institutional friction encompasses both "hard" barriers, such as unilateral tariff shocks and retaliatory measures, and "soft" infrastructure bottlenecks [4]. These soft bottlenecks include legal ambiguities, inefficient customs clearance procedures, localized data flow restrictions, and increasingly prevalent Local Content Requirements (LCRs) [5], [6]. Together, these frictions act as an "implicit tax" on cross-border transactions, exacerbating transaction costs and triggering cascading vulnerabilities across the supply chain network.

While institutional friction affects various sectors, cross-border agri-food supply chains are uniquely vulnerable. Unlike the high-tech or manufacturing industries, agricultural products—notably soybeans, sorghum, and fresh produce—are highly perishable and geographically dependent [7]. This makes them acutely sensitive to time delays, particularly customs inefficiencies are particularly devastating because agri-food spoilage is not linear but follows a threshold model. A delay of 24 hours for hard grains might be manageable, but for fresh produce like cherries or berries, exceeding a 12-hour threshold at border inspection can trigger an entire shipment's quality downgrade from 'fresh' to 'processing grade,' resulting in a value loss of 50-70%. This is not merely an 'implicit tax'; it is a binary, catastrophic failure point. Moreover, agricultural commodities are frequently targeted as precise retaliatory tools during geopolitical conflicts, rendering their supply chains highly susceptible to sudden tariff hikes and bilateral trade embargoes [8]. Consequently, the ability of agri-food supply chains to absorb these institutional shocks and adaptively evolve remains a critical yet underexplored area.

This vulnerability is particularly acute in emerging transnational economic corridors—such as those traversing Central Asia along the Belt and Road Initiative (BRI). In these landlocked transit hubs, institutional frameworks are still evolving; and cross-border frictions remain pronounced, presenting a unique context for observing resilience evolution.

Despite the growing body of literature on supply chain resilience, current research predominantly focuses on the manufacturing sector and often employs static assessment models. A comprehensive understanding of the dynamic evolutionary mechanisms of resilience within the agri-food sector under institutional friction is notably lacking. To address this research gap, this paper aims to systematically review the multidimensional disruption mechanisms of institutional friction and synthesize the evolutionary paths of supply chain resilience.

2 Institutional Friction: Mechanisms of Disruption in Cross-Border Trade

Institutional friction operates not merely as a boundary barrier but as a systemic disruptor that permeates the entire cross-border supply chain network. To systematically evaluate its impact on agri-food supply chains, it is imperative to deconstruct these frictions into three distinct mechanisms: asymmetric tariff shocks, soft infrastructure bottlenecks, and digital trade barriers.

2.1 Tariff Shocks and Asymmetric Retaliatory Measures

The most explicit manifestation of institutional friction is the imposition of punitive tariffs and subsequent retaliatory measures. Recent empirical evidence from global trade conflicts demonstrates that tariff shocks generate asymmetric disruptions across supply chain echelons [9], [10]. Unlike broad macroeconomic downturns, targeted tariffs specifically distort cross-border procurement strategies, forcing enterprises to prematurely abandon cost-optimized supply networks in favor of geographically proximal but potentially sub-optimal alternatives. For agricultural commodities, which operate on notoriously thin profit margins and are highly dependent on specific climatic zones, these sudden tariff hikes not only erode thin profit margins but, more critically, exploit the supply-side rigidity of agriculture. Unlike manufactured goods, the biological lead time of crops is fixed. A tariff shock in Q3 cannot be mitigated by simply increasing Q4 production, leading to irreversible contract defaults and upstream inventory write-offs[11]. For instance, a 25% retaliatory tariff on soybeans, as witnessed in the US-China trade war, does not merely increase prices; it fundamentally severs a year-long planting, harvesting, and shipping cycle, forcing suppliers into bankruptcy before any network reconfiguration can occur. . Furthermore, retaliatory tariffs in the agricultural sector are frequently deployed as asymmetric geopolitical weapons. This strategic targeting disproportionately affects upstream producers and exporters, inducing severe demand-side volatility and forcing a reactive, often inefficient, reconfiguration of global agricultural trade flows [12].

2.2 The "Implicit Tax" of Soft Infrastructure

While tariffs represent overt barriers, a significant portion of institutional friction manifests as an "implicit tax" derived from soft infrastructure bottlenecks. This encompasses legal ambiguities, excessive regulatory compliance costs, and notably, customs inefficiencies. Studies on customs performance under trade friction indicate that administrative delays and opaque inspection protocols significantly elevate transaction costs [13], [14]. In the context of agri-food supply chains, where product perishability strictly dictates logistical timelines, these soft barriers are particularly devastating. Prolonged customs clearance and rigorous sanitary and phytosanitary (SPS) compliance checks effectively function as non-tariff barriers, accelerating product degradation and increasing spoilage rates . Consequently, the unpredictability of legal and administrative frameworks fundamentally undermines the reliability of cross-border lead times, crippling the efficiency-driven just-in-time (JIT) agricultural delivery models.

For overland agri-food trade routed through Eurasian transcontinental corridors, these soft infrastructure bottlenecks often manifest as disjointed cross-border transit protocols and localized language barriers. Such non-tariff frictions effectively negate the geographical advantages of landway transit, further necessitating an evolutionary approach to border management.

2.3 Digital Trade Barriers and Data Localization

As global trade rapidly digitalizes, a novel dimension of institutional friction has emerged: digital trade barriers and stringent data localization requirements. While digital technologies are often heralded as resilience enhancers, uncoordinated cross-border data regulations paradoxically create operational friction for multinational suppliers. Current literature suggests an "inverted U-shaped" relationship between data flow restrictions and enterprise resilience, Moderate, standardized data regulations can compel enterprises to enhance cybersecurity protocols and build consumer trust, thereby marginally improving long-term operational resilience. [8]However, excessive data localization policies and the prohibition of cross-border data transfers act as severe digital bottlenecks. For complex agri-food supply chains that increasingly rely on real-time data analytics—such as IoT-based cold chain monitoring and algorithmic demand forecasting—these digital frictions stifle technological innovation. They fragment the centralized visibility of the supply chain, forcing enterprises into a state of "digital isolation" that ultimately erodes their adaptive capacity against external shocks. [11]

3 Multidimensional Assessment of Supply Chain Resilience

The traditional paradigm of assessing supply chain resilience has heavily relied on unidimensional metrics, primarily focusing on rapid recovery or robust buffering capacity. As shown in Table 1, in the context of protracted institutional friction and the fragmented global trade environment, a multidimensional evaluation framework is required to accurately capture the structural vulnerabilities and dynamic adjustments of cross-border agri-food suppliers.

Table 1. Summary of Key Literature on Trade Friction and Supply Chain Resilience

Author(s) & Year	Core Focus / Theme	Methodology	Key Findings regarding Resilience
Kang et al. (2024)	Sino-U.S. tariff shocks & supply chain risk	Textual Analysis / Empirical	Tariff shocks create asymmetric disruptions; high-tech and low-efficiency firms face higher risks.
Banomyong et al. (2024)	Mitigating disruptions in cross-border suppliers	Quantitative Assessment	Highlights the need for supplier-centric evaluations beyond buyer-dominant views.
Covarrubias (2023)	Smart Borders and cross-border transport	Case Study Analysis	Digital automation at borders significantly reduces customs delays and enhances transit resilience.
Asuming (2023)	Geopolitical risk and ESG practices	Literature & Case Synthesis	Robust ESG integration and ecosystem synergy act as strategic buffers against geopolitical volatility. Identifies an 'inverted U-shaped' relationship between data restrictions and corporate resilience in a sample of Chinese manufacturing firms (working paper; findings require further validation in other sectoral contexts)
Yao & Zhang (2024)	Cross-border data flow restrictions	Bidirectional fixed-effects model	

3.1 The Ternary Theoretical Framework

To comprehensively assess resilience, recent scholarship has increasingly adopted a ternary theoretical framework, deconstructing the concept into three sequential dimensions: efficiency, adaptability, and evolution capability . Efficiency refers to the system's initial absorptive capacity—its ability to withstand immediate tariff shocks or customs delays without catastrophic operational failure. [9]

Adaptability reflects the short-term tactical reconfiguration, such as rerouting logistics or sourcing alternative buyers to bypass sudden trade barriers. Most critically, evolution capability denotes the long-term strategic transformation of the supply chain architecture, moving beyond mere recovery to achieve a structurally superior, friction-resistant state . This evolutionary perspective is particularly vital for agri-food supply chains, which must continuously co-evolve with shifting local content policies and geopolitical realignments.[12]

3.2 Supplier-Centric Quantitative Assessment

A significant limitation in the existing literature is the disproportionate focus on the resilience of core buying enterprises, often neglecting the upstream nodes. To rectify this, scholars have advocated for a paradigm shift toward supplier-centric quantitative assessments . By adapting the Logistics Performance Index (LPI) and integrating it with firm-level operational data, researchers can construct dedicated cross-border supplier performance indices. These tools allow for a granular evaluation of how upstream agri-food producers mitigate the "implicit taxes" of institutional friction, thereby providing a more equitable and holistic measurement of network-wide resilience rather than a purely buyer-dominant view .

3.3 Dynamic vs. Static Measurement: Leveraging Machine Learning

Furthermore, the methodological trajectory of resilience assessment is shifting from static, ex-post evaluations to dynamic, real-time measurements. Traditional econometric models often fail to capture the real-time sentiment and perceived risks associated with rapidly changing trade policies. Consequently, cutting-edge research is increasingly utilizing Natural Language Processing (NLP) techniques, such as Latent Dirichlet Allocation (LDA) and Word2Vec models, to conduct textual analysis of corporate Management Discussion and Analysis (MD&A) reports . By parsing textual data, these machine learning algorithms can quantitatively gauge the real-time fluctuations in managerial sentiment regarding institutional friction and dynamically map the enterprise's perceived resilience trajectory. [13]This methodological innovation offers unprecedented empirical granularity for assessing risk exposure in highly volatile agri-food markets.

4 Evolutionary Paths and Mitigation Strategies for Agri-Food Supply Chains

In response to the pervasive disruptions caused by institutional friction, multinational enterprises must transition from reactive buffering to proactive, evolutionary mitigation strategies. As shown in Figure 1, for cross-border agri-food supply chains, this evolutionary path manifests through network reconfiguration, technological empowerment, ecological synergy, and strategic adaptation to local policies.

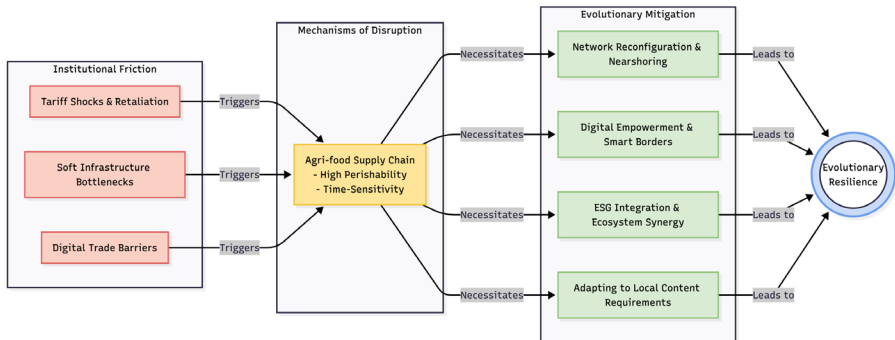


Fig. 1. Conceptual Framework of Evolutionary Resilience under Institutional Friction

4.1 Reconfiguration and Network Stickiness

A primary strategic response to escalating trade protectionism is the spatial reconfiguration of supply networks, most notably observed in the "China Plus One" strategy and the broader trend of nearshoring or friendshoring. By diversifying sourcing locations, enterprises aim to circumvent concentrated geographic risks and tariff barriers. However, existing literature emphasizes the inherent "network stickiness" that constrains rapid reconfiguration, particularly within the agri-food sector. Due to high sunk costs in localized agricultural infrastructure, long-term contract commitments, and strict climatic dependencies for crop yields, agri-food supply chains cannot be seamlessly relocated.[14] Therefore, the evolutionary path involves a delicate balance: maintaining critical upstream partnerships while incrementally building redundant capacity in secondary markets to enhance geographic agility without triggering massive capital depreciation.

4.2 Digital Empowerment and "Smart Borders"

To counteract the "implicit tax" of soft infrastructure bottlenecks and customs inefficiencies, digital empowerment serves as a critical evolutionary buffer. The integration of cutting-edge technologies—such as Artificial Intelligence (AI) for demand forecasting, Logistechs for dynamic routing, and Legal Tech for automated compliance—significantly reduces institutional distance. In cross-border agricultural trade, where

time-to-market is paramount, the implementation of blockchain-enabled "Smart Borders" offers transformative potential. [15]By creating immutable, shared ledgers for phytosanitary certificates and customs declarations, these digital solutions mitigate information asymmetry, accelerate clearance processes, and directly reduce the spoilage rates of perishable goods. Thus, digital adoption transcends operational efficiency; it becomes a fundamental mechanism for structural resilience against bureaucratic friction. Empirical cases in Eurasian corridors suggest that digitizing SPS certificates can significantly reduce border holding times. This acceleration is critical for perishable goods, as even marginal reductions in delay can lower the probability of crossing the spoilage threshold, thereby directly contributing to minimizing food loss [15].

4.3 Ecosystem Synergy and ESG Integration

Beyond technological and spatial adjustments, resilience evolution necessitates a paradigm shift towards ecosystem synergy, underpinned by Environmental, Social, and Governance (ESG) principles.[16] Empirical studies suggest that robust ESG integration acts as a strategic buffer against geopolitical volatility. For instance, investments in sustainable agricultural practices and energy independence reduce vulnerability to energy price shocks commonly associated with global trade conflicts. Furthermore, fostering cross-border trust and collaborative planning among stakeholders—including governments, logistics providers, and local farmers—creates a cohesive ecosystem. This collaborative synergy ensures that when institutional shocks occur, the burden is distributed across the network rather than disproportionately crushing vulnerable upstream suppliers.

4.4 Adapting to Local Content Requirements (LCRs)

Finally, the paradigm of navigating fragmented globalization requires a strategic pivot in how enterprises perceive protectionist policies. Rather than viewing Local Content Requirements (LCRs) purely as restrictive barriers, resilient supply chains adapt by transforming these mandates into avenues for regional integration and domestic capacity building. By actively investing in localized processing facilities and transferring technological know-how to local agricultural communities, multinational enterprises can align their operational goals with host-country industrial policies. This proactive compliance can secure market access and foster deeper regional integration. However, this strategic pivot must be balanced against the 'network stickiness' discussed in Section 4.1. While deep localization may insulate the supply chain from cross-border frictions, it could simultaneously reduce the firm's agility to exit or reconfigure in response to future, unforeseen shocks in the host country itself. The resilience-enhancing effect of LCR adaptation is therefore contingent and requires careful calibration; it transforms one set of frictions but potentially creates new sources of rigidity.

5 Identifying the Research Gaps

While existing literature provides a foundational understanding of supply chain resilience, the specific intersection of institutional friction and cross-border agri-food networks reveals significant research voids. Identifying these gaps is crucial for advancing both theoretical paradigms and practical mitigation strategies.

5.1 Sectoral Imbalance and Agricultural Perishability

Current empirical studies on supply chain resilience exhibit a pronounced sectoral imbalance, predominantly focusing on high-tech, automotive, and general manufacturing industries. These sectors, while economically vital, do not possess the strict geographic dependencies and biological perishability inherent to the agri-food sector. The unique vulnerabilities of agricultural commodities—such as their susceptibility to spoilage during prolonged customs delays and their frequent use as targeted retaliatory tools in geopolitical conflicts—remain underexplored. There is a critical need for sector-specific empirical research that quantifies the impact of institutional friction on agricultural food loss. Future research should therefore move beyond a generalized notion of 'perishability' and develop a contingency framework that maps the interaction between specific types of institutional friction (e.g., tariff volatility vs. procedural delays) and commodity-specific spoilage thresholds (e.g., grain storage life vs. fresh produce transit time). This would allow for a predictive, rather than merely descriptive, understanding of agri-food vulnerability.

5.2 Methodological Limitations: The Need for Dynamic Simulation

Methodologically, the majority of existing literature relies on static econometric models... There is a conspicuous absence of dynamic simulation approaches capable of capturing the recursive feedback between macro-level policy shocks and micro-level operational decisions. Bridging this gap is non-trivial. Macro models like GTAP (Global Trade Analysis Project) are designed for comparative-static, economy-wide analysis and lack firm-level decision rules, while micro-level models often cannot account for economy-wide price feedbacks.

A promising, albeit complex, avenue for future research lies in sequential or hierarchical modeling. One approach could involve using a multi-regional input-output (MRIO) table, disaggregated for the agri-food sector, to map the direct and indirect propagation pathways of a specific tariff shock. The output of this macro-level analysis—such as changes in bilateral trade costs or sectoral demand—could then be used as exogenous 'stress test' inputs into a discrete-event simulation or System Dynamics (SD) model of a representative agri-food supply chain. This would allow researchers to translate a policy announcement (e.g., a 15% tariff) into simulated micro-outcomes: increased inventory holding times, cascading delays, and ultimately, spoilage rates. Such a macro-to-micro simulation framework would provide the empirical granularity

currently missing in the literature, moving beyond post-hoc evaluation towards predictive vulnerability mapping.

5.3 The Intersection of Digital Adoption and Customs Friction

Furthermore, while the theoretical benefits of digital technologies (AI, blockchain) in enhancing resilience are widely acknowledged, empirical studies lack granularity regarding their application at the border. Specifically, there is a lack of quantitative research measuring exactly how the adoption of specific digital tools (e.g., "Smart Borders") substantially mitigates customs-induced friction and translates into measurable reductions in agricultural spoilage rates.

6 Conclusion

6.1 Synthesis of Key Findings

The transition toward fragmented globalization has fundamentally altered the operational landscape for multinational enterprises. This review synthesizes the multifaceted mechanisms of institutional friction—ranging from asymmetric tariff shocks to the "implicit tax" of soft infrastructure and digital barriers. We demonstrate that for cross-border agri-food supply chains, resilience is not merely a static capacity for recovery, but an ongoing evolutionary trajectory. This trajectory demands a strategic shift from passive absorption to active network reconfiguration, digital empowerment, and ecosystem synergy.

6.2 Managerial Implications

For cross-border agri-food suppliers and policymakers, the implications are profound. Strategically, enterprises must move beyond purely cost-driven procurement toward resilience-driven network designs, strategically balancing "network stickiness" with nearshoring agility. Furthermore, managers should reframe Local Content Requirements (LCRs) not merely as compliance burdens, but as opportunities for deeper regional integration. Policymakers, conversely, must recognize that excessive soft infrastructure bottlenecks act as a hidden tariff that disproportionately harms agricultural food security, necessitating the accelerated deployment of transparent, digitalized customs protocols.

6.3 Future Research Directions

Future research must transcend static, buyer-centric evaluations. It is imperative to develop dynamic, supplier-centric assessment frameworks tailored to the biological and logistical realities of the agri-food sector. Specifically, the integration of System Dynamics (SD) and multi-regional economic models to simulate complex policy shocks will provide critical foresight, equipping both enterprises and governments

with the analytical tools necessary to navigate the uncertainties of a new, friction-heavy trade order.

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