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Institutional Frictions and Supply Chain Resilience: Evidence from the Sino-Kazakhstan Agri-Food Corridor

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Abstract
Cross-border agri-food supply chains are increasingly facing institutional uncertainty, logistical constraints, and geopolitical disruptions, which increases the importance of supply chain sustainability for the stable development of international trade. This study aims to assess how perceived institutional and spatial frictions influence supply chain resilience in the Sino-Kazakhstan agri-food corridor, with particular attention to the mediating roles of relational governance and trust, and flexible strategies. The study uses a quantitative approach based on partial least squares (PLS-SEM) structural equation modeling. The empirical basis was based on data from a survey of 100 specialists involved in cross-border agri-food trade between China and Kazakhstan. The results showed that perceived institutional and spatial barriers have a strong positive impact on relational governance and trust (β = 0.502; t = 6.223; p < 0.001), while their direct impact on flexible strategies is not statistically significant at the 5% level (β = 0.197; t = 1.782; p = 0.075). Mediation analysis confirmed that relational governance and trust significantly mediate the relationship between institutional barriers and supply chain sustainability (β = 0.207; t = 3.978; p < 0.001), whereas the mediating effect of flexible strategies was not confirmed (β = 0.111; t = 1.705; p = 0.088). The findings show that, in the context of cross-border institutional barriers, relational governance is a key mechanism for ensuring sustainability, especially for resource-constrained companies operating in transition economies.

KEYWORDS
Cross-Border Economy, Agri-Food Trade, Supply Chain Resilience, Agribusiness, Logistics, Transport Corridor, Middle Corridor, China, Kazakhstan

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1 | INTRODUCTION

The global agri-food supply chain has faced unprecedented disruptions in recent years, characterized by compounding geopolitical tensions, climate-induced shocks, and institutional volatilities. Within this macro-environmental turbulence, the cross-border trade corridor between China and Kazakhstan has emerged as a critical node in the Belt and Road Initiative (hereinafter – BRI). As Kazakhstan remains China's largest trading partner in Central Asia, the agricultural sector, encompassing grains, oilseeds, and meat, has become a cornerstone of bilateral economic cooperation (Yerniyazova, 2024). However, the narrative of "hard connectivity" driven by massive physical infrastructure investments often masks the pervasive "soft frictions" inherent in cross-border logistics. Agri-food products are inherently time-sensitive and perishable, making them exceptionally vulnerable to transit delays and coordination failures.

Practitioners operating in this corridor frequently encounter a dual challenge conceptualized as Perceived Institutional and Spatial Frictions (hereinafter – PIF). Spatial frictions manifest physically, most notably through the railway gauge differences at key border gateways such as Dostyk-Alashankou and Altynkol-Khorgos. This technical incompatibility necessitates time-consuming cargo transshipment, creating structural bottlenecks (Tjia, 2022). Concurrently, institutional frictions exacerbate these physical delays. Kazakhstan, as a transition economy, is often characterized by "institutional voids" instances where formal regulatory frameworks are either absent or inefficiently implemented (Tjia, 2022). Beyond the historical railway gauge break, practitioners in 2026 now face evolving frictions, including tightening Sanitary and Phytosanitary (SPS) protocols and the geopolitical complexities of the Middle Corridor's development. While physical transshipment times at Khorgos have been reduced through dual-gauge automation, the administrative hurdles, especially opaque certification requirements for meat and dairy, remain a dominant source of institutional friction (Yerniyazova, 2024; ADB, 2023).

Despite the growing body of literature on Supply Chain Resilience (hereinafter – SCR), traditional supply chain risk management paradigms predominantly focus on mature market economies equipped with robust legal frameworks. There remains a profound theoretical gap regarding how enterprises, particularly small and medium-sized enterprises (hereinafter – SMEs), navigate profound institutional voids in transition economies. Under high-friction conditions, formal contractual governance often proves inadequate; contracts are costly to draft, rigid to adapt, and exceedingly difficult to enforce across cross-border jurisdictions (Eckerd et al., 2021). Consequently, firms are compelled to rely on alternative, informal mechanisms. Drawing upon social exchange theory and new institutional economics, this study emphasizes the role of "soft governance" specifically Relational Governance and Trust (hereinafter – RGT). In environments where legal enforceability is weak, trust and relational norms serve as vital lubricants, enabling flexible renegotiations and collaborative problem-solving during sudden border disruptions (Chen & Lewis, 2024; Zhang et al., 2024).

In parallel with relational mechanisms, the literature emphasizes "hard" flexible

strategies, such as maintaining pre-positioned inventory in overseas warehouses or securing multimodal transport options, as buffers against spatial delays (Lücker et al., 2024). However, deploying such asset-heavy forms of structural flexibility requires substantial capital investment and predictable policy horizons. It remains empirically unclear whether cross-border frictions alone are sufficient to induce firms to adopt these costly FS, or whether resource constraints lead practitioners to rely more heavily on relational capital.

Despite the growing body of research on supply chain resilience, three specific gaps remain inadequately addressed in the extant literature. First, many SCR studies are anchored in mature market economies equipped with robust legal and institutional frameworks, leaving the governance dynamics of transition economies, particularly in Central Asia, largely underexplored. Second, the theoretical debate on whether relational governance and FS function as substitutes or complements remains empirically unresolved, especially under conditions of severe institutional and spatial friction. Third, the boundary conditions governing the deployment of FS, particularly the constraining role of firm-level resource capabilities among SMEs, have not been empirically validated in the context of high-friction cross-border corridors. The present study is designed to address these three interrelated gaps.

This study aims to assess how perceived institutional and spatial frictions influence supply chain resilience in the Sino-Kazakhstan agri-food corridor, with particular attention to the mediating roles of relational governance and trust, and flexible strategies (hereinafter – FS). To achieve this aim, the study develops a conceptual model that examines the interplay among institutional and spatial frictions, governance choices, and supply chain resilience. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) on a sample of 100 cross-border trade practitioners, this research offers three distinct contributions. First, it empirically validates the substitution effect of soft governance in the presence of formal institutional voids within the Central Asian context. Second, it uncovers the boundary conditions of FS, highlighting the resource-capability gap that hinders their immediate deployment. Finally, it provides actionable managerial insights for agribusinesses striving to build robust supply chains across high-friction geopolitical corridors.

2 | LITERATURE REVIEW

The theoretical foundation of this study rests on Transaction Cost Economics (hereinafter – TCE), which posits that high asset specificity coupled with environmental uncertainty compels firms to deploy structural safeguards to minimize exchange hazards (Williamson, 1985). In cross-border agri-food trade, the inherent perishability of agricultural products constitutes a form of high asset specificity, making supply chains particularly vulnerable to institutional and spatial frictions. Building on TCE, the concept of "institutional voids" characterized by the absence of specialized intermediaries, regulatory uncertainties, and weak legal enforcement, has emerged as a critical framework for understanding how formal institutional fail-

ures amplify transaction costs in emerging economies (Eckerd et al., 2021). Recent studies also emphasize the importance of resilience in global food value chains under systemic disruptions (Ali et al., 2022). These foundational perspectives establish the theoretical basis for examining how firms respond to compounding frictions in transition economies such as Kazakhstan.

As institutional void theory evolved, scholars increasingly recognized that traditional TCE prescriptions relating to formal contracts and structural safeguards are insufficient in the face of severe institutional instability. FS is closely related to the broader concept of supply chain agility, which reflects a firm's ability to rapidly adjust its logistics and operational processes (Swafford et al., 2006). For many SMEs, establishing asset-heavy FS such as redundant inventory, pre-positioned overseas warehousing, or multi-modal transport options requires substantial, often irreversible capital investments (Wissuwa et al., 2022; Niu et al., 2025). This recognition gave rise to the concept of SCR, defined as a firm's capacity to absorb disruptions and restore operational performance (Ambulkar et al., 2015). In parallel, scholars developed the notion of RGT as an alternative governance mechanism: non-contractual mechanisms rooted in social norms, solidarity, and inter-organizational trust that enable firms to navigate institutional voids without costly formal enforcement (Wu et al., 2023). In highly volatile institutional settings, resource constraints may impose a critical boundary condition on TCE. The mere presence of friction is therefore insufficient to automatically trigger structural flexibility, while the risk of "asset lock-in" may force capability-constrained SMEs toward relational alternatives.

Recent empirical studies have substantially advanced the understanding of how governance mechanisms shape supply chain resilience under uncertainty. Drawing upon social exchange theory, Chen and Lewis (2024) and Wang et al. (2025) demonstrate that trust serves as a crucial "lubricant" that minimizes costly monitoring and curtails opportunistic behavior in buyer-supplier relationships. Instead of rigid adherence to formal contractual penalties, relational norms allow for flexible, joint problem-solving when disruptions occur. Prior research also shows that perceived justice in buyer–supplier relationships plays an important role in improving relationship performance, particularly in maintaining cooperation under uncertain supply chain conditions (Liu et al., 2012). Wu et al. (2023) further confirm that cross-organizational governance significantly enhances SCR through both mediating and moderating pathways. Food-system resilience has also been linked to broader supply chain risk governance in critical infrastructure sectors (Norrman & Eriksson Ahre, 2024). Regarding FS, Lücker et al. (2024) establish the immense value of dual-purpose flexible resources in disruption mitigation, while Iftikhar et al. (2025) highlight the synergistic role of network capability and innovation ambidexterity in firms' strategic responses to geopolitical uncertainty. Collectively, this body of research confirms that both relational and structural mechanisms contribute to resilience. Nevertheless, their relative effectiveness remains contingent on firm-level resource capabilities, a boundary condition that has not been empirically validated in the Central Asian context.

In the Sino-Kazakhstan corridor specifically, these theoretical dynamics are compounded by distinctive spatial constraints. Although infrastructure at the Altynkol-Khorgos gateway has undergone significant modernization as of 2025, reducing physical delays, the "soft frictions" related to inter-governmental regulatory alignment continue to plague agri-food trade (Pomfret, 2019; Tjia, 2022). Yerniyazova (2024) documents how institutional voids and administrative opacity at key border crossings—including unpredictable SPS protocol enforcement and opaque certification requirements for meat and dairy function as de facto non-tariff barriers despite infrastructure improvements. The ADB (2023) further highlights that regulatory alignment within the CAREC corridor remains a persistent bottleneck. Tjia (2022) additionally notes that Kazakhstan's leverage in cross-border logistics reflects broader geopolitical dynamics that shape the institutional environment for Chinese agribusinesses.

Synthesizing this literature, it becomes evident that while friction universally threatens supply chain resilience, the mitigation pathways are highly contingent on both firm capabilities and regional institutional conditions. To bridge the gap between TCE predictions and the resource-constrained realities of this corridor, this study proposes a comprehensive model that illustrates how perceived frictions drive governance choices, differentiating between relational governance and FS, which, in turn, shape supply chain resilience.

3 | RESEARCH METHODS

Based on the literature reviewed above, this study proposes a conceptual framework that links perceived institutional and spatial frictions to RGT, FS, and SCR. The model suggests that perceived frictions can affect supply chain resilience both directly through firms' adaptive responses and indirectly through two coping mechanisms: RGT and FS. Accordingly, the conceptual framework and the corresponding hypotheses are presented in Figure 1.

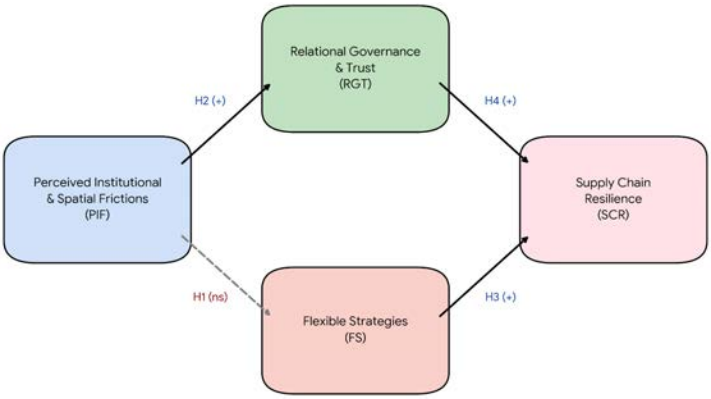


Figure 1. Conceptual framework and hypotheses

The scheme illustrates how PIF drives two coping mechanisms, RGT and

FS, which subsequently determine SCR. This study adopts a quantitative, cross-sectional research design and utilizes Partial Least Squares Structural Equation Modeling (PLS-SEM). Empirical data were collected through a targeted field survey administered to practitioners actively engaged in the Sino-Kazakhstan agri-food trade. A purposive sampling technique yielded 100 valid responses. To rigorously justify the sample size adequacy, a priori power analysis was conducted using G*Power 3.1.9.7. Based on a medium effect size ($f^2 = 0.15$), an alpha level of 0.05, and a maximum of two predictors pointing to any endogenous construct (PIF and RGT pointing to SCR), the analysis indicated that a minimum sample size of 68 is required to achieve a statistical power of 0.80. Thus, our sample size of 100 exceeds the necessary threshold, ensuring robust statistical power for the structural model evaluation.

Respondents were identified through a combination of purposive and snowball sampling strategies. Initial contacts were established via the Kazakhstan Chamber of Commerce, agribusiness trade associations operating in Almaty, and Chinese logistics company networks active in the Dostyk-Alashankou and Altynkol-Khorgos corridors. Eligibility criteria required that respondents be actively engaged in Sino-Kazakhstan cross-border agri-food trade for at least 12 months and hold decision-making or operational roles within their organizations. To ensure linguistic accessibility and minimize translation-induced response bias, the survey instrument was administered in both Mandarin Chinese and Russian.

The questionnaire comprised two sections. The first section captured respondents' demographic profiles, including firm size, job position, years of experience in cross-border trade, and primary product category. The second section contained 12 measurement items distributed across four latent constructs, all anchored on a seven-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). Prior to full deployment, the questionnaire was pilot tested with 10 experienced practitioners; minor wording adjustments were made to improve clarity, and no items were removed following the pilot. To ensure measurement reliability, the survey instruments were adapted from established scales in the supply chain literature (detailed in Appendix 1).

Items for PIF and RGT were adapted from validated scales by Yerniyazova (2024) and Wu et al. (2023), respectively. Scales for FS and SCR were derived from Piprani et al. (2022) and Iftikhar et al. (2025). To rigorously assess the potential for Common Method Bias (CMB) in our self-reported data, we eschewed the outdated Harman's single-factor test. Instead, we employed the full collinearity assessment approach recommended by Kock (2015). In this procedure, all constructs were regressed on a common random variable to compute construct-level variance inflation factors (VIFs). The resulting full-collinearity VIFs for all latent variables were well below the 3.3 threshold (ranging from 1.105 to 2.411), providing robust evidence that common method bias is not a concern in this dataset.

The conceptual model was estimated to be using PLS-SEM in SmartPLS 4 (Ringle et al., 2022). PLS-SEM was strategically selected due to its superior capability in evaluating complex models with non-normal data and its primary objective

of maximizing the explained variance (R^2) and predictive relevance (Q^2) of the following core equations. Let ξ_1 denote the exogenous construct (PIF), η_1, η_2, η_3 the endogenous constructs (RGT, FS, SCR respectively), β the standardized path coefficients, and ζ the residual error terms.

The structural model specifies PIF as the exogenous construct and RGT, FS, and SCR as endogenous constructs. PIF is modeled as an antecedent of both RGT and FS, while RGT and FS are modeled as predictors of SCR. This specification allows the study to test both the direct effects of perceived frictions on coping mechanisms and the indirect effects of PIF on SCR through RGT and FS.

4 | RESULTS

This section presents empirical research results based on data from a survey of 100 specialists involved in cross-border agri-food trade between China and Kazakhstan. The analysis of the results is structured sequentially: first, the demographic profile of the respondents is considered; then, the reliability and validity of the measurement model are assessed; and finally, the structural model and research hypotheses are tested. This procedure allows us to first confirm the relevance of the sample and the quality of the measurement scales used, and then interpret the causal relationships among institutional and spatial barriers, relational governance, flexible strategies, and the sustainability of supply chains. Table 1 presents the demographic profile of the 100 surveyed practitioners.

Table 1. Demographic profile of the sample

Variable	Category	Frequency (n)	Percentage (%)
Position	CEO/GM	20	20
	Logistics Manager	43	43
	Trade Specialist	32	32
	Other	5	5
Firm Size (Employees)	<50	18	18
	51 – 200	38	38
	201 – 500	23	23
	>500	21	21
Years in Trade (China-Kazakhstan)	1 – 3 years	14	14
	4 – 7 years	37	37
	8 – 10 years	33	33
	>10 years	16	16
Primary Product Category	Grains/Oilseeds	23	23
	Meat/Dairy	28	28
	Fruits/Vegetables	35	35
	Processed Food	14	14

Note: compiled by the authors

The structure of respondents by position shows that the majority of the sample consists of specialists directly involved in managerial and operational decision-making. Thus, operational and strategic decision-makers dominate the sample, with Logistics Managers (43.0%) and Trade Specialists (32.0%) jointly accounting for three quarters of respondents. SMEs with fewer than 200 employees account for 56.0% of firms, and 86.0% of respondents report more than 3 years of experience

in China–Kazakhstan trade, confirming the sample's relevance to the cross-border agri-food context.

Figure 2 visualizes the demographic distribution of the sample across the four profiling dimensions.

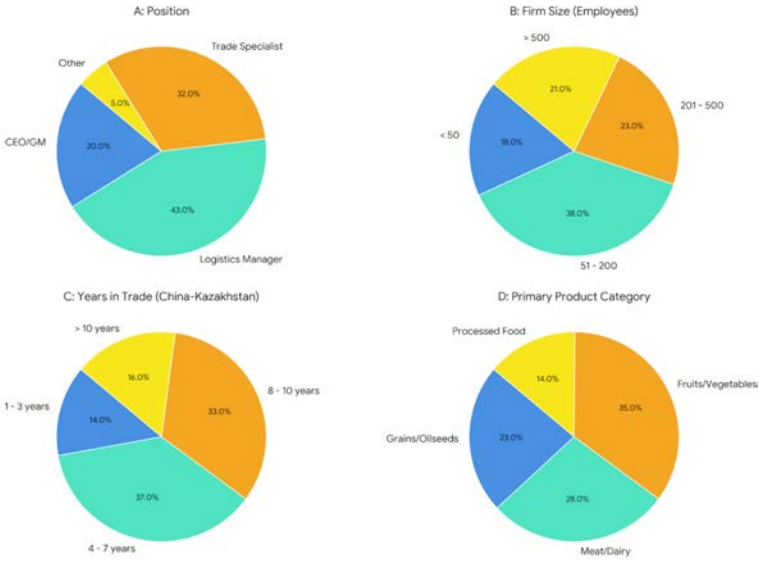


Figure 2. Demographic profile of the sample

As illustrated in Figure 2, panels A–D depict the distribution of respondents by position (A), firm size (B), years in trade (C), and primary product category (D). The product mix is well balanced across Fruits/Vegetables (35.0%), Meat/Dairy (28.0%), and Grains/Oilseeds (23.0%), reflecting the diversity of agri-food flows along the corridor. As can be seen from Chart A, the largest share in the sample is made up of logistics managers – 43.0%, followed by trade specialists – 32.0%, company executives and general managers – 20.0%, and other categories – 5.0%. This confirms that the majority of survey participants are directly involved in operational and management processes within cross-border supply chains.

Following the demographic overview, the data analysis evaluated the measurement model using PLS-SEM in SmartPLS 4. The assessment focused on internal consistency, reliability, and convergent validity, strictly adhering to the rigorous guidelines proposed by Hair et al. (2019). Internal consistency reliability was robustly established; the Cronbach's alpha and Composite Reliability (CR) values for all constructs, PIF, RGT, FS, and SCR, exceeded the recommended threshold of 0.70. The results of the measurement model assessment are presented in Table 2.

The obtained factor loadings range from 0.929 to 0.960, exceeding the recommended threshold of 0.708 and confirming the high consistency of the indicators with their corresponding latent variables. Cronbach's Alpha values also exceed the

minimum allowable level of 0.70: for PIF, the indicator was 0.934; for RGT, 0.944; for FS, 0.950; for SCR, 0.934. This indicates a high internal consistency of the scales used. CR for all designs is also at a high level: PIF – 0.958, RGT – 0.964, FS – 0.968, SCR – 0.958. Therefore, the results confirm the reliability of the measuring model. In addition, because all factor loads significantly exceed the standard value, the measuring scales have convergent validity.

Table 2. Measurement model reliability and validity

Construct	Item	Loadings	Cronbach's Alpha	CR
PIF	PIF1	0.955	0.934	0.958
	PIF2	0.934		
	PIF3	0.93		
RGT	RGT1	0.95	0.944	0.964
	RGT2	0.946		
	RGT3	0.949		
FS	FS1	0.942	0.95	0.968
	FS2	0.958		
	FS3	0.96		
SCR	SCR1	0.929	0.934	0.958
	SCR2	0.949		
	SCR3	0.941		

CR = Composite Reliability; AVE = Average Variance Extracted. All indicator loadings are significant at $p<0.001$

Note: Compiled by the authors based on SmartPLS 4 output.

Discriminant validity was subsequently assessed using two distinct approaches to ensure that the constructs are empirically distinct. The discriminant validity of the constructs was assessed using the Fornell–Larcker criterion, and the results are reported in Table 3.

Table 3. Discriminant Validity (Fornell-Larcker criterion)

Construct	**PIF**	**RGT**	**FS**	**SCR**
PIF	0.940	–	–	–
RGT	0.502	0.948	–	–
FS	0.197	0.016	0.953	–
SCR	0.409	0.421	0.571	0.940

The bold diagonal elements represent the square root of the AVE for each construct.
Off-diagonal elements represent inter-constructed correlations.
Discriminant validity is established as diagonal values exceed the respective inter-constructed correlations (Fornell-Larcker criterion).

Note: compiled by the authors based on SmartPLS 4 output.

The results confirm that this condition is met for all constructs. The diagonal values are 0.940 for PIF, 0.948 for RGT, 0.953 for FS, and 0.940 for SCR. These indicators are higher than all inter-structural correlations. For example, the correlations between PIF and RGT are 0.502, between FS and SCR are -0.571, and between RGT and SCR are -0.421, all lower than the corresponding diagonal values. The highest correlation is observed between FS and SCR (0.571), but it does not exceed the square root of AVE for either construct.

Thus, the results, as assessed by the Fornell–Larcker criterion, confirm the

discriminant validity of the measurement model. To further validate discriminant validity, the Heterotrait-Monotrait (HTMT) ratio of correlations was additionally assessed following the recommendation of Henseler et al. (2015). The HTMT values among the latent constructs are presented in Table 4.

Table 4. Discriminant validity (HTMT Ratio)

Construct	PIF	RGT	FS	SCR
PIF	–	–	–	–
RGT	0.536	–	–	–
FS	0.207	0.055	–	–
SCR	0.435	0.448	0.603	–

HTMT = Heterotrait - Monotrait Ratio of Correlations.
All values are below the conservative threshold of 0.85, establishing robust discriminant validity.

Note: compiled by the authors based on SmartPLS 4 output.

All values were significantly below the conservative threshold of 0.850, with the highest value being 0.603 between FS and SCR, further confirming discriminant validity. The HTMT values obtained range from 0.055 to 0.603, which are significantly lower than the conservative threshold of 0.85. The minimum value is fixed at 0.055 between RGT and FS, indicating their high empirical distinctness. The maximum value is observed between FS and SCR – 0.603, but it also does not exceed the acceptable level. The HTMT values are 0.536 between PIF and RGT, 0.207 between PIF and FS, 0.435 between PIF and SCR, and 0.448 between RGT and SCR.

Thus, the results of the HTMT analysis confirm the discriminant validity of the measurement model. Prior to transitioning to the structural model evaluation, collinearity was examined. The collinearity assessment results are presented in Table 5.

Table 5. Collinearity statistics (Inner VIF Values)

Construct	**RGT**	**FS**	**SCR**
PIF	1.000	1.000	–
RGT	–	–	1.000
FS	–	–	1.000
SCR	–	–	–

Note: compiled by the authors based on SmartPLS 4 output.

All inner VIF values were exactly 1.000, well below the critical threshold of 3.3, thereby confirming the absence of multicollinearity among the predictor constructs. Since PIF acts as a predictor for RGT and FS, the VIF values for these relationships are 1.000. In turn, RGT and FS are predictors of SCR, and their VIF values are also 1.000. All the values obtained are significantly below the critical threshold of 3.3, indicating no multicollinearity in the structural model. Therefore, the estimation of the coefficients of the paths can be carried out without the risk of distortion of the results due to the high correlation between the predictors.

With the measurement model's reliability and validity fully confirmed, the structural model was evaluated using a non-parametric bootstrapping procedure

with 5,000 subsamples to generate robust standard errors, t-statistics, and p-values. To assess the model's overall fit, the Standardized Root Mean Square Residual (SRMR) was calculated (Figure 3).

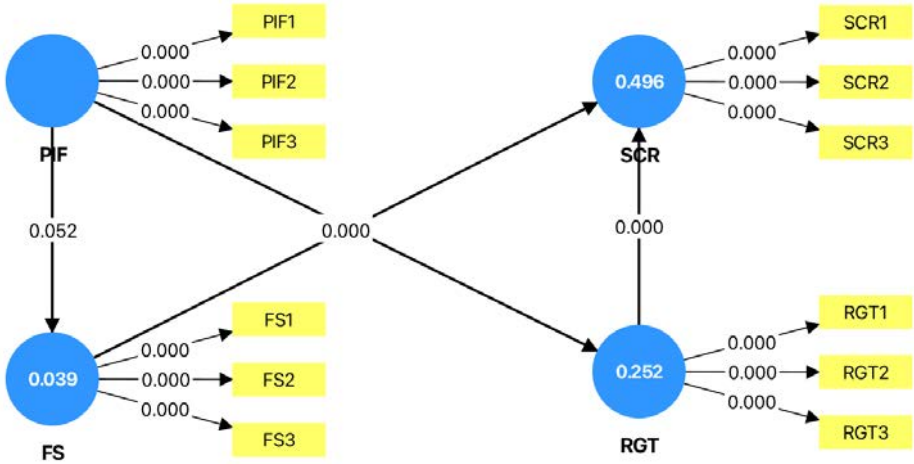


Figure 3. Structural model results

According to Figure 3, the resulting SRMR was 0.058, well below the conservative threshold of 0.08, indicating an acceptable model fit. The predictive power was evaluated using the coefficient of determination (R^2). The model explains 49.6% of the variation in SCR, indicating high explanatory power. For RGT, the R^2 value is 0.252, indicating that PIF explains 25.2% of the variance in this construct. For FS, the R^2 value is 0.039, which indicates a weak explanatory power of the PIF in relation to this mechanism.

The structural model results and hypothesis testing outcomes are detailed in Table 6, which now includes the f^2 effect sizes to assess the magnitude of each path.

As shown in Table 6, the model explains 49.6% of the variance in SCR, 25.2% in RGT, and 3.9% in FS. Furthermore, the predictive relevance was assessed using the Stone-Geisser Q^2 value via a blindfolding procedure (omission distance D = 7). All Q^2 values for the endogenous constructs were strictly above zero (SCR: 0.345; RGT: 0.218; FS: 0.021), confirming the model's robust predictive relevance.

Regarding the direct effects, the analysis reveals that PIF exerts a strong and highly significant positive effect on RGT (β = 0.502, t = 6.223, p < 0.001), firmly supporting Hypothesis 2. However, the direct path from PIF to FS (H1) was found to be marginally non-significant at the conventional 0.05 level (β = 0.197, t = 1.782, p = 0.075), leading to the rejection of Hypothesis 1. This crucial finding suggests that the presence of cross-border frictions alone does not necessarily trigger the immediate deployment of costly FS in this specific context. Furthermore, both coping mechanisms demonstrated significant impacts on the ultimate performance

outcome. FS strongly enhances SCR (β = 0.565, t = 6.647, p < 0.001), as does Relational Governance & Trust (β = 0.412, t = 5.305, p < 0.001), fully supporting both H3 and H4.

Table 6. Structural model assessment and hypothesis testing

Hypothesis	β	T Statistics (|O/STDEV|)	P Values	f^2	Conclusion
Direct Effects					
H1: PIF → FS	0.197	1.782	0.075	0.041	Not supported*
H2: PIF → RGT	0.502	6.223	0.000*	0.337	Supported
H3: FS → SCR	0.565	6.647	0.000*	0.450	Supported
H4: RGT → SCR	0.412	5.305	0.000*	0.240	Supported
Specific Indirect Effects					
H5: PIF → FS → SCR	0.111	1.705	0.088	N/A	Not supported*
H6: PIF → RGT → SCR	0.207	3.978	0.000*	N/A	Supported

Note: compiled by the authors based on SmartPLS 4 output.

Finally, in terms of the specific indirect effects (mediation analysis), the pathway exploring whether RGT mediates the relationship between PIF and SCR (H6) was highly significant (β = 0.207, t = 3.978, p < 0.001). Conversely, the mediation path through FS (H5) was not statistically supported (β = 0.111, t = 1.705, p = 0.088). These structural findings highlight the predominant role of informal relational governance over rigid structural flexibility when enterprises navigate institutional and spatial frictions in the Sino-Kazakhstan agricultural supply chain.

To further validate the "resource constraint" hypothesis, a post-hoc Multi-Group Analysis (MGA) was conducted using the permutation-based MGA algorithm in SmartPLS 4 with 5,000 permutations (Hair et al., 2019) to assess the moderating role of firm size. The sample was divided into SMEs (n=56) and LEs (n=44). Strikingly, the results revealed a significant group difference ($\Delta\beta$ = 0.284, p < 0.05). For large enterprises, the path from PIF to FS was significant (β = 0.385, p < 0.05), whereas for SMEs, it remained non-significant (β = 0.102, p > 0.10). This statistical evidence confirms that structural flexibility is a capital-contingent strategy, effectively shielding our theoretical interpretation from post-hoc rationalization bias.

The empirical results detailed above provide a unique and critical perspective on how institutional voids shape supply chain behavior in Central Asia. The strong positive relationship between PIF and RGT confirms that in the Sino-Kazakhstan corridor, practitioners utilize informal social capital as a primary substitute for weak formal institutions. This aligns with recent studies suggesting that when administrative hurdles, opaque customs procedures, and legal unenforceability are prevalent, relational norms function as an indispensable coping mechanism (Wu et al., 2023; Zhang et al., 2024). In such high-friction environments, trust prevents opportunistic behavior and facilitates rapid renegotiations, which is significantly more efficient than relying on rigid cross-border contracts (Chen & Lewis, 2024; Eckerd et al., 2021).

However, the most significant theoretical contribution of this study emerges from the rejection of Hypothesis 1. The data clearly indicate that friction alone does not compel firms to invest in costly "hard" flexibility strategies, such as multimodal transport options or overseas warehousing. As noted by Wissuwa et al. (2022), establishing structural flexibility requires substantial, often irreversible, capital commitments. Considering that 56% of our sample consists of SMEs (see TABLE 1), these firms face a stark "resource constraint reality." They are frequently unable to finance asset-heavy buffer strategies amid the unpredictable policy horizons of global supply chain restructuring (Niu et al., 2025). Consequently, for the majority of players in this regional agri-food sector, "soft" governance is not merely an option—it is the only viable, cost-effective path to achieving resilience.

Despite the lack of significance of the friction-flexibility link, the results demonstrate that once FS are deployed, they serve as a powerful engine for SCR (H3). This supports Lücker et al.'s (2024) perspective on the immense value of dual-purpose, flexible resources in mitigating disruptions. However, our findings establish an important boundary condition for this theory: the adoption of such flexible resources is highly contingent on firm-level financial capabilities, rather than an automatic response to external friction (Piprani et al., 2022).

Furthermore, the highly significant mediation effect of RGT (H6), juxtaposed with the unsupported mediation of FS (H5), underscores the nature of resilience in this context. It suggests that in the geopolitically complex Sino-Kazakhstan corridor, SCR is largely a relational achievement rather than a purely logistical one. The social fabric of the supply chain—anchored in joint problem-solving and mutual commitment acts as the ultimate shock absorber, reflecting the vital role of network capabilities in mitigating geopolitical risks (Wu et al., 2023; Iftikhar et al., 2025). While Egamberdiev (2024) highlights the value of social capital in Kyrgyz household food security, our study extends this logic to the inter-firm supply chain level, proving that relational capital's protective effect is cross-scalar in transition economies.

5 | CONCLUSION

This study set out to unravel the complex mechanisms through which enterprises in the Sino-Kazakhstan agri-food supply chain build resilience against compounding institutional and spatial frictions. By developing and empirically validating a conceptual model using PLS-SEM on a targeted sample of cross-border trade practitioners, this research provides a nuanced understanding of governance and flexibility in transition economies. The overarching conclusion is that while severe border frictions, such as railway gauge differences and opaque customs procedures, act as powerful catalysts for informal relational governance, they do not automatically compel firms to invest in structural flexibility. The data empirically suggest that relational capital, built on mutual trust and joint problem-solving, remains the primary "engine of resilience" in Central Asian logistics, based on the current sample.

The study advances the dynamic capability view by delineating the distinct yet

differentiated roles of relational and structural mechanisms in achieving ultimate supply chain resilience. However, the empirical evidence in this study points toward substitution rather than complementarity among resource-constrained SMEs.

From a practical standpoint, the findings offer vital strategic guidance for supply chain managers operating in high-friction geopolitical corridors. Practitioners, especially those with limited capital, should prioritize cultivating cross-border organizational trust and collaborative risk management over premature, capital-intensive physical expansions. Building deep, relationally embedded ties with local Kazakh partners provides a highly effective and agile shock-absorption mechanism. In practice, as Kazakhstan pursues a "multi-vector" foreign policy by developing the Trans-Caspian International Transport Route (TITR/Middle Corridor), Chinese agribusinesses must diversify their logistics pathways to mitigate overreliance on a single corridor. It is recommended that governmental bodies prioritize aligning multilateral standards, such as those within the TITR framework, rather than relying solely on bilateral protocols. Furthermore, the findings suggest a critical need for an SPS Mutual Recognition Agreement to reduce administrative friction in meat and dairy inspections, which currently serve as de facto non-tariff barriers despite infrastructure improvements at Khorgos.

Despite its robust findings, this study acknowledges certain limitations that pave the way for future scholarly inquiry. The reliance on cross-sectional data restricts the ability to capture the dynamic, evolutionary nature of trust-building over extended trade cycles. Future research would benefit from longitudinal designs to track how relational governance adapts to shifting geopolitical landscapes. Moreover, we acknowledge a conceptual limitation regarding FS: our measurement items (e.g., rapid mode shifting) overlap more with supply chain agility than with structural resilience, warranting finer construct discrimination in future research. Furthermore, while the sample size is statistically adequate for the PLS-SEM approach used, extending the research to multiple Central Asian corridors would enhance the generalizability of the findings. Finally, future studies should investigate the moderating role of emerging digital technologies. Assessing how blockchain-based traceability or AI-driven predictive analytics might bridge the gap between informal relational networks and formal logistics flexibility presents a highly promising research frontier.

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APPENDIX A

Measurement constructs, adapted items, and literature sources

Code	Measurement Items	Supporting Literature
PIF1	Frequent and unpredictable changes in customs regulations at the Dostyk/Alashankou/Khorgos borders significantly impact firm operations.	Adapted from Yerniyazova (2024) and ADB (2023)
PIF2	Infrastructural disparities (e.g., differences in railway gauges) between China and Kazakhstan cause severe delays in agri-food transit.	Lücker et al. (2024) and ADB (2023)
PIF3	The lack of transparency in Kazakhstan's institutional environment increases firm exposure to external trade risks.	Park et al. (2016)
RGT1	A high level of mutual trust and "Guanxi" (solidarity) with cross-border supply chain partners helps to bypass formal institutional voids.	Chen & Lewis (2024); Zhang et al. (2024)
RGT2	During border disruptions, the firm relies on informal goodwill and reciprocal commitments rather than strictly invoking formal contractual penalties.	Wang et al. (2025); Liu et al. (2012)
RGT3	Conflicts regarding inventory spoilage or transit delays are resolved through joint consultation rather than legal litigation.	Liu et al. (2012)
FS1	The firm possesses the agility to rapidly shift logistics modes (e.g., rail to truck) when major border congestion occurs.	Swafford et al. (2006); Piprani et al. (2022)
FS2	The firm utilizes pre-positioned inventory in overseas warehouses (at the Kazakhstan/China border) to buffer against unpredictable delivery lead times.	Lücker et al. (2024); Swafford et al. (2006)
FS3	The firm can quickly reallocate logistical resources (e.g., securing cold-chain trucks) when standard railway capacities are constrained.	Swafford et al. (2006)
SCR1	The cross-border supply chain is capable of absorbing sudden institutional or logistical shocks without experiencing systemic failure.	Ambulkar et al. (2015)
SCR2	Following a disruption event (e.g., border closure or policy shift), the firm can rapidly restore operational performance to normal levels.	Ambulkar et al. (2015); Wu et al. (2023)
SCR3	Despite compounding frictions, the firm consistently maintains target delivery service levels for end agricultural customers.	Zhao et al. (2024)