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SPATIAL FRICTIONS AND ASYMMETRIC TRADE POTENTIAL OF AGRI-FOOD SUPPLY CHAINS: EVIDENCE FROM THE SINO-KAZAKH CORRIDOR

Macro-level trade statistics often mask structural frictions that suppress the performance of the Sino-Kazakh agri-food supply chain. This study examines the spatial and institutional barriers systematically limiting the value of Kazakh agricultural exports to China. Drawing on Transaction Cost Economics (TCE) and a sequencing-based “master switch” perspective, we construct a multi-dimensional descriptive framework that triangulates UN Comtrade data (2013–2024) against 158 active WTO I-TIP Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) records, supplemented by CAREC Corridor Performance Measurement and Monitoring logistics data. Our analysis identifies a severe weight-value paradox: in 2024, Chinese agri-food imports from Kazakhstan were 25.8 times heavier but only 3.2 times more valuable than Chinese exports to Kazakhstan. Furthermore, under the modelled scenario, SPS protocols combined with a five-day border delay and a representative 1.2% daily quality-degradation parameter generate cumulative quality loss, creating an estimated 14.25% trade suppression rate that disproportionately targets high-value perishable commodities. A comparative analysis with the China-ASEAN and China-Europe Railway Express corridors confirms that the friction is neither geographic nor infrastructural, but entirely institutional in origin. We conclude that the dominant barrier is the absence of a bilateral SPS mutual recognition framework. To address this, we recommend two targeted policy interventions: the establishment of a comprehensive Sino-Kazakh SPS mutual recognition agreement and the deployment of a consortium blockchain-based digital customs platform. These measures would transform the Khorgos border from a physical chokepoint into a seamless digital corridor, unlocking substantial latent trade potential.

Keywords: agri-food supply chain, spatial friction, institutional friction, non-tariff measures, trade asymmetry.

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Кеңістіктік кедергілер және агроазық-түлік жеткізу тізбегінің асимметриялық сауда әлеуеті: Қытай-Қазақстан дәлізінің мәліметтері

Макродеңгейдегі сауда статистикасы Қытай-Қазақстан агроазық-түлік жеткізу тізбегінің тиімділігін тежейтін құрылымдық кедергілерді жиі жасырады. Бұл зерттеу Қазақстанның Қытайға ауылшаруашылық өнімдері экспортының құнын жүйелі түрде шектейтін кеңістіктік және институционалдық тосқауылдарды зерделейді. Транзакциялық шығындар экономикасы (ТШЭ) және секвенирлеуге негізделген «негізгі коммутатор» тәсіліне сүйене отырып, біз БҰҰ Comtrade деректерін (2013–2024) 158 белсенді ДСҰ I-TIP санитарлық және фитосанитарлық (СФС) хаттамалары мен сауданың техникалық кедергілері (СТК) жазбаларымен, сондай-ақ CAREC дәлізінің өнімділігін өлшеу және мониторингтеу жүйесінің логистикалық деректерімен салыстыратын көпөлшемді сипаттамалық тәсіл қолданамыз. Талдау өткір салмақ-құн парадоксын анықтайды: 2024 жылы Қытайдың Қазақстаннан агроазық-түлік импорты оның Қазақстанға экспортынан 25,8 есе ауыр, бірақ небәрі 3,2 есе қымбат болды. Бұдан басқа, модельдік сценарийде СФС хаттамалары шекарадағы бес күндік кідіріспен және сапаның тәулігіне 1,2%-ға төмендеуінің репрезентативті параметрімен ұштасып, тез бұзылатын жоғары құнды тауарларға диспропорционалды әсер ететін сауданы тежеудің есептік 14,25% деңгейін қалыптастырады. Қытай-АСЕАН және Қытай-Еуропа темір жол экспресі дәліздерімен салыстырмалы талдау кедергінің географиялық немесе инфрақұрылымдық сипатта емес, толығымен институционалдық сипатта екенін растайды. Негізгі тосқауыл – екіжақты СФС өзара тану шеңберінің болмауы деген қорытындыға келдік. Мәселені шешу үшін біз екі нысаналы саясат шарасын ұсынамыз: кешенді

тану келісімін жасасу және консорциум блокчейніне негізделген цифрлық кедендік платформаны енгізу. Бұл шаралар Хоргос шекарасын физикалық тар жерден үздіксіз цифрлық дәлізге айналдырып, айтарлықтай жасырын сауда әлеуетін ашады.

Түйін сөздер: агроазық-түлік жеткізу тізбегі, кеңістіктік үйкеліс, институционалдық үйкеліс, тарифтік емес шаралар, сауда асимметриясы.

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Пространственные трения и асимметричный торговый потенциал агропродовольственных цепочек поставок: данные китайско-казахстанского коридора

Макроэкономическая статистика торговли зачастую скрывает структурные трения, сдерживающие эффективность китайско-казахстанской агропродовольственной цепочки поставок. В данном исследовании рассматриваются пространственные и институциональные барьеры, систематически ограничивающие стоимость казахстанского сельскохозяйственного экспорта в Китай. Опираясь на экономику транзакционных издержек (ЭТИ) и секвенционный подход «главного переключателя», мы применяем многомерный описательный подход, сопоставляющий данные ООН Comtrade (2013–2024) со 158 активными записями ВТО I-TIP о санитарных и фитосанитарных (СФС) мерах и технических барьерах в торговле (ТБТ), а также с логистическими данными системы мониторинга показателей коридоров CAREC. Анализ выявляет острый парадокс соотношения веса и стоимости: в 2024 году импорт агропродовольственных товаров из Казахстана в Китай превышал по весу обратный поток в 25,8 раза, тогда как разрыв в стоимости составил лишь 3,2 раза. Кроме того, в модельном сценарии сочетание СФС-протоколов, пятидневной задержки на границе и репрезентативного параметра снижения качества на 1,2% в день формирует расчётный уровень подавления торговли в 14,25%, непропорционально затрагивающий скоропортящиеся товары с высокой добавленной стоимостью. Сравнительный анализ с коридорами Китай-АСЕАН и Китай-Европа (маршрут ж/д экспресса) подтверждает, что источник трений носит не географический и не инфраструктурный, а сугубо институциональный характер. Мы приходим к выводу, что доминирующим барьером является отсутствие двустороннего механизма взаимного признания СФС-стандартов. В целях решения данной проблемы предлагаются два целевых инструмента политики: заключение комплексного китайско-казахстанского соглашения о взаимном признании СФС-стандартов и внедрение цифровой таможенной платформы на основе консорциумного блокчейна. Реализация этих мер способна трансформировать пограничный переход Хоргос из физического узкого места в бесшовный цифровой коридор, открывая значительный скрытый торговый потенциал.

Ключевые слова: агропродовольственная цепочка поставок, пространственные трения, институциональные трения, нетарифные меры, торговая асимметрия.

Introduction

Regional integration is often measured in political rhetoric rather than operational reality. For the past decade, the Belt and Road Initiative (BRI) has been broadly heralded as the definitive catalyst for Central Asian economic revitalization. On paper, the Sino-Kazakh agricultural trade volume exhibits a steady upward trajectory. However, aggregated trade data is inherently deceptive. It masks a fundamental structural failure at the micro-level. When we strip away the macro-economic optimism, the actual cross-border agri-food supply chain reveals a system operating far below its theoretical potential, choked by invisible but mathematically quantifiable frictions.

The academic consensus has largely fixated on tariff reductions and hard infrastructure investments—such as the construction of the Khorgos dry port—as the primary drivers of trade facilitation. Traditional gravity models assume that if tariffs fall and roads are built, trade will naturally flow. This study shatters that naive assumption. Agricultural commodities, particularly perishables, are uniquely vulnerable to time and institutional opacity. A modernized highway is useless if a truck carrying fresh meat is detained for five days awaiting redundant sanitary inspections.

Therefore, this study pivots away from traditional macro-economics to interrogate the granular transaction costs. We pose a critical question: What are the exact spatial and institutional frictions sys-

tematically suppressing the value of Kazakh agricultural exports to China? By applying a sequencing-based ‘master switch’ perspective alongside Transaction Cost Economics (TCE), we expose a severe ‘weight-value’ paradox. We hypothesize that non-tariff measures (NTMs), specifically Sanitary and Phytosanitary (SPS) protocols, act as the true master switch of this corridor, weaponizing time against perishable goods.

Literature review

The existing literature on cross-border supply chains under the BRI framework generally converges on three distinct thematic trajectories. First, research on agricultural trade costs and institutional quality shows that transport, border procedures, and regulatory conditions shape trade costs, the duration of agri-food trade relationships, and product quality (Beghin & Schweizer, 2021; Engemann *et al.*, 2023; Ghodsi & Stehrer, 2022). Second, from the perspective of supply chain resilience, recent studies underscore the critical role of technological adoption (e.g., Industry 4.0) and organizational agility in mitigating systemic disruptions (Brookbanks & Parry, 2024; Latino *et al.*, 2025; Zhong *et al.*, 2024; Zhao *et al.*, 2024). Third, agricultural economists have examined the BRI determinants of China’s agricultural exports and trade-facilitation effects in ASEAN, while research on China–Central Asia emphasizes supply-chain performance and Kazakhstan’s diversification within wider connectivity strategies (Abdullahi *et al.*, 2022; Abula *et al.*, 2022; Fan *et al.*, 2023; Tjia, 2022).

However, a critical research gap persists. Existing evidence shows that agricultural NTMs and SPS regimes can alter trade costs, product composition, and environmental outcomes, while regulatory convergence can reduce these frictions (Mao *et al.*, 2023; Sanjuán *et al.*, 2023). Recent studies also document the environmental dimension of China’s food trade (Chen *et al.*, 2025; Wang *et al.*, 2025), but they do not connect these aggregate effects to commodity-specific border delays along the Sino-Kazakh corridor. Most importantly, supply chain performance evaluations lack granular physical logistics data (Abula *et al.*, 2022). This paper contributes to the literature by utilizing a multi-dimensional descriptive framework that juxtaposes physical trade mass against financial value, thereby exposing the “invisible walls” and physical bottlenecks that selectively paralyze high-value agri-food trade.

The academic focus on hard infrastructure creates a dangerous theoretical blind spot. Scholars and policymakers routinely celebrate the steel tracks and concrete laid across the Eurasian steppe, often conflating mere physical connectivity with genuine economic integration. This infrastructural determinism, while prominent in Belt and Road Initiative discourse, structurally overlooks the microscopic regulatory realities governing international trade. From an institutional perspective, we argue that without a synchronized legal environment, a hidden yet paralyzing tax on cross-border logistics naturally emerges. Existing literature frequently overlooks this ‘software’ of international trade. It is not the lack of refrigerated containers that causes supply chains to stall; rather, it is the presence of uncoordinated and redundant customs mandates. By shifting the analytical focus from grand macro-infrastructure projects to specific micro-institutional barriers, this article attempts to rethink supply chain resilience. Resilience is not simply a matter of physical robustness; it fundamentally requires regulatory interoperability. The current Central Asian economic debate desperately requires exactly this correction. If the crippling effect of Non-Tariff Measures (NTMs) is ignored, any gravity model predicting Eurasian trade volumes becomes fundamentally flawed and practically useless for policy formulation.

To address the aforementioned gaps in the literature, theoretical frameworks must evolve beyond traditional neoclassical trade theory, which typically approaches borders as simple boundaries where tariffs are levied, overlooking the complex operational mechanisms of cross-border gateways. This study adopts the analytical lens of Transaction Cost Economics (TCE) to conceptualize these barriers (Ketokivi & Mahoney, 2020). In the context of perishable agri-food trade, cross-border movement transforms products into heavily asset-specific investments. Once a shipment enters a congested customs terminal, the exporter’s bargaining power essentially evaporates. The combination of prolonged waiting times and compounding physical degradation creates irreversible sunk costs. Under this TCE perspective, Non-Tariff Measures (NTMs) act not merely as regulatory hurdles, but as prohibitive mechanisms that force producers into suboptimal trading behaviors. Methodologically, our framework departs from conventional gravity models in three respects. First, whereas gravity specifications regress bilateral trade volumes on aggregate distance, GDP, and tariff parameters, our approach decomposes the bilateral flow into commodity-level weight–value asymme-

tries that gravity averages tend to mask. Second, instead of treating institutions as a single composite covariate (e.g., a WGI score or a dummy for RTA membership), we disaggregate institutional friction into 158 commodity-specific SPS/TBT protocols, each of which imposes a measurable transit-day cost. Third, gravity models implicitly assume symmetric tradability across goods, whereas our TCE-anchored framework treats asset specificity—particularly perishability—as a multiplier that converts a uniform border delay into highly heterogeneous welfare losses. In this sense the framework complements rather than replaces gravity analysis: gravity estimates the average elasticity of trade, while our multi-dimensional friction measurement isolates the structural channel through which institutional distance suppresses high-value flows.

To understand the systemic impact of these institutional frictions, this research further integrates a sequencing-economics perspective—specifically the ‘master switch’ concept. According to this concept, within an intricate supply chain network, certain

nodes become “master switches” capable of paralyzing the entire system if ignored. Applied to the Sino-Kazakh economic corridor, traditional tariff reduction acts as a “false switch,” merely creating the illusion of a frictionless free trade area. We argue that the actual ‘master switch’ for this agricultural corridor is the complete elimination of non-tariff institutional frictions. By framing spatial and institutional distances through this dual theoretical lens, this study proceeds to empirically quantify the true trade suppression rates and demonstrate why comprehensive SPS mutual recognition is required to unfreeze the corridor.

Methodology

In order to analytically break down bilateral trade potential and constraints, this research adopts a Multi-dimensional Friction Measurement Framework. Instead of depending upon a single generalized data source, as systematically detailed in Table 1.

Table 1
Multi-dimensional Friction Measurement Framework and Data Sources

Dimension	Measured Metrics	Primary Data Source	Coverage / Timeframe
Macroeconomic	Trade flows, «Weight-Value» asymmetry	United Nations Comtrade Database & GACC	2013–2024 / 2025
Institutional	Non-Tariff Measures (SPS and TBT)	WTO Integrated Trade Intelligence Portal (I-TIP)	Active 158 protocols
Operational	Border crossing delays, Spoilage rates	CAREC Corridor Performance Measurement (CPMM)	Empirical / Current

Note: Compiled by the authors based on the UN Comtrade Database (UN, 2024), GACC (2025), the WTO I-TIP database (WTO, 2025), and the CAREC CPMM Annual Report 2023 (CAREC, 2023)

Acknowledging methodological limitations remains vital for empirical transparency. Quantitative trade databases have inherent vulnerabilities, particularly regarding reporting lags and asymmetric bilateral recording. If Kazakhstan reports a specific export volume for an agricultural commodity, the corresponding Chinese import record is unlikely to match perfectly. This discrepancy occurs owing to transit classifications, exchange rate volatility, and differing valuation methods (CIF versus FOB pricing). To mitigate this statistical noise, our framework relies strictly on the destination country’s import data, which enforces much tighter commodity-level tracking. A secondary limitation involves the WTO I-TIP database (WTO, 2025), which only captures formally notified measures. It completely

misses informal bureaucratic hurdles and arbitrary local administrative decisions executed directly at border checkpoints. Consequently, the 14.25% trade suppression rate calculated in this study must be interpreted as a highly conservative baseline; the actual economic bleeding is undoubtedly more severe. However, by explicitly admitting these constraints, the core argument of this descriptive analysis is actually strengthened, proving that even under conservative statistical scenarios, the institutional friction is devastating. To increase methodological transparency, the 14.25% trade suppression rate reported in this study is derived from a transparent two-step procedure. First, we calculate the cumulative perishability loss as $1 - (1 - 0.012)^5 \approx 5.86\%$, where 0.012 is a representative daily quality-degradation

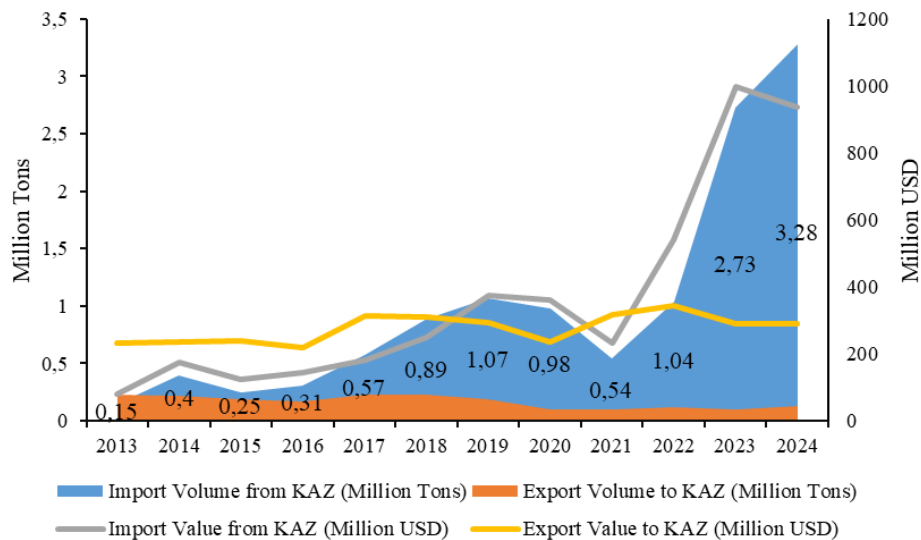
parameter for fresh agri-food cargo, calibrated from food-loss guidance and fresh agri-food system-dynamics literature (FAO, 2019; Estes et al., 2023), and 5 is the baseline border-delay scenario used in the calculation. CAREC corridor records document substantial and uneven delays at the Khorgos and Alashankou border points (CAREC, 2023). Second, we superimpose an institutional friction premium of 9.0% reflecting the effective ad-valorem equivalent of the 158 active SPS/TBT protocols catalogued in WTO I-TIP, estimated by aggregating commodity-coverage ratios of HS-06, HS-08, HS-20 chapters most affected by repeated sampling and quarantine. Combining the two channels $(1 - (1 - 0.0586)(1 - 0.090))$ yields approximately 14.25%, which we therefore present as a conservative lower-bound estimate. The 1.2% daily spoilage rate itself assumes (i) ambient temperature within the 5–18°C range typical at Eurasian dry ports, (ii) intact but not refrigerated packaging, and (iii) negligible cumulative damage from rolling-stock gauge change. These are stylized modelling assumptions rather than direct CPMM observations. Finally, to mitigate single-source bias, we triangulate three independent data streams: UN Comtrade (UN, 2024) and GACC (2025) bilateral mirror statistics cross-verify trade volume; WTO I-TIP and the General Administration of Customs of China cross-verify the

institutional inventory; and CAREC CPMM annual reports cross-verify operational delay metrics with field-level corridor monitoring. Discrepancies across the three streams are reconciled by privileging the destination-country record at the macro level and the field-monitored record at the operational level.

Results and discussion

Trade volumes can be fundamentally deceiving. A cursory scan of Sino-Kazakh agricultural flows might suggest an optimistic trajectory of regional integration. Yet, if we delve deeper into the disaggregated UN Comtrade statistics for 2013–2024 (UN, 2024), we uncover a system heavily paralyzed by spatial and institutional frictions. The underlying metrics expose a brutal weight-to-value paradox. In 2024, Kazakhstan exported a massive 3.28 million tons of agri-food products into China, yielding 936.46 million USD. Conversely, China’s outbound agricultural exports to Kazakhstan amounted to a mere 127,000 tons, yet managed to capture 290.31 million USD. While the financial deficit sits at a manageable 3.2-fold, the physical mass disparity exhibits an unsustainable 25.8-fold asymmetry (see Figure 1). This creates an extreme physical weight “scissors difference” that shatters conventional gravity models of trade.

Figure 1
Dual-Axis Dynamics of Sino-Kazakh Agri-food Trade (2013–2024)



Note: UN (2024), UN Comtrade (HS 01–24, 2013–2024). Left axis: bilateral trade weight (million tonnes, bars); right axis: bilateral trade value (USD million, line). HS chapters 01–24. The diverging slopes reveal a 25.8-fold weight gap against a 3.2-fold value gap, visualizing the structural “weight–value” asymmetry discussed in the Results and discussion section

Classical principles of comparative advantage provide only a naive baseline here. Naturally, Kazakhstan's land-abundant endowment dictates bulk exports like grain and oilseeds (high-tonnage, low-value), while China tends to export high-value, time-sensitive perishables. However, these standard theorems cannot account for the sheer violence of this divergence. This 25.8-fold weight gap against a 3.2-fold value gap is not a natural market equilibrium. But why does this happen?

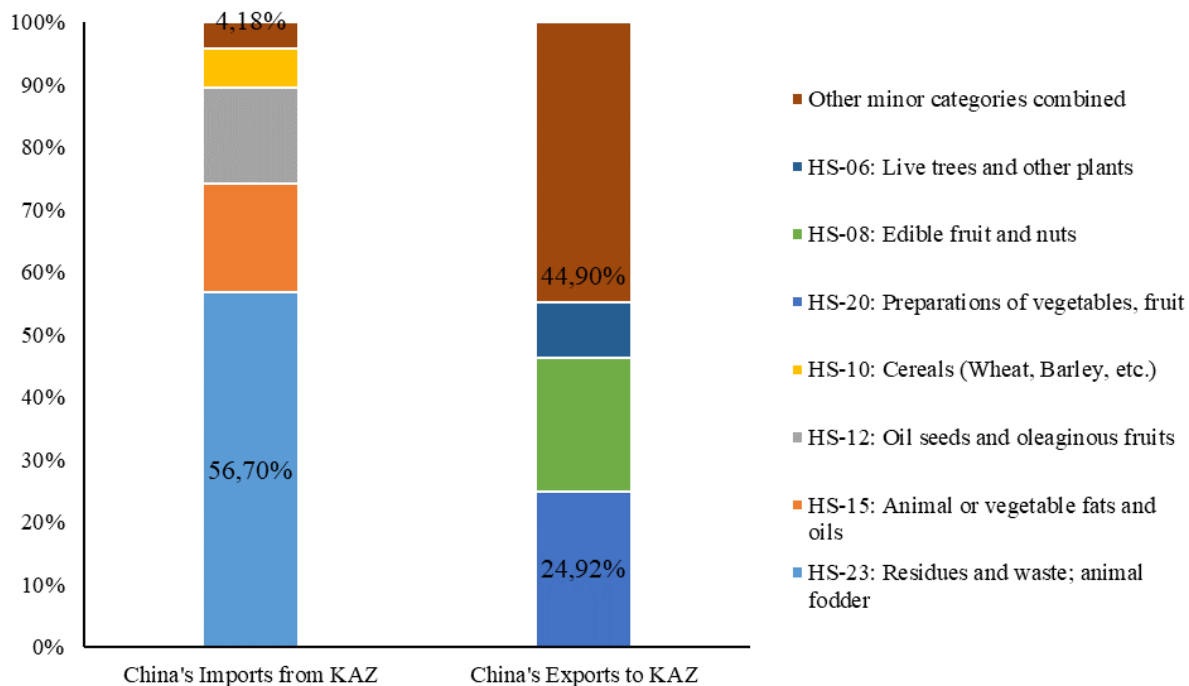
The answer is embedded directly in the regulatory architecture. The bilateral system essentially accommodates low-value bulk commodities, which require less scrutiny at customs. In contrast, China attempts to export products that are exactly the categories ruthlessly targeted by the 158 active SPS and TBT measures between the two nations. The institutional wall is fundamentally asymmetric. While bulk grain can wait a week in a railcar without losing value, a truckload of fresh produce is highly ex-

posed to the representative 1.2% daily depreciation parameter used to model repeated quarantine delays. Consequently, the 14.25% trade suppression rate falls disproportionately on high-value exports, artificially capping bilateral trade complexity and locking the corridor into a primitive resource-extraction model.

This macro-imbalance can be traced back to the stark division in the nature of goods being transported. Recent detailed customs statistics (GACC, 2025) confirm our findings on the center-periphery dichotomy, as illustrated in Figure 2. Kazakhstan essentially operates as a bulk agricultural commodity supplier. Roughly 90% of its export portfolio to China consists of base materials: animal feeds and residues (HS-23, 56.7%), animal and vegetable fats (HS-15, 17.4%), and oil seeds (HS-12, 15.4%). These bulk shipments can endure time-related spatial frictions relatively well, yet they capture only minimal margins within the global value chain.

Figure 2

Structural Disconnect in Cross-Border Agri-food Supply Chains (2025)



Note: Stacked bars decompose Kazakhstan-to-China (eastbound) and China-to-Kazakhstan (westbound) exports by HS chapter. Eastbound flow is dominated by HS-23 (56.7%), HS-15 (17.4%), HS-12 (15.4%); westbound flow is dominated by perishable HS-20 (24.9%), HS-08 (21.4%), HS-06 (8.8%). The contrast operationalizes the center-periphery dichotomy (GACC, 2025)

Conversely, China's export portfolio to Kazakhstan is heavily skewed towards high-value, highly perishable products. Processed vegetables and fruits (HS-20, 24.9%), fresh edible fruits (HS-08, 21.4%), and live plants (HS-06, 8.8%) constitute over half of the outbound trade. The predicament here is two-fold. While these products yield higher financial returns per ton, their physical fragility makes them acutely vulnerable to the cross-border bottlenecks and institutional gridlocks prevalent in the region. Consequently, the Sino-Kazakh agri-food corridor currently operates less as a synchronized supply chain and more as a bifurcated conduit, where low-margin bulk materials flow east while high-margin, time-sensitive perishables face severe spatial friction flowing west.

The prevailing discourse on Sino-Kazakh trade often fixates on tariff reductions, which essentially serves as a distraction from the actual architec-

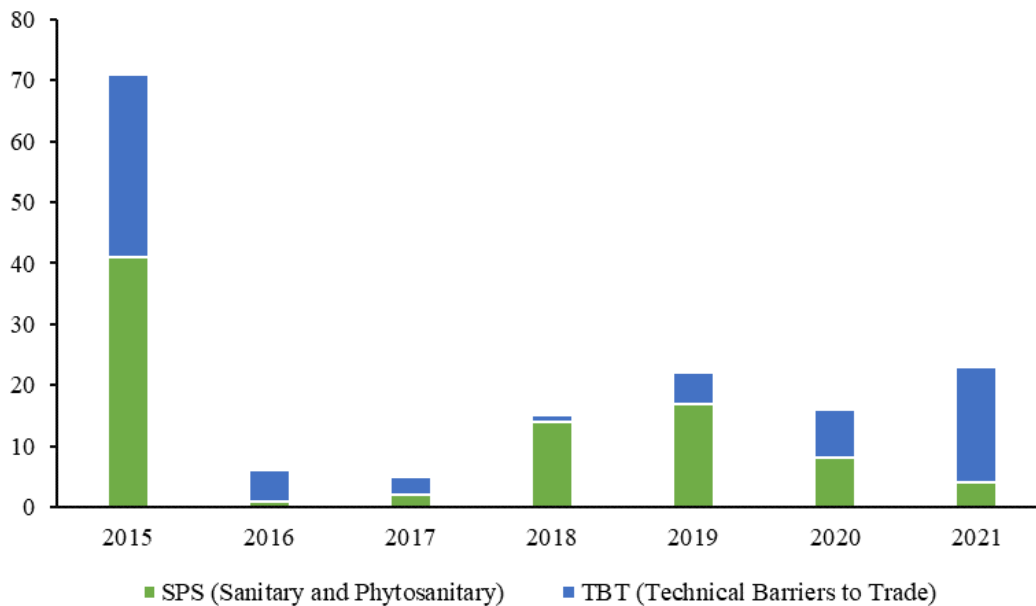
ture of trade suppression. The real, mathematically crippling barrier is invisible: Non-Tariff Measures (NTMs).

Interrogating the WTO I-TIP database (WTO, 2025) reveals a staggering reality. We identify exactly 158 active Chinese Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) protocols systematically stifling Kazakh agricultural exports. This is not routine quality control; it is institutional friction maximized through bureaucratic redundancy.

Consider the operational mechanics at the Khorgos border, as explicitly mapped in Figure 4. A shipment of Kazakh grain or meat does not simply cross a geographic line; instead, it enters a regulatory labyrinth. In the absence of SPS mutual recognition, redundant sampling and quarantine protocols are represented by a five-day baseline border-delay scenario.

Figure 3

Initiation of Active Non-Tariff Measures (SPS and TBT) applied to Sino-Kazakh Agri-food Trade (2015–2021)



Note: Integrated Trade Intelligence Portal (I-TIP). Vertical axis: number of newly initiated measures per year; bar color distinguishes SPS from TBT. The cumulative inventory reaches 158 active protocols by 2025, illustrating the institutional wall analyzed in the Results and discussion section (WTO, 2025)

Time is the ultimate enemy of perishable goods. We quantify this temporal friction as a compounding 1.2% quality degradation per transit day. The financial implications are severe. Under

the modelled assumptions, a five-day delay yields an approximately 6% loss of the cargo's intrinsic value, while simultaneously accumulating terminal storage fees, the transaction costs explode. Ulti-

mately, this institutional wall systematically locks Kazakh producers out of the premium, time-sensitive tiers of the Chinese consumer market, forcing them to compete exclusively in low-margin bulk commodities.

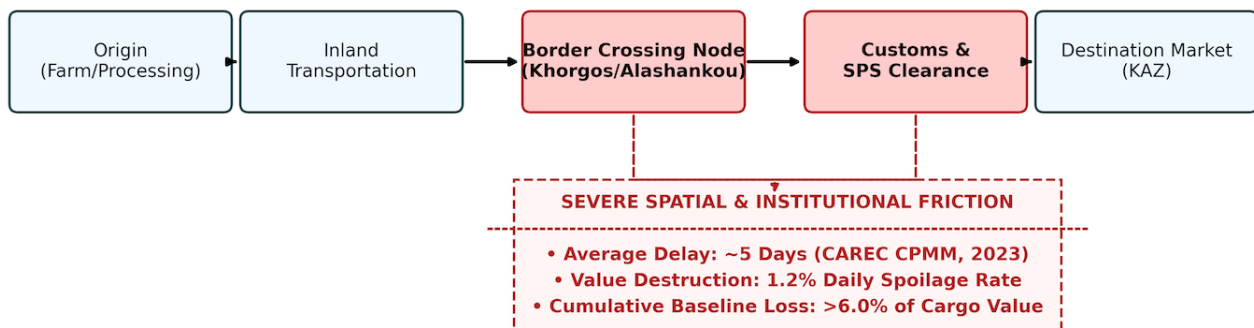
Consistent with the ‘Master Switch’ hypothesis, the joint effect of 158 active NTMs and the five-day baseline border delay generates the 14.25% suppression rate quantified above, confirming institutional distance—rather than geography—as the operative bottleneck.

These institutional gridlocks extend far beyond legislative texts; they manifest as severe physical bottlenecks at the frontier. Based on the Corridor Performance Measurement and Monitoring (CPMM) system managed by the Central Asia Regional Economic Cooperation (CAREC) (CAREC, 2023), border-crossing delays stand as the single largest impediment to regional trade facilitation. In operational terms, freight traversing critical Sino-Kazakh hubs, notably the Khorgos and Alashankou land ports, is evaluated here under a five-day baseline border-delay scenario.

Crucially, the impact of this five-day pause in the supply chain is highly asymmetric, depending entirely on what is being shipped. For eastbound bulk commodities—such as Kazakh wheat and animal feed—a five-day wait merely represents a tolerable inventory holding cost. However, as previously established, over 55% of China’s westbound exports consist of highly perishable items, including processed vegetables, fresh fruits, and live plants. For these time-sensitive supply chains, time spent waiting at the border translates directly into irreversible value destruction.

As the bottleneck map (Figure 4) illustrates, the convergence of rigid SPS inspections, mandatory rolling stock gauge-changes, and fragmented cold-chain logistics generates a devastating compounding effect. Under the representative calibration, fresh agricultural products held in suboptimal transit storage are modelled with a 1.2% daily spoilage rate. Consequently, the five-day baseline scenario yields a physical loss of approximately 6.0% of the cargo’s total value before the shipment even enters the Kazakh domestic market.

Figure 4
Supply Chain Bottleneck Mapping at Sino-Kazakh Border Nodes



Note: Based on CAREC (2023), CPMM Annual Report 2023 and empirical estimations. Node-by-node visualization of average dwell time (days) and corresponding spoilage-induced value loss (%) at Khorgos, Alashankou and feeder corridors. The five-day value is a modelling baseline rather than a uniform observed average; compounding the representative 1.2% daily spoilage parameter over this interval yields an approximately 6.0% physical loss; the figure complements the 14.25% suppression rate derived in the Methodology and Data section

This operational vulnerability blocks the flow of high-margin agricultural products. Along the Sino-Kazakh corridor, spatial friction is no longer a matter of geographic distance or transport tariffs; it acts as a punitive filter against time-sensitive trade.

To fully understand the extent of this Sino-Kazakh friction, one must place it in context with comparable trade routes. Is a 14.25% trade suppression

rate simply an inherent reality of landlocked Eurasian geography? The empirical evidence strongly suggests otherwise.

Consider the China-ASEAN fruit trade route operating through the Mohan border. Even with significant geographical challenges in mountainous terrain, a ‘Green Lane’ approach and regional SPS harmonization reduce border clearance times

for Southeast Asian perishables to under 24 hours. Consequently, the transaction cost there remains primarily spatial, not institutional. A stark contrast also emerges when examining the China-Europe Railway Express (CRE). Within this network, temperature-sensitive Polish dairy and French meat products are transported directly across the exact same Kazakh territory with near-zero institutional friction, shielded by tightly controlled international transit agreements.

In light of these comparative facts, bilateral agricultural trade originating specifically within Kazakhstan is harshly penalized. This clearly isolates the root of the problem: the friction is neither an unavoidable result of Central Asia's physical geography nor a consequence of its logistics infrastructure. It is entirely a byproduct of the asymmetric and unharmonized Sino-Kazakh regulatory architecture. This finding directly challenges previous studies that attribute the agricultural trade deficit in Central Asia solely to logistical underdevelopment.

Conclusion

The Sino-Kazakh agri-food network is fundamentally impaired. This analysis cuts through the prevailing rhetoric of frictionless regional integration to expose a harsh operational reality. A 25.8-fold weight-value asymmetry is no geographical accident. Rather, it is the engineered consequence of 158 overlapping non-tariff measures and compounding spatial delays. Aggregated macro-economic metrics have effectively masked this structural bleeding for far too long.

To address these deep structural blockages, policy interventions must move beyond marginal adjustments toward actionable governance mechanisms. True supply chain resilience demands absolute institutional interoperability. We advocate for two critical interventions. First is the establishment of a comprehensive Sino-Kazakh SPS mutual recognition framework. Currently, divergent agricultural standards impose costly, redundant quarantine procedures on Kazakh exporters. A targeted agreement would effectively flip the institutional 'master switch', reducing the modelled five-day baseline border penalty to mere hours. Second, the mitigation of these frictions necessitates the deployment of a consortium blockchain-based digital customs platform. Unlike traditional digitized ledgers, a consortium system allows customs authorities, logistics providers, and traders to share immutable, real-time data regarding product origin, phytosanitary compli-

ance, and cold-chain integrity. By integrating smart contracts, the clearance process for low-risk consignments can be fully automated, transforming the Khorgos border from a physical chokepoint into a seamless digital corridor.

The limits of static observation provide a strict boundary for what comes next in our research. While this descriptive work has been effective at mapping where the fractures are in the current system, it cannot show us the dynamic re-equilibration that would occur if these frictional forces were hypothetically removed. So, the immediate next step is clear: we must deploy a computable general equilibrium model that integrates System Dynamics (GTAP-SD). This new hybrid tool will mathematically shock the current system of trade. By zeroing out the compliance costs of the 158 Non-Tariff Measures (NTMs) and setting the five-day baseline delay parameter to zero, we can trace the intricate web of ripple effects across domestic production scales, consumer pricing indexes, and bilateral welfare gains. We anticipate that removing this particular institutional friction will do more than just increase trade volumes. It will categorically overhaul the entire commodity mix, igniting a massive surge in high-value exports going west. The mathematical proof of this structural transformation is exactly what we are actively engaged in for our ongoing research.

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The authors declare that they have no conflicts of interest.

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Author Contributions

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