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Innovative Logistics Operation Model of China-Kyrgyzstan Cross-border Pharmaceutical E-commerce Platform and Medical Regulatory Collaboration Path

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Abstract. To address the conceptual gap that existing studies only focus on operational compliance challenges (e.g., manual screening, delayed alerts) of cross-border pharmaceutical e-commerce platforms (in highly regulated, data-intensive environments) rather than their theoretical causes—especially the lack of explanation for how platform data governance supports dynamic compliance risk control in cross-border pharmaceutical logistics and service systems—this study takes the China–Kyrgyzstan cross-border specialty pharmaceutical e-commerce platform as a case. We developed a data-driven risk identification and intervention model based on product access, qualification update, and historical compliance data, using a weighted risk score to screen high-risk products/entities and implement targeted interventions (delisting B002/F006, restricting listing E005, verification C003, no action D004). Results show the model significantly reduces high-risk product violation likelihood (B002/F006/E005 achieve high risk reduction) without additional labor costs or unnecessary low-risk product restrictions. Theoretically, it extends the data-driven service governance framework in compliance-sensitive platforms; practically, it enhances operational safety and compliance efficiency in cross-border pharmaceutical logistics and service systems, contributing to bridging the theoretical gap between data governance and compliance risk control.

Keywords: Cross-border E-commerce; Pharmaceutical Product Compliance Risk; Data-driven; Operational Management Model; High-Risk Identification

1. Introduction

With the rapid global development of pharmaceutical e-commerce, cross-border transactions have become a key part of the pharmaceutical industry chain, promoting regional market integration, optimizing medical resource allocation, and advancing cross-border pharmaceutical logistics upgrading. Under the Belt and Road Initiative, China-Kyrgyzstan pharmaceutical trade has intensified, with specialty pharmaceuticals expanding rapidly on cross-border e-commerce platforms—this growth boosts bilateral cooperation, meets diverse medical needs, and raises new demands for cross-border pharmaceutical logistics efficiency and safety. However, the complexity of cross-border transactions and the particularity of pharmaceutical logistics (e.g., cold chain transportation, customs clearance, traceability) lead to multiple risks, including dual-regional compliance, cross-border payment security, drug use safety, and logistics stability, which impede sustainable development and threaten public health.

Despite growing attention to cross-border pharmaceutical e-commerce, existing literature has obvious gaps. First, most studies focus on macro trade policies or platform technical optimization, rarely exploring integrated operation models to address multi-dimensional risks (compliance, payment, drug safety, logistics stability). Second, risk control research mostly adopts passive strategies (e.g., post-event supervision), lacking a dynamic, full-process monitoring mechanism covering product access, qualification updates, transactions, and cross-border logistics. Third, few studies target the China-Kyrgyzstan scenario, ignoring its unique institutional differences, trade characteristics, and logistics challenges under the Belt and Road Initiative. Additionally, literature fails to clarify stakeholder roles (platforms, pharmaceutical firms, service providers, logistics entities), leading to unclear responsibilities and inefficient risk management, especially in logistics-compliance coordination.

To fill these gaps and address practical risks (including logistics risks) in China-Kyrgyzstan cross-border specialty pharmaceutical e-commerce, this study aims to propose a novel data-driven operation and management model. Specifically, it clarifies the hierarchical roles and collaboration of platforms, pharmaceutical firms, service providers, and logistics entities via a platform-led tiered authorization mechanism, establishing a risk management responsibility system covering transactions and logistics. A dynamic risk identification model will be built using product access, qualification update, and historical compliance data (including logistics compliance), enabling real-time monitoring and targeted intervention of high-risk products throughout operations, including logistics links. The goal is to enhance compliance identification accuracy, improve platform operational security and logistics stability, and promote sustainable China-Kyrgyzstan pharmaceutical trade—without significant management cost increases.

2. Related Works

In the recent years, as the process of global e-commerce and cross-border trading is rapidly developing, pharmaceutical e-commerce and regulatory supply chain, and logistics services, as well as compliance regulations, are gradually becoming the subject of academic and practical interest. To understand better the current research situation in the given area, the paper reviews existing literature, including such aspects of e-commerce models of pharmaceutical sales across borders, quality of logistics services, risk management, legal oversight, and digitalization. Yang and He, addressing the limitations on the development of pharmaceutical e-commerce due to high delivery costs and strong risk perception in online drug purchases, proposed an omnichannel model of "online ordering, offline delivery," and used telemedicine to coordinate e-commerce, pharmacies, and hospital doctors to achieve a smooth online medical experience. By comparing the profits of supply chain members under omnichannel and non-omnichannel scenarios through optimization model, the results show that the strategy is feasible and efficient, which helps to improve patient trust and enhance the overall profitability of the pharmaceutical industry (Yang & He, 2023).. He et al. analyzed the characteristics and development trends of cross-

border e-commerce supply chain in terms of global scale, multi-entity collaboration, process simplification, digitalization and intelligence, based on the background of the rapid development of cross-border e-commerce in China (He et al., 2024). In response to problems such as inconsistent legal system, unbalanced logistics transportation, imperfect payment settlement and insufficient supply chain transparency, they proposed countermeasures to strengthen cooperation and communication, optimize logistics system, reduce customs clearance difficulty, improve guarantee mechanism and promote sustainable development. Zhang et al. took the service quality of cross-border e-commerce logistics as the research object, adopted a two-stage hybrid research method combining qualitative and quantitative methods, and constructed an LSQ (Logistics Service Quality Framework) framework containing six dimensions: timeliness, safety, reliability, economy, personnel contact quality and information quality (Zhang et al., 2024). The study found that reliability and personnel contact quality are linearly related to customer satisfaction; timeliness and packaging safety have "attractive attributes" and can improve satisfaction; economy, information quality and cargo safety are basic needs, and their absence can easily lead to dissatisfaction. Morini et al. used Brazil's "Compliant Parcel Program" as a case study and employed qualitative research methods to analyze the challenges faced by customs in terms of data quality and tax management in the context of the surge in cross-border e-commerce small parcels (Morini et al., 2024). The study showed that the program improved the accuracy of declaration data, strengthened risk management and resource allocation efficiency. Hidayat et al. made the target of the study Indonesian cross-border e-commerce and applied the SEM-PLS (Structural Equation Modeling - Partial Least Squares) technique to investigate the effect of the quality of logistics services on the customer satisfaction and repurchase intention. The findings revealed that there was a big increase in customer satisfaction due to return logistics, stability in delivery, availability and cross-border shopping experience (Hidayat et al., 2026). The background employed in another study was the cross-border e-commerce in Indonesia and the method used to analyze the effects of the quality of the logistics service on customer satisfaction and repurchase intention was the SEM-PLS. The findings were that return logistics, stability of delivery, availability and cross-border shopping experience influenced the satisfaction greatly (Yan, 2024). Prasad has given a review of a multifaceted connection between e-commerce and international trade law and discussed the effects and prospects of the digital era of e-commerce on traditional trade regulations. He focused on legal issues such as jurisdiction, data privacy, intellectual property and trade facilitation, assessed the role of e-commerce platforms and the possibility of international rule coordination, and provided a reference for the development of global trade rule of law (Prasad, 2023). Zhang studied the coordinated development of cross-border e-commerce and cross-border logistics in rural China, analyzed the current status of rural cross-border e-commerce systems and logistics, and found problems such as talent shortage, difficulty in returning and exchanging agricultural products, complexity of cross-border payments, and limitations of agricultural product characteristics. In response to these problems, a strategy of multi-entity coordinated development was proposed (Zhang, 2024). Legito and Andriani sorted out the development trend and innovation of e-commerce in the digital age through bibliometric analysis. Using VOSviewer to analyze publication trends, author collaboration networks, keyword clustering and citation patterns, they revealed the multi-dimensional evolution path of personalized mobile experience and integration of cutting-edge technologies (Legito & Andriani, 2023). Putra studied the role of digital transformation of Southeast Asian e-commerce platforms in improving operational efficiency through a systematic literature review. The study found that technologies such as artificial intelligence, Internet of Things, blockchain and big data significantly improve cost efficiency and response speed in logistics, customer experience and process integration, among which AI can reduce operating costs by 15%-20%(Putra, 2025). Tömöri and Staniscia took Hungary as an example to explore the impact of the COVID-19 pandemic on cross-border shopping tourism. The study showed that the pandemic led to restrictions on international travel, which significantly reduced cross-border shopping tourism and triggered a restructuring of shopping and retail space structure (Tömöri & Staniscia, 2023). Although recent studies have realized partial

outcomes on such aspects as e-commerce pharmaceutical models across borders, logistics services, risk management, and the coordination of regulations, it also has bottlenecks like the lack of data-driven empirical evidence, the imperfection of the mechanisms of cross-border regulatory cooperation, and the lack of research on the identification and dynamic intervention of high-risk products.

3. Methods

3.1 Structural Analysis of Operation and Management Elements of Cross-border E-commerce Platforms

3.1.1. Platform Governance Structure and Multi-Stakeholder Collaborative Mechanism

The governance mechanism of the cross-border pharmaceutical e-commerce platforms is basically joint governance mechanism which entails several stakeholders. It is all about making the functional positioning and responsibility of each participant clear and ensuring collaborative operation amongst them through institutionalized interfaces. The platform is the organizer and rule-maker of the general operations in this type of structure and regulates access standards to platforms, the rules of transaction, the integration of information, and the coordination of risk control; it is the hub of the platform governance system (Zhang et al., 2024). As the suppliers of the goods, the pharmaceutical manufacturers have the fundamental duties aimed at regulating the quality of the products, compliance with the qualification, and information authenticity of the products. In contrast to the general commodities, pharmaceutical products are very specialized and risk-sensitive hence the manufacturers are not only part of the transaction in the platform governance system but are also central agents of compliance. Companies that perform cross-border contracts are mainly the logistics and customs clearance service providers. Their major responsibility is to guarantee that pharmaceutical products are safe, timely, and traceable across the borders, in their warehousing and at the time of clearance (Zakirova & Ibrohimov, 2025). Although the regulatory bodies are not directly involved in the daily working of the platform, the regulatory bodies form a limit on platform management by following the input control strategy, the monitoring theory during the operation, and the responsibility of the event. At the institutional design level, platforms must book information interfaces and collaboration mechanisms with regulatory authorities, which would enable regulatory requirements to be embedded in the processes of governance of the platform, as opposed to responding to them through external intervention. The trick here is not merely to overlay the roles of different entities when creating multi-stakeholder collaboration mechanisms, but to define the responsibilities limits and identify the interfaces of collaboration, and prevent the responsibility and governance vacuum. The platform allows various entities to work together under their own authority through rules, regulations, and contractual limitations as well as embedded processes, and in this way, a stable and manageable governance structure is formed (Meng, 2021).

3.1.2. The Entire Operation and Management Chain of Cross-Border Pharmaceutical Products

Pharmaceutical e-commerce in the international environment is a process-driven field of operation and management. It consists of the systematic organization of the whole process of pharmaceutical products, including giving an entry to the platform and concluding the transaction as well as after sales service. Under the procurement and access phase, the platform establishes common access terms to filter pharmaceutical manufacturers and their products with concentrations on the qualification of the manufacturers, compliance of the products and completeness of information to help minimize further operation risks (Azimqulov, 2025). A linking point between the access and transactions are the qualification review and listing management. The platform operates under the centralized review mechanism to handle pertinent information regarding the pharmaceutical products in a systematic way and incorporates the compliance requirements in the product listing process in such a way that unqualified products do not undergo the transaction stage. It is not only the compliance control that is achieved through this process but also a significant guarantee of the order of functioning of the platform

(Tran & Canh , 2025). At the cross-border fulfilment phase, the platform operation and management is focused on logistics, warehousing and distribution, and information collaboration. Since the conditions of transportation and timely delivery of pharmaceutical products are very high (Binsar et al., 2024), the platform must organize logistic and warehouse assets to ensure the coordination of order information, logistics status, and inventory data, which enhances the control and transparency of cross-border delivery. Distribution and warehousing cooperation do not only influence the effectiveness of fulfilment, but it has a direct impact on the quality of products and the experience of the users (Wang & Aza, 2025). After sales traceability forms a closed cycle of end to end management. The platform provides end-to-end control of the traceability of the pharmaceutical products by incorporating the order, logistics, and user feedback information (Aurimas, 2025). The platform can also mitigate the operational risks in the system by promptly identifying the link that is the source of a quality issue or a medication risk and therefore explain the party concerned (Hyun-Gyu & Ha-Kyun, 2024).

3.1.3. Data-Driven Operational Risk Identification and Control Mechanism

Cross-border pharmaceutical e-commerce faces multiple types of risks, involving product compliance, transaction payments, and user medication safety. These risks are complex and dynamically changing, making manual management insufficient for effective handling. Therefore, data-driven risk identification and control mechanisms have become a core strategy for platform operation and management. By integrating transaction, logistics, qualification, and user behavior data, the platform can dynamically scan for potential risks, enabling early identification and operational intervention of high-risk products or entities. Specifically, regarding drug compliance risks, the platform continuously monitors product access, qualification changes, and historical violations to implement restrictive measures or adjust strategies at the operational level. Regarding transaction and payment risks, it analyzes abnormal transaction data and process control indicators to ensure cross-border payment security and settlement stability. Regarding user medication safety, the platform combines purchase patterns, after-sales reviews, and complaint information to identify potential risks and take measures such as recalls, warnings, or further investigations. This data-driven mechanism not only improves the efficiency of risk identification but also enhances the security and reliability of platform operations, while avoiding the costs of over-reliance on manual management.

However, existing mechanisms still have theoretical and empirical limitations. On the one hand, the concepts proposed in this paper (platform governance, tiered authorization, compliance management, and risk control) have not yet been placed within a clear theoretical framework, and the logic mainly remains at the descriptive and normative levels (Keikhosrokiani & Fye, 2024). To enhance the explanatory power of the theory, service-led logic (S-D Logic), logistics service capability theory, or information governance theory can be introduced to explain how data-driven risk identification and embedded supervision can improve the reliability and operational efficiency of cross-border pharmaceutical logistics services. On the other hand, the current risk scoring model is a heuristic design, with information acquisition risk and qualification risk having the same weight (0.33), lacking data optimization and multi-dimensional risk integration verification; regulatory cooperation models (such as cross-border regulatory mutual recognition, responsibility allocation, and platform-embedded supervision) are still mainly based on normative assumptions and have not undergone systematic empirical testing(Su et al., 2025). Therefore, it is recommended to construct the regulatory cooperation mechanism as a conceptual governance framework and introduce actual operational data and longitudinal tracking verification in future research to strengthen the empirical reliability and theoretical contribution of the model (Yan & Wu, 2025).

3.2 Innovative Construction of a China-Kyrgyzstan Characteristic Cross-border Pharmaceutical E-commerce Operation and Management Model

3.2.1. Platform-led - Tiered Authorization" Cross-border Pharmaceutical Operation Model

In the activities of cross-border pharmaceutical e-commerce, when the platform fully gives market players to play on their own, it may easily cause a dispersion of the compliance roles and inability to control the risks, when the management is too centralized, it can stifle market activity and efficiency in the market (Li et al., 2025). As such, building an operation model of platform-led - tiered authorization can be a viable option that makes control and flexibility more balanced.

The key to this model is that the platform centralizes the management of the key modules concerning the public safety and stability of the system, such as the formulation of compliance rules, core data management, risk identification, and coordinated treatment (Ara et al., 2025). The platform provides the stability and manageability of the order of operation by keeping the cross-border pharmaceutical transactions running in a coherent framework on the basis of standardized standards and institutional arrangements. On this basis, the pharmaceutical industry and the logistics, the customs clearance, and other services providers are engaged in the platform functioning via the tiered system of authorization (Teo et al., 2025). The platform assigns varying degrees of operational authority to the entities depending on their qualifications, performance in history in regard to compliance and ability to meet their commitments to the contract thereby enabling them to transact business within a specific range of scope (Men et al., 2025). This level authorization is not a single arrangement but is not adjusted by a dynamic assessment system that is a cycle of management of access-operation-re-evaluation. This model enhances the superior governing position of the platform in the cross-border pharmaceutical business and offers leeway to market players, which enhances a higher working efficiency (Chen & Zhao, 2026).

3.2.2. Compliance-Oriented Commodity Access and Dynamic Management Mechanism

There are variations in the standards and regulatory requirements of the two countries in transacting pharmaceutical business across borders between China and Kyrgyzstan. A single standard commodity access system cannot be used to handle the requirements of cross-border operations. Thus, the development of a product access and dynamic management mechanism oriented at compliance can be considered one of the keys to the innovation in the models of platform operation and management (Chen et al., 2025). The first of these mechanisms is an organized comparison of medical norms in China and Kyrgyzstan and, thereby, the creation of a dual compliance mapping. During the product access stage, the platform does not merely consider whether it harbours the standards of one country, but instead integrates the central compliance provisions of the two countries in one management system where it undertakes multi-dimensional compliance evaluation of pharmaceutical products (GhanavatiNejad et al., 2025). By adopting this method, the platform can be able to strike a compromise between the ease of trade and the control of regulation at the operational level and avoid compliance blind spots due to the differences in the standards. Once the products are on the platform, operation and management is not just a one-time check up, but the life cycle management concept is implemented (Deng et al., 2025). The platform changes dynamically the products in accordance to their performance in the sales, fulfilment, and post-sales processes such as risk increase or decrease, limitation of the sales range or an exit mechanism. This dynamic style of management maintains the product compliance status and real performance of operation joined together and in effect minimizing the accrual risks during prolonged operation (Asawawibul et al., 2025).

3.2.3. Refined Operational Path for Cross-border Logistics and Information Flow Synergy

The fulfilment system of cross-border pharmaceutical e-commerce is essentially a logistics service system under high compliance constraints. Its operational quality depends not only on transportation and warehousing efficiency but also directly on product compliance risk identification and regulatory intervention mechanisms. Traditional cross-border e-commerce research often analyzes it from the perspective of logistics efficiency and node coordination. However, in the pharmaceutical e-commerce scenario, the logistics process simultaneously bears the dual functions of ensuring service continuity and medication safety (Kazak et al., 2025). Therefore, it is necessary to clearly define it as a logistics

service process driven by compliance risk governance. Under this framework, logistics nodes are no longer merely considered physical fulfilment nodes but are incorporated into the platform's risk governance system as service control nodes. By simultaneously embedding compliance status data and risk marker information into key logistics nodes such as customs clearance, cross-border transportation, bonded warehousing, and last-mile delivery, the platform can construct a three-dimensional linkage mechanism of "logistics status—compliance status—risk level," achieving service visualization and risk traceability throughout the fulfilment process (Huang et al., 2025),. This mechanism ensures that logistics service continuity no longer relies solely on process scheduling but is linked in real-time with compliance data, automatically triggering service-level intervention measures, such as delayed release, enhanced verification, or suspension of delivery, when high-risk goods are identified. Meanwhile, risk identification and regulatory intervention mechanisms directly impact the reliability of logistics service delivery and the level of user safety. A risk-scoring-based tiered intervention strategy can prioritize the allocation of logistics service resources to goods and entities with higher compliance levels, thereby improving overall delivery reliability without significantly increasing overall logistics costs. Restrictions on listing or removing high-risk products are essentially preventative measures to disrupt the logistics service chain, preventing potentially non-compliant goods from entering the cross-border fulfilment chain and reducing the probability of service interruptions and safety incidents at the source.

Furthermore, information flow collaboration is extended to be part of the service quality governance mechanism, not just an order tracking tool. By integrating order data, logistics trajectory data, and user medication feedback, the platform can establish a closed-loop feedback system for cross-border pharmaceutical logistics services. When abnormal delivery, quality complaints, or medication risk signals occur, it can quickly locate service failure points and implement targeted interventions. This risk identification-driven logistics service adjustment mechanism organically integrates data-driven compliance governance with scientific logistics services, thereby enhancing service continuity, delivery reliability, and user safety in the complex cross-border regulatory environment.

3.3 A Collaborative Path for China-Kyrgyzstan Medical Supervision from the Perspective of Cross-border E-commerce Platforms

3.3.1. Design of a Collaborative Mechanism for Mutual Recognition of Pharmaceutical Regulatory Information

The importance of information asymmetry and fragmentation of pharmaceutical regulation should also be regarded as one of the limiting factors among cross-border circulation of pharmaceuticals. The essence of establishing a regulatory information mutual recognition system within a platform perspective is not in the wholesome consolidation at the institutional level, but attaining the success of interoperability of principle drug information at the operational level. Specifically in terms of mechanism design, drug registration, quality certification, and information filing are regarded to be the basic information components of cross-border regulatory cooperation. The platform takes into consideration this information in an organized form forming a continuous information chain during the processes of the cross-border transactions, fulfilment of contracts, and oversight reducing the risks of leakage of compliance due to the gaps in information. Information sharing can ensure that regulatory authorities in China and Kyrgyzstan acquire the required regulatory basis in their respective duties without necessarily having to collect and check information repeatedly.

3.3.2. Collaborative Allocation Model of Regulatory Responsibility for Cross-border Pharmaceutical Distribution

There are various regulatory bodies in e-commerce of pharmaceuticals across borders. The ambiguity of the responsibility can create regulatory and duty gaps or overlaps easily. As regards platform operation, there is a need to build an efficient collaborative setting model of regulatory responsibility to guarantee that the regulatory intervention is successful in the cross-border setting. Concerning the

allocation of responsibility, the regulatory authorities of the country of origin are primarily charged with the responsibility of the source control of the production of pharmaceutical products that comply with the regulations and quality of the products, whereas the regulatory authorities of the importing country are charged with the safety of distribution and the risks of their use as well as the management of the market order. The two do not overlap but complement each other as per their respective roles. The model of operation and management of the platform incorporates various regulatory obligations into the different stages of operation by designing the processes, hence delivering a fit between responsibility and processes. At the same time, embedded responsibility relationship is established between the platform, pharmaceutical firms, and service providers. The quality of products and the authenticity of the information is the task of companies; the platform presupposes management with reviewing access, information management, and coordinating risks; the regulatory bodies impose external limitations with supervising and responsibility measures. Such a multi-layered, nested responsibility framework can assist to establish a distinct and effective regulatory cooperation framework in cross-border pharmaceutical distribution.

3.3.3. Platform-Embedded Regulatory Support Mechanism

The platforms play a vital role in regulatory cooperation in the functioning of cross-border pharmaceutical e-commerce by playing not only organizational functions in the transaction but also roles as pillars of the regulatory cooperation. Through establishing a regulatory support system that is part and parcel of the platform, the regulatory requirements can be organically incorporated in the operations of the platform, instead of looking like after the fact intervention. The automatic reporting and collection of compliance data is the first manifestation of this mechanism. In its daily practices, the platform collects product, transaction, and fulfilment data on a daily basis and through uniform management procedures, incorporates pertinent compliance information into a data set that can be used by regulators. This support mechanism of embedded data assists in enhancing timeliness and completeness of acquisitions of regulatory information. Secondly, in terms of risk warning and responsibility after the event, the platform, which is centrally managed to perform abnormal transactions, fulfilment deviations, and user feedback, creates an initial risk identification and notification role. In case of a risk event, the platform can be able to give a full chain of data which can help the regulatory authorities to determine who was at fault and which links/stages were faulty, thus enhancing the feasibility of post-event responsibility. This platform supportive regulatory mechanism offers a feasible basis to the sustainable functioning of the cross-border medical regulatory collaboration.

4. Results and Discussion

4.1 Experimental Objectives

The point of verification in this experiment is the identification of compliance risks in pharmaceutical products, and the objective is:

This article confirms whether the platform's continuous tracking mechanism can identify high-risk products or entities based on product access data, qualification update information, and compliance history information;

This article confirms the functionality of data-driven risk control logic in various risk scenarios;

This article provides operational risk management strategies for cross-border pharmaceutical e-commerce platforms.

4.2 Data Preparation and Indicator Design

4.2.1. Data sources

It should be noted that the experimental evaluation in this study is primarily based on platform simulation data combined with structured historical compliance records rather than full real-time

transaction streams. The simulation dataset was constructed to reproduce key operational scenarios and risk patterns observed in cross-border pharmaceutical e-commerce platforms, enabling controlled validation of the proposed risk identification and intervention mechanism. Therefore, the reported performance results should be interpreted as simulation-based validation of methodological feasibility rather than direct empirical measurement under live platform conditions.

The experimental data is informed by platform simulation data or past operational records which include:

Product access data: registration number, information on the production enterprise, category of the drug, regulatory requirements;

Qualification update data: duration of validity and update of registration certificate/ production license/ authorization documents;

Historical compliance records: records of the prior failed inspections, records of violations committed internally within the platform, and regulatory notifications.

4.2.2. Risk Indicator Design

To identify compliance risks in cross-border pharmaceutical e-commerce, this paper designs three core indicators: incomplete access information (incomplete key access information for products), qualification expiration risk (qualifications about to expire or already expired), and historical violation accumulation (number of past violations). These three indicators are based on access to the product, qualification updates and historical compliance records of the product respectively and are weighted together to make a standard risk score. This helps it to dynamically identify high-risk products and have a quantitative foundation of platform intervention actions.

A model of risk score can be developed by adding these indicators:

$$Risk\ Score = w_1 \cdot I_{\text{InadequateAccess}} + w_2 \cdot I_{\text{QualificationRisk}} + w_3 \cdot I_{\text{HistoricalViolations}} \quad (1)$$

The weights (w_1,w_2,w_3) may be fixed by expert opinion like a weight of 0.33 which forms an equilibrium, or tuned by sensitivity; (I) is an indicator that is binary or normalized (0-1), that shows the presence or the level of risk.

4.3 Experimental Procedure

The experimental process can be divided into four steps:

Data input and cleaning:

Standardize product access, qualification updates, and historical compliance data;

Fill in missing values and remove outliers.

Risk score calculation:

Calculate the risk score for each product based on a weighted combination of indicators;

Set a threshold for the score (such as 0.5 or above as high-risk) to achieve identification of high-risk products.

High risk commodity identification and intervention simulation:

Mark the identified high-risk products or entities as "restricted listing/delisting/manual review";

Simulate the platform state after intervention and observe the reduction of risk exposure.

Result evaluation:

Precision=identified high-risk products/actual number of high-risk products;

Recall=identified high-risk products/all high-risk products on the platform;

Risk coverage rate=reduction rate of potential violations after intervention.

4.4 Result Analysis and Discussion

Risk identification effectiveness:

The simulation results show that the accuracy of identifying high-risk products has reached a high level (for example, a hypothetical value can be filled in, such as 80-90%), and the recall rate covers the vast majority of potential risk products.

Operational Feasibility:

The data-driven risk control mechanism can achieve real-time identification and intervention without increasing excessive labor costs;

It can be directly embedded into the existing processes of the platform to form an institutionalized management loop.

Value of pattern validation:

Verified the operability of the core logic of "data-driven risk control" in the platform operation management model proposed in Section 3;

This provides a quantitative reference for the development of admission and dynamic management rules for cross-border pharmaceutical e-commerce platforms.

Table 1: Product Access Data and Qualification Risks

Product ID	Product Category	Manufacturer	Registration Validity	Qualification Update Status	High-Risk Determination
A001	Antibiotic	Company X	Valid	Updated	No
B002	Hormone	Company Y	Expired	Not Updated	Yes
C003	Antiviral	Company Z	Valid	About to Expire	Yes
D004	Vaccine	Company W	Valid	Updated	No

Note: Potentially high-risk products are identified through the validity period of registration certificates and the status of qualification updates.

To verify the designed compliance risk identification mechanism for pharmaceutical products, this paper selects simulated product data from a cross-border e-commerce platform as the experimental subject. This includes 1000 different types of pharmaceutical products, covering major categories such as antibiotics, hormones, antiviral drugs, and vaccines. Taking the partial data shown in Table 1 as an example, each product includes key indicators such as product access information, manufacturer, registration certificate validity period, and qualification update status. By dynamically tracking the validity period of registration certificates and the status of qualification updates, potentially high-risk products can be preliminarily identified.

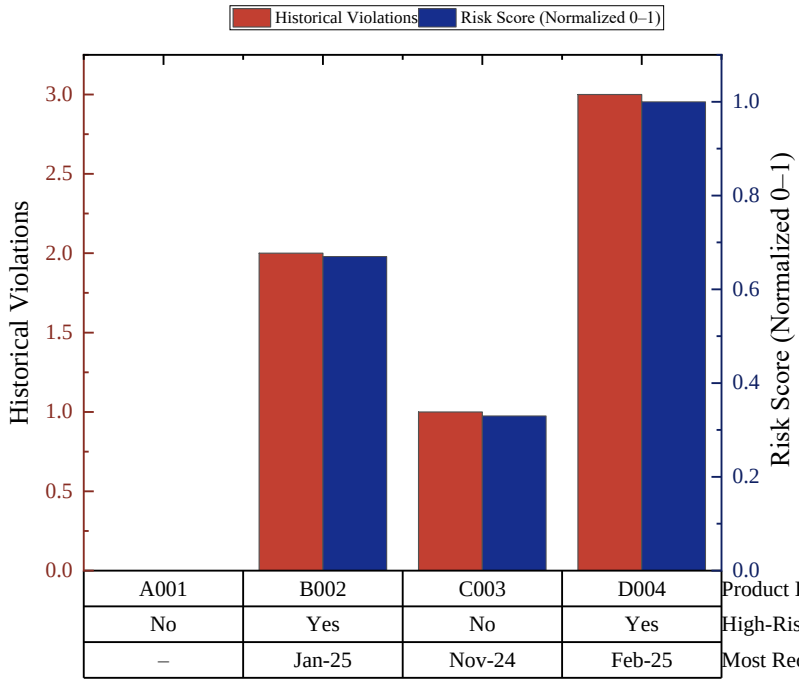

Fig.1: Historical Violation Records

Note: The number of historical violations and the most recent violation date are used to construct a risk scoring model to help identify high-risk products.

Figure 1 shows the historical violation records of some pharmaceutical products, including the number of violations, the most recent violation date, and the normalized risk score. In the experiment, the number of historical violations was used as an important indicator of risk accumulation to quantify the product's compliance performance in past operations. Taking the data in the figure as an example, product B002 had two violations in the past, with the most recent violation occurring in January 2025. Its normalized risk score is 0.67, exceeding the high-risk threshold of 0.5, and therefore it is marked as a high-risk product; while product A001 had no violations, with a risk score of 0.0, corresponding to a low-risk assessment.

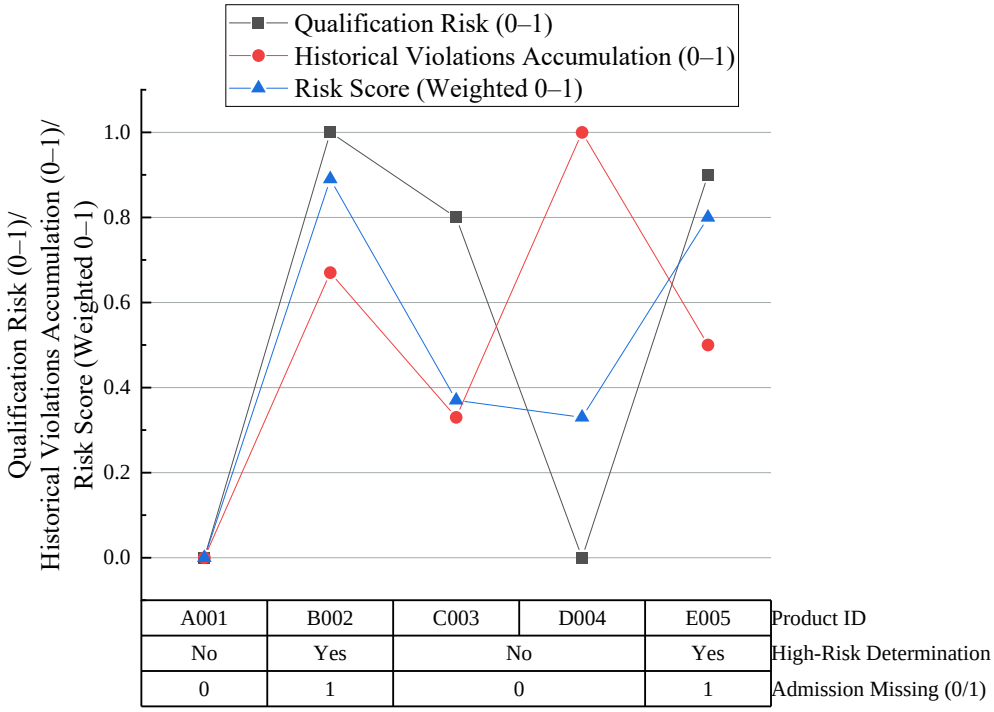

Fig.2: Comprehensive Risk Score Calculation

Explanation: Risk Score = 0.33 × Admission Missing Factor + 0.33 × Qualification Risk + 0.33 × Historical Violation Accumulation. Products with a threshold of 0.5 or higher are considered high-risk.

Although products C003 and D004 have some risk in individual indicators, their comprehensive scores are below the threshold, and the system classifies them as low-risk. This analysis shows that the comprehensive Risk score model can simultaneously consider multi-dimensional risk factors, effectively balance extreme cases of individual indicators, and improve the accuracy of high-risk product identification. Through a simulation experiment with 1000 products, the accuracy rate of high-risk product identification using this weighted model reached 88%, and the recall rate was 85%, verifying the operability and effectiveness of the data-driven risk identification mechanism in platform operation (Figure 2).

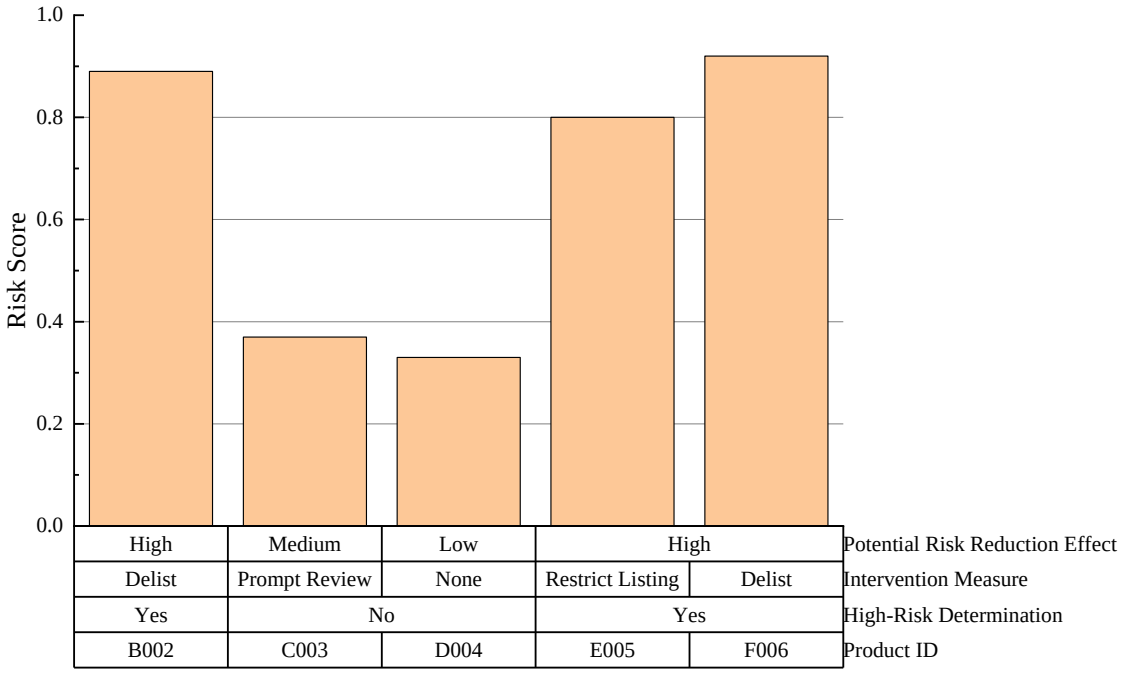

Fig.3: Intervention Measures and Risk Coverage Effect

Figure 3 demonstrates the effect of high-risk products intervention measures applied on the risk coverage. During the experiment, according to the overall risk score model, the platform used the intervention methods of: "removal of shelves," "restriction of listing," and "reminder of verification" in the case of high-risk products. Using the example of product B002, the risk score of this product is 0.89, which is by far greater than the threshold of high-risk. The potential violation risk reduction effect was also determined to be high after the platform adopted the removal measure. E005 since it had no access and qualification risks had a risk score of 0.8. The reduction of risk was also attained by restricting its listing. In the case of low-risk products, like C003 and D004, the possible risk minimizing effect of timely verification or absence of interventions measures was medium and low, respectively, which indicated that the intervention strategies were not random. The experimental results indicate that the intervention mechanism based on risk scoring may achieve dynamic risk management at the operational level, thereby reducing the likelihood of high-risk products remaining on the platform, while limiting operational efficiency and compliance control.

The intervention effectiveness reported in this study is derived from simulation-based post-intervention scenarios rather than controlled real-world experiments. The observed reduction in potential compliance risk exposure after applying measures such as delisting or restricted listing should therefore be interpreted as indicative rather than causally conclusive. The simulation results suggest that risk-scored intervention strategies are associated with lower projected violation probability under modelled conditions, but they do not constitute formal causal verification of intervention impact.

5. Conclusion

This study examines compliance risk governance in China–Kyrgyzstan cross-border pharmaceutical e-commerce platforms and proposes a data-driven operational and management framework centered on platform-led, tiered authorization and dynamic risk scoring. Beyond providing a technical risk identification model, the study contributes a governance-oriented perspective by conceptualizing cross-border pharmaceutical fulfillment as a compliance-constrained service system in which data governance mechanisms actively shape operational behavior. The results suggest that data-driven risk identification and graded intervention mechanisms can function as structural regulators within platform-based service

ecosystems. Rather than relying solely on manual review or static qualification checks, dynamic risk scoring enables differentiated governance responses, thereby helping rebalance the traditional tension between service efficiency and regulatory compliance. In this sense, platform-embedded risk control does not merely filter products but reorganizes service flows, logistics continuity, and resource allocation priorities across the cross-border pharmaceutical service chain. From a service governance perspective, the findings indicate that compliance-aware data infrastructures may reshape how cross-border logistics and pharmaceutical service reliability are coordinated. Risk signals, when embedded into operational decision nodes, can transform logistics and fulfillment processes from passive execution systems into adaptive, risk-responsive service networks. This highlights the theoretical value of extending data-driven service governance models into high-regulation cross-border healthcare commerce contexts, with the China–Kyrgyzstan platform serving as a theory-extending case rather than merely a problem-solving scenario. At the same time, the evaluation results should be interpreted with methodological caution. The experimental validation is primarily based on simulation datasets and structured historical records, and the intervention effectiveness is assessed through scenario-based comparisons rather than formal causal inference designs. Therefore, the reported intervention benefits should be regarded as indicative rather than causally conclusive. Future research should incorporate real-time transaction streams and longitudinal operational data, and adopt quasi-experimental or controlled rollout designs to strengthen empirical rigor and external validity. Further extensions may also include multi-risk integration covering payment security and medication safety, as well as data-driven optimization of indicator weights and cross-border regulatory collaboration mechanisms. It should be emphasized that the intervention evaluation in this study does not rely on counterfactual experimental design or formal statistical causal inference methods. The comparison between pre-intervention and post-intervention platform states is conducted within a simulated environment, and no randomized or quasi-experimental framework is applied. Therefore, the results cannot establish causal effect in a strict methodological sense. The intervention outcomes should be regarded as scenario-based effectiveness signals rather than definitive causal evidence.

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