

Assessment Indicator System for Market Connectivity of the Hainan Free Trade Port in China

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Abstract: On December 18, 2025, the Hainan Free Trade Port in China officially commenced its island-wide customs closure operation. This marks the practical implementation of its institutional framework characterized by front-line liberalization, second-line management, and on-island freedom. This paper provides an operational definition of market penetration and establishes two subsystems: a facilitation penetration subsystem (U1) and a risk prevention and control subsystem (U2). In terms of index design, a three-tier indicator system is constructed. U1 primarily evaluates the level of penetration, incorporating indicators such as customs clearance efficiency, reduction of institutional costs, and second-line traffic flow. U2 mainly assesses risk controllability, including indicators like tax compliance, risk early warning, and emergency response. Methodologically, the indicators are first standardized. Then, the weights for the two subsystems are determined using the entropy weight method and combined weighting. Subsequently, this paper introduces a coupling coordination degree model to develop a controllable openness coordination index. This index addresses a core research question: as the level of facilitation improves, whether risk prevention and control capabilities can keep pace and whether synergistic effects are achieved. This study translates key systemic requirements for customs closure operations into observable and quantifiable indicators, thereby creating a set of reproducible evaluation tools. These tools can be applied for operational assessment in the first year of customs closure, stress testing, system refinement, and ultimately, for developing a sustainable and updatable policy dashboard.

Keywords: Hainan Free Trade Port; Island-Wide Customs Closure Operation; Market Connectivity; Trade Facilitation; Risk Prevention and Control

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1.Introduction

1.1 Research Background and Importance

The establishment of the Hainan Free Trade Port is a key initiative by China to advance high-level opening-up. The island-wide customs closure operation signifies that relevant systems are accelerating their shift toward a comprehensive and institutionalized openness. According to the Hainan Provincial Government's notice, the full island closure officially took effect on December 18, 2025. Simultaneously, a series of supporting documents were implemented, including those concerning front-line and second-line tax policies for inbound and outbound goods, the catalogue of taxable imported goods,

measures for duty-free processing value-added management, lists of prohibited items, and customs supervision regulations. This creates a clear institutional boundary and observable policy transition point, providing a practical basis for constructing an evaluative framework that is monitorable, comparable, and adjustable.

The performance evaluation of customs clearance operations should not remain one-dimensional. On one hand, it is necessary to measure the improvements in trade facilitation, clearance efficiency, and the reduction of institutional transaction costs resulting from the opening-up policy. On the other hand, it is also essential to assess whether supervision measures—such as tax certification monitoring, risk identification, and closed-loop management—are sufficient to manage the increased risks associated with a higher degree of openness. In other words, the core of customs clearance operations is not a choice between openness and supervision, but rather the synergy of achieving controllable openness.

Therefore, rather than focusing solely on macro-level outcome variables, this paper develops a rolling evaluation system based on operational performance.

1.2 Research Questions

Focusing on the policy goal of achieving controllable openness, this paper addresses three testable research questions:

- (1) How can market penetration under the island's closed operation be defined and disaggregated to simultaneously reflect the structural characteristics of the “first line”, “second line,” and “free trade zones” on the island?
- (2) How can a three-tier indicator system be established to translate key institutional elements into observable and measurable indicators, thereby generating a continuously updatable composite index?
- (3) As the level of trade facilitation increases, does risk control capacity improve correspondingly? How can replicable statistical or modeling tools be employed to characterize the synergistic relationship between openness and regulation?

1.3 Research Approach and Identification Strategy

This study takes December 18, 2025, as the system impact point (t_0) and adopts an evaluation framework that progresses from index system construction to index compilation and finally to coordinated assessment:

- (1) Constructing a three-tier indicator system for the dual (“twin”) systems.
- (2) Standardizing indicators and assigning weights to form the U_1 and U_2 sub-indices.
- (3) Building a coordination index, based on the coupling coordination degree model, to comprehensively assess whether the openness is controllable.
- (4) Employing methods such as regression discontinuity design or event study analysis to test for structural changes in the indices. This empirical test is grounded in key policy events and institutional information, primarily sourced from provincial government notices and the publicly available data caliber of the National Development and Reform Commission.

1.4 Research Contributions

Conceptual Contribution: This paper proposes an operational definition of “market penetration” within the context of customs clearance operations. By decomposing it into two subsystems—trade facilitation penetration and risk controllability—it enables the quantitative expression of “controllable openness.”

Methodological Contribution: A three-tier indicator system for dual (“twin”) systems is constructed. By employing the entropy method / combined weighting approach and the coupling coordination degree model, a computable composite index is formulated. This methodology addresses the critical challenge of evaluating trade facilitation and risk management within a unified analytical framework.

Policy Contribution: Key institutional features of customs clearance operations—such as zero-tariff expansion, establishment of second-line ports, qualified market access, and targeted supervision—are mapped into specific indicators and monitoring metrics. This forms a scrolling policy dashboard, providing a practical tool for operational evaluation, stress testing, and systematic iteration during the first year of the island-wide closure operation.

2. Scoring Efficiency

Research on trade facilitation has traditionally relied on established evaluation frameworks. Key international benchmarks include the World Bank's (2018) Logistics Performance Index and the OECD's (2013) Trade Facilitation Indicators, which primarily assess national-level administration such as customs efficiency, infrastructure, and procedural simplification.

Anderson & van Wincoop (2004) advanced the core concept of trade costs, emphasizing the critical role of institutional transaction costs in enabling smooth trade. However, these conventional methods are predominantly designed with a single customs border as the unit of analysis. Consequently, they struggle to capture the dual regulatory structure unique to the Hainan Free Trade Port, characterized by front-line liberalization and second-line control. The central challenge for Hainan lies not in the efficiency of any single port, but in achieving synergy between the convenience afforded by front-line liberalization and the security and compliance ensured by second-line management. Existing international indicators are not readily adaptable to this distinctive institutional architecture.

When evaluating the impact of free trade zone (FTZ) policies, a common approach in the literature is to employ difference-in-differences (DID) models to assess their effects on aggregate outcomes such as trade volume and investment. Recent methodological advances, including multi-period or staggered DID designs, have provided more accurate tools for analyzing policies that are rolled out gradually over time. However, a major limitation of these studies is their predominant focus on the overall effectiveness of policies. They tend to lack a granular analysis of the operational linkages between the front line, second line, and the internal island economy. This makes it difficult for such analyses to inform the nuanced, real-time monitoring and management required after the implementation of island-wide customs closure operations.

The core challenge in building a free trade port lies in balancing liberalization with effective control. Risk management is a crucial precondition for ensuring that openness is both sustainable and secure. Relevant policy documents have established a comprehensive risk management framework covering taxation, prohibited goods, and customs supervision. However, most academic discussions remain at the level of textual description or institutional proposals, lacking a dynamic monitoring system that can be integrated and directly compared with trade facilitation indicators. Consequently, it remains difficult to empirically verify a key practical question: whether the degree of openness is adequately matched by the corresponding regulatory capacity.

The selection of an appropriate methodology is critical when constructing a multi-dimensional comprehensive evaluation system. Saaty's (1980) Analytic Hierarchy Process (AHP) provides a widely used framework for determining indicator weights by synthesizing expert judgments. Complementarily, Shannon's (1948) information entropy theory underpins an objective weighting method—the entropy weight method—which automatically adjusts weights based on the inherent distribution of the data. This makes it particularly suitable for scenarios requiring high-frequency monitoring. By integrating these subjective and objective weighting approaches and subsequently applying a coupling coordination degree model, the level of coordination between two systems (e.g., trade facilitation and risk prevention/control) can be effectively quantified. This integrated methodology constitutes the core analytical toolkit needed to measure the dynamic quality of controllable openness.

In summary, the existing literature exhibits three main limitations:

First, the index system is structurally misaligned. There is a lack of evaluation indicators that fully correspond to the distinct institutional architecture of Hainan's customs closure operation.

Second, the analytical dimension is fragmented. Research on trade facilitation and risk management has long been conducted in separation, lacking a unified analytical framework to quantitatively assess their coordination.

Third, the policy linkage is weak. Macro-level policy impact evaluations are difficult to translate into observable signals that can be directly linked to the implementation of specific policy documents (e.g., Ministry of Finance and Customs Announcement No. 12 [2025] and General Administration of Customs Announcement No. 158 [2025]).

The goal of this study is to address these gaps. First, drawing on specific institutional documents governing customs closure operations, we construct a three-tier indicator system comprising two subsystems: trade facilitation and risk prevention/control. Next, by integrating a combined weighting approach with a coupling coordination degree model, we build a Controllable Openness Coordination Index (D-index). Ultimately, this process yields a policy monitoring tool capable of transforming key institutional requirements into observable, measurable, and regularly tracked indicators. This tool is designed to provide robust methodological support for operational evaluation and timely policy adjustment during the initial phase of the island-wide customs closure.

3.Three-Tier Indicator System: Structured Mapping of Observable Indicators for Multi-Line Management

Principles for Indicator Construction :

1. Structural Consistency: Indicators must directly correspond to the three-tier institutional architecture of front line – second line – island-wide operations.
2. Dual-Objective Integration: Both trade facilitation and risk prevention/control are measured within a unified framework, avoiding a singular focus on either aspect.
3. Data Accessibility & Substitutability: Each third-tier indicator specifies primary data sources and alternative measurement standards, ensuring the system’s functionality for rolling updates during the initial year of customs closure.
4. Policy Explanatory Power & Manageability: Indicator movements must be clearly linked to specific policy actions (e.g., port facility upgrades, clearance process reforms, account book supervision, adjustments to catalogs/lists).
5. Temporal Comparability: The system must enable comparisons, at minimum, across the pre- and post-closure periods (benchmark date $t_0 =$ December 18, 2025) and support quarterly rolling comparisons.

Table 1. Market Penetration Assessment Indicator System

Subsystem	Secondary Dimension	Tertiary Indicator (Code)	Indicator Definition (Proposed Caliber)	Direction	Frequency
U1 Facilitation Penetration	A1 Front-Line Clearance Efficiency	A1-1 Average Release Time	Average time from declaration to release for imports at front-line ports (minutes/hours)	-	Monthly/ Quarterly
		A1-2 Direct Release Ratio	Percentage of eligible goods cleared through direct release at front-line ports (%) (Aligned with port operation capacity)	+	Monthly/ Quarterly
		A1-3 Inspection Sampling Rate	Number of shipments inspected at front-line ports / Total number of declarations (%)	±	Monthly/ Quarterly
	A2 Second-Line Transit Efficiency	A2-1 Transit Time	Average time from declaration to transit at second-line ports	-	Monthly/ Quarterly
		A2-2 Congestion Intensity	Peak-hour queue time / Capacity utilization rate (index)	-	Monthly/ Quarterly
		A2-3 Duty Adjustment Processing Time	Average processing time for duty reassessment or settlement on zero-tariff goods	-	Quarterly
	A3 Institutional Transaction Costs	A3-1 Per-Shipment Compliance Cost	Average compliance cost per customs declaration or tax certification for enterprises (survey or sample data)	-	Half Year/ Year
		A3-2 Regulatory Transparency Score	Catalogs, lists, and predictability of procedures (expert rating or text quantification)	+	Quarterly/ Year
		A3-3 Beneficiary Coverage Ratio	Number of entities benefiting from preferential policies / Estimated total entities with import demand on the island (%)	+	Quarterly/ Year
	A4 Intra-island Circulation & Domestic-Foreign Trade Integration	A4-1 Intra-island Circulation Convenience Index	Ratio of circulation frequency to restriction incidents for zero-tariff goods within the island (index)	+	Quarterly
		A4-2 Integration Intensity Index	Coverage rate / Share of enterprises adopting identical standards for both domestic and foreign trade (%)	+	Year
		A4-3 Port-Air Connectivity Index	Number of international routes, flight/bus frequency density, or throughput growth rate (index)	+	Quarterly/ Year

Subsystem	Secondary Dimension	Tertiary Indicator (Code)	Indicator Definition (Proposed Caliber)	Direction	Frequency
U2 Risk Prevention & Control	B1 Tax Collection & Compliance	B1-1 Duty Recovery Compliance Rate	Amount of recovered duties fully collected / Total amount of duties due for recovery (%)	+	Quarterly
		B1-2 Irregular Benefit Claim Rate	Number of shipments with irregular benefit claims / Total number of shipments benefiting (%)	-	Quarterly
		B1-3 Tax Documentation Error Rate	Rate of declaration errors, amendments, or rejections for tax-related documents (%)	-	Monthly/ Quarterly
	B2 Restricted/ Prohibited Lists & Border Enforcement	B2-1 List Hit Disposal Rate	Rate of cases involving hits on restricted/prohibited lists disposed of in accordance with regulations (%)	+	Quarterly
		B2-2 Border Non-compliance Severity	Volume / Value / Index of prohibited/restricted goods entering non-compliantly	-	Quarterly
		B2-3 Permit Processing Time	Average time for quota/license processing (working days)	-	Quarterly
	B3 Risk Identification & Targeted Supervision	B3-1 Risk Targeting Hit Rate	Number of risk-based inspections yielding a hit / Total number of risk-based inspections conducted (%)	+	Quarterly
		B3-2 False Positive Rate	Number of risk-based inspections cleared without violation / Total number of risk-based inspections conducted (%)	-	Quarterly
		B3-3 Audit Closed-loop Rate	Number of audit findings with rectification closed / Total number of audit findings (%)	+	Half Year/ Year
	B4 Emergency Response & Resilience Governance	B4-1 Incident Response Time	Average time from risk incident detection to full resolution	-	Quarterly
		B4-2 System Availability	Operational uptime of key regulatory/clearance information systems (%)	+	Monthly/ Quarterly
		B4-3 Market & Public Sentiment Stability Index	Magnitude of logistics/price volatility triggered by emergency incidents (index)	-	Quarterly

Note: Direction indicates the contribution of an indicator to the composite index: + denotes a positive indicator (larger values are better); -denotes a negative indicator (smaller values are better); ± indicates a threshold or bilateral risk indicator (values should ideally fall within a specific range; neither too high nor too low is optimal).

4.Methods and Models: Constructing the Controllable Openness Coordination Index from Indicators

(1) Indicator Standardization

Let the original value of the i-th tertiary indicator at the region/port level (or aggregated for the entire island) in period t be denoted as x_{it} . The min-max normalization method is applied as follows:

Positive indicator (Higher value indicates better performance) :

$$z_{it} = \frac{x_{it} - \min(x_i)}{\max(x_i) - \min(x_i)}$$

Negative indicator (Lower value indicates better performance) :

$$z_{it} = \frac{\max(x_i) - x_{it}}{\max(x_i) - \min(x_i)}$$

Bilateral (Threshold) Indicator: An ideal range $[L_i, U_i]$ is first defined for the indicator. Values falling within this interval are considered optimal, while deviations in either direction are penalized.

Example:

$$z_{it} = 1 - \frac{|x_{it} - m_i|}{\max(|x_i - m_i|)} \left(m_i = \frac{L_i + U_i}{2} \right)$$

(2) Weighting: Entropy Method Combined with Integrated Weights

The entropy weight method reflects the inherent dispersion of the data, making it particularly suitable for high-frequency monitoring after customs closure. Meanwhile, a limited set of expert-assigned weights is incorporated to ensure structural consistency with the policy framework.

Calculation of Weight Proportions : $p_{it} = \frac{z_{it}}{\sum_{t=1}^T z_{it}}$

Entropy Value : $e_i = -k \sum_{t=1}^T p_{it} \ln(p_{it})$, $k = \frac{1}{\ln T}$

Information Utility : $d_i = 1 - e_i$

Entropy Weight : $w_i^E = \frac{d_i}{\sum_i d_i}$

Composite Weight (weighted average with expert-assigned weight $w_i^{(S)}$):

$$w_i = \lambda w_i^{(E)} + (1 - \lambda) w_i^{(S)}, \quad \lambda \in [0, 1]$$

(3) Subsystem Index (U1, U2)

For the set of indicators belonging to subsystem k, where $k \in \{1, 2\}$, we denote this set as Ω_k :

$$U_k(t) = \sum_{i \in \Omega_k} w_i z_{it}$$

(4) Coupling Coordination Degree: The Controllable Openness Coordination Index (D-Index)

Coupling Degree (reflecting the intensity of interaction between systems) :

$$C(t) = \frac{2\sqrt{U_1(t)U_2(t)}}{U_1(t) + U_2(t)}$$

Comprehensive Development Index :

$$T(t) = \alpha U_1(t) + \beta U_2(t), \quad \alpha = \beta = 0.5 (\text{Benchmark})$$

Core Metric: The Coupling Coordination Degree:

$$D(t) = \sqrt{C(t) \cdot T(t)}$$

Interpretation Rules for the Controllable Openness Coordination Index (D-Index):

- 1) A rising D-Index indicates a synchronous improvement in both trade facilitation (U1) and risk control (U2), reflecting an enhancement in the overall quality of controllable openness.
- 2) An increase in U1 (facilitation) accompanied by a decrease in U2 (risk control) signals a potential mismatch between the intensity of openness and regulatory capacity, implying heightened risk exposure.
- 3) An increase in U2 (risk control) accompanied by a decrease in U1 (facilitation) suggests that excessive regulatory tightening may be impeding market penetration, leading to a loss of economic efficiency.

(5) Robustness and Sensitivity

- 1) The model is tested under alternative weighting schemes: equal weighting, weights derived from principal component analysis (PCA), and using entropy weights alone (excluding expert weights).
- 2) A short-term index is constructed using only the subset of indicators available at high frequency (e.g., monthly). Its trend and turning points are then compared with those of the full index to assess consistency.
- 3) For bilateral indicators with defined optimal ranges $[L_i, U_i]$, the stability of the composite index (D) ranking is tested by applying a $\pm 10\%$ perturbation to both the lower and upper bounds of these intervals.

5. Data Sources and Implementation Plan for a Quarterly Dashboard in the First Year of Customs Closure

(1) Data Acquisition: A Three-Tier Data Architecture

Tier 1: Administrative and Operational Data

This tier comprises high-frequency, system-generated data directly obtained from port and regulatory information systems. Key metrics include: average release time, inspection sampling rate, risk targeting hit rate, rate of document amendments/rejections, transit efficiency metrics, incident processing times, case disposal rates for restricted items, duty recovery status.

Tier 2: Open Statistics and Industry Data

This tier consists of publicly available macro and industry statistics that reflect market activity and capacity. Examples include: cargo throughput, vessel/route frequency, trade volume, logistics cost indices, relevant commodity price indices.

Tier 3: Enterprise-Specific Costs and Perceptions

This tier captures micro-level costs and qualitative assessments through enterprise surveys or sampling. It focuses on: average per-shipment compliance cost, perceived scores for regulatory transparency and predictability, enterprises' assessment of policy stability and uncertainty.

(2) Closure Shock Point and Comparison Window

Taking $t_0 =$ December 18, 2025 as the policy shock point, the evaluation period is structured into the following three distinct windows:

Pre-Closure Baseline Period: 2024 Q1 – 2025 Q3.

Transition & Disturbance Period: 2025 Q4.

Post-Closure Evaluation Period: Starting from 2026 Q1.

(3) Quarterly Dashboard for the First Year of Customs Closure

Hainan's established network of 8 designated front-line ports and 10 second-line ports provides a stable and measurable unit of observation, making it well-suited for systematic quarterly tracking of operational flows. At the same time, relevant tax policies and the import tax catalogue explicitly designate the customs closure date as their effective node. This clear temporal boundary creates natural quarterly intervals for observing the fidelity and quality of policy implementation post-closure.

6. To Perform Stress Testing and Support Institutional Optimization with the Controllable Openness Coordination Index (D)

(1) The Managerial Implication of the D-Index: A Metric for "Controllable Openness".

The systemic objective of the island-wide customs closure operation is not mere deregulation, but the pursuit of orderly openness under effective management. The Hainan Provincial Government notice explicitly sets the commencement date of the closure and integrates key policies—such as tax measures, the taxable goods catalogue, customs supervision rules, value-added processing policies, and prohibited/restricted lists—into a single, coherent implementation framework. This design inherently requires that trade facilitation (U1) and risk prevention and control (U2) be jointly advanced and held accountable for outcomes from the outset. Consequently, this paper proposes that the quarterly monitoring mechanism be institutionalized as a closed-loop policy cycle:

1) Monitoring & Visualization: Generate quarterly values for the U1 (Facilitation Penetration), U2 (Risk Prevention & Control), and D (Coordination) indices, and visualize the secondary dimensions via radar charts.

2) Early Warning & Diagnosis: Activate yellow/red alerts based on predefined thresholds and mismatch rules (detailed in Appendix B, e.g., $U1 \uparrow$ & $U2 \downarrow$, or a declining D-index), signaling potential imbalances or heightened risks.

3) Policy Response & Intervention: Deploy targeted measures from a modular policy toolbox, including adjustments to port procedures, credit management protocols, risk model parameters, list enforcement, and tax certification accounting rules.

4) Review & Accountability: Map the implemented policy responses back to specific indicator changes (e.g., directional shifts in A2-1 Transit Time, B1-2 Irregular Benefit Claim Rate, or B3-2 False Positive Rate) to create verifiable and auditable governance records, closing the management loop.

(2) Four-Quadrant Diagnostic Matrix: Policy Implications and Action Priorities Based on the U1 (Facilitation) vs. U2 (Risk Control) Framework.

Table 2. Four-Quadrant State Diagnosis Based on the Coordination Between Facilitation and Risk Control

Quadrant	State / Profile	Typical Manifestations	Nature of Risk	Action Priority
I High U1 – High U2	Ideal Synergy	Steady increase in the D-index, with simultaneous improvements in efficiency and compliance	Sustainable Openness	Maintain & Fine-tune
II High U1 – Low U2	Capability Mismatch	Fast clearance coupled with rising irregular benefit claims and violations of prohibited/restricted lists	Systemic Regulatory Risk	Highest: Prioritize Strengthening U2
III Low U1 – High U2	Over-Regulation	Strong risk indicators but deteriorating transit/customs efficiency	Efficiency Loss & Industrial Spillover	High: Ease Controls to Unleash U1
IV Low U1 – Low U2	Dual-Weakness Trap	Slow, inefficient, and disorderly operations	Governance Failure	Highest: Overhaul Processes / Restructure System

Note: Quadrant II signifies more than a need for stricter inspections; it fundamentally indicates that the intensity of market openness has outpaced the current capacity of the regulatory framework. Conversely, Quadrant III represents a scenario where regulatory objectives are met, but at the prohibitive cost of excessive transaction costs and procedural burdens, a dynamic that will ultimately erode the credibility and sustainability of the opening-up policy.

(3) Stress Testing of Front-Line Liberalization

This implies that the liberalization of front-line ports will lead to a structural surge in the volume of declarations, benefit claims, and the incentives for regulatory arbitrage. Consequently, a robust regulatory foundation, integrating catalogue-based management with dynamic risk profiling, must be established as a non-negotiable baseline.

Suggested Stress Test Scenarios:

Scenario S1 (Surge in Benefit Claims):

This scenario tests the system's efficiency under high-volume pressure. The key requirement is that the average release time (A1-1) must not deteriorate significantly. However, a simultaneous increase in both the tax documentation error rate (B1-3) and the irregular benefit claim rate (B1-2) would trigger a mismatch warning, indicating that speed is compromising accuracy and compliance.

Scenario S2 (Tax Policy Shock):

This scenario assesses the system's adaptability to major policy changes, such as an expansion of the import taxable goods catalogue. The focus should be on monitoring changes in institutional transaction costs, specifically the regulatory transparency score (A3-2) and the per-shipment compliance cost (A3-1), to gauge the policy's impact on the business environment.

Scenario S3 (Increased Enforcement on Restricted Lists):

This scenario examines enforcement integrity following the explicit extension of restricted/prohibited list controls to cover the entire Hainan island at the front line, effective from the customs closure date. The test monitors whether this consolidation leads to a measurable rise in list hit disposal rates (B2-1) or other enforcement metrics, ensuring the new mandate translates into effective on-ground action.

(4) Stress Testing "Second-Line Control": Batch Departures, Consolidated Declarations, and Tax Certificate Reconciliation

The core governance challenge at the second line lies in balancing dual imperatives: it must effectively control key goods (notably zero-tariff items subject to tax adjustments) while avoiding the transformation of island-mainland logistics into a source of new friction costs. As reported by the People's Daily prior to the closure, most goods, barring specific categories requiring regulated exit channels, are permitted to leave the island via non-customs-regulated channels, with innovative facilitation modes such as batch departures and consolidated declarations being implemented. Consequently, this paper proposes that

stress testing of the second line should concentrate on two critical operational chains:

- 1) The Logistics Chain (Efficiency Focus) : this chain evaluates fluidity and is characterized by second-line transit time (A2-1), congestion intensity (A2-2), and duty adjustment processing time (A2-3).
- 2) The Tax Certificate Chain (Compliance & Closure Focus): this chain assesses fiscal control integrity and is monitored through the duty recovery compliance rate (B1-1), the irregular benefit claim rate (B1-2), and the tax documentation error rate (B1-3).

Proposed Trigger Rules for Policy Intervention:

Rule 1: Process Overhaul vs. Over-Inspection

If logistics efficiency indicators (Dimension A2) deteriorate without a corresponding improvement in tax compliance metrics (Dimension B1), it signifies that heightened controls are failing to yield intended compliance gains. The appropriate response is to prioritize streamlining processes or upgrading information systems, rather than defaulting to across-the-board increases in physical inspections.

Rule 2: Targeted Risk Model Calibration vs. Generalized Slowdown

If the irregular benefit claim rate (B1-2) rises while the risk targeting hit rate (B3-1) declines or stagnates, it indicates a failure of the risk identification model. The required action is the immediate calibration of risk control parameters and enhancement of cross-agency data sharing, not the imposition of generalized slowdowns on all enterprises.

7. Conclusion

(1) Core Conclusion: Defining and Assessing Closure Performance through the Lens of Controllable Openness

The key to the island-wide closure of Hainan Free Trade Port is not just to be more open or more regulated. The key is for openness and regulatory capacity to advance together. Based on this, this paper divides market penetration into two parts: facilitation penetration (U1) and risk prevention and control (U2). This paper uses the coupling coordination degree (D) to measure whether the two subsystems improve together. The purpose of doing this is simple: to change the phrase “open yet well-managed” into a set of indicators that can be constantly calculated, compared, and updated.

(2) Framework Contribution: A Paradigm Shift from Outcome to Operational Assessment

In the past, trade volume and investment amount were often used to evaluate policies. However, in the operation of customs clearance, many problems lie not in the final outcomes, but in the process itself—for example, prolonged clearance times, second-line traffic congestion, tax documentation errors, over-inspection in risk control, and failure to close audit loops.

This study shifts the evaluation focus forward to assess performance at the operational level, specifically in terms of efficiency, cost, boundary compliance, and management closure. This approach enables an operable, repeatable, and rolling assessment from the very first year of customs closure implementation.

(3) Future Research Directions

Future research could explore making risk management more adaptive. Risk identification indicators can be integrated with enhanced data sharing, tiered credit management, and dynamic control rules—all without compromising the current level of openness. The goal is to reduce false positives (over-inspection) and improve the targeting hit rate. This approach aims to make second-line control less reliant on blanket inspections and more dependent on precise, intelligence-led interventions.

Appendix

Table 3. List of Abbreviations and Symbols

Category	Symbol	Interpretation
Abbreviation	FTP	Free Trade Port
	MCI	Market Connectivity Index
	AHP	Analytic Hierarchy Process
	Entropy	Entropy Weight Method (EWM)

Category	Symbol	Interpretation
Index	(U_1)	Facilitation Connectivity Subsystem Index (FCSI)
	(U_2)	Risk Prevention and Control Subsystem Index (RCSI)
	(C)	Coupling Degree
	(T)	Integrated Development Index (Weighted)
	(D)	Coupling Coordination Degree (Controllable Openness Coordination Index)
Parameter	(λ)	Integration Coefficient of Entropy Weights and Expert Weights
	(ρ)	Weights of (U ₁ , U ₂) in (T) (with a baseline of 0.5/0.5)

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Reference

- [1] Anderson, J. E., & van Wincoop, E. (2004). Trade costs. *Journal of Economic Literature*, 42(3), 691–751.
- [2] Callaway, B., & Sant’Anna, P. H. C. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, 225(2), 200–230.
- [3] OECD. (2013). Trade facilitation indicators: The potential impact of trade facilitation on developing countries’ trade. OECD Publishing.
- [4] Roth, J., Sant’Anna, P. H. C., Bilinski, A., & Poe, J. (2023). What’s trending in difference-in-differences? A synthesis of the recent econometrics literature. *Journal of Econometrics*, 235(2), 2218–2244.
- [5] Saaty, T. L. (1980). *The analytic hierarchy process*. McGraw-Hill.
- [6] Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, 27(3), 379–423.
- [7] World Bank. (2018). *Connecting to compete 2018: Trade logistics in the global economy (LPI report)*. World Bank.
- [8] Ministry of Finance of the People’s Republic of China, General Administration of Customs, State Taxation Administration. (2025). Notice on Tax Policies for the First Line, Second Line, and Intra-island Import and Export of Goods in the Hainan Free Trade Port (Cai Guanshui [2025]No. 12).
- [9] General Administration of Customs of the People’s Republic of China. (2025). Announcement on Issuing the “Measures for Customs Supervision of the Hainan Free Trade Port” (Announcement No. 159 of 2025).
- [10] General Administration of Customs of the People’s Republic of China. (2025). Announcement on Issuing the “Interim Measures for Tax Administration of Value-added Processing Duty Exemption in the Hainan Free Trade Port” (Announcement No. 158 of 2025).
- [11] Ministry of Commerce of the People’s Republic of China. (2025). Announcement on Issuing the “List of Goods and Articles Prohibited or Restricted from Import and Export in the Hainan Free Trade Port” (Announcement No. 43 of 2025).
- [12] People’s Government of Hainan Province. (2025). Announcement on the Full Island Customs Closure Operation of the Hainan Free Trade Port (Qiong Fu Han [2025] No. 278).