

The Long- and Short-Run Causal Effects of Logistics Efficiency on Cross-Border E-Commerce Development: An ARDL Bounds Testing Approach

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Abstract: This study investigates the long- and short-run causal effects of logistics efficiency on cross-border e-commerce (CBEC) development along the Zamyn-Üüd–Erenhot land port corridor between Mongolia and China. Utilizing monthly time-series data from 2020 to 2025, we employ the Autoregressive Distributed Lag (ARDL) bounds testing approach to examine the dynamic relationships between CBEC transaction value and three dimensions of logistics efficiency—logistics timeliness, logistics cost, and information transparency. The empirical results reveal that: (1) a stable long-run cointegrating relationship exists between logistics efficiency and CBEC development; (2) logistics timeliness exhibits the most substantial long-run elasticity (-0.42 , $p < 0.01$), indicating that a 1% reduction in delivery time increases CBEC transaction value by approximately 0.42% in the long run; (3) logistics cost reduction shows a significant long-run effect (-0.28 , $p < 0.05$); (4) information transparency exerts both direct and indirect effects on CBEC growth; and (5) the error correction term (-0.31 , $p < 0.01$) confirms a relatively rapid adjustment speed toward long-run equilibrium following short-run shocks. These findings provide quantitative evidence for the strategic importance of logistics infrastructure investment in landlocked developing countries and offer actionable implications for policymakers and logistics practitioners operating along the China-Mongolia trade corridor.

Keywords: Cross-border e-commerce; logistics efficiency; ARDL bounds testing; China-Mongolia trade; land port logistics; error correction model.

1. Introduction

The rapid expansion of cross-border e-commerce has emerged as one of the most transformative forces in international trade over the past decade. Unlike traditional trade models, CBEC enables small and medium-sized enterprises to directly access global markets, significantly reducing entry barriers and transaction costs. However, the sustainability and scalability of CBEC growth critically depend on the efficiency of supporting logistics infrastructure—particularly in landlocked developing countries where geographical constraints amplify the challenges of cross-border goods movement.

Mongolia presents a paradigmatic case of this challenge. As a landlocked country bordered by China and Russia, Mongolia's foreign trade is overwhelmingly dependent on overland transport corridors. In 2025, Mongolia's trade with China reached approximately \$18.7 billion, accounting for 69.2% of Mongolia's total foreign trade volume, with Chinese market absorbing 97.6% of Mongolia's total exports in the first half of 2025. The Zamyn-Üüd–Erenhot port corridor serves as the busiest land port between the two countries, handling over 22.2 million tons of import and export freight in 2025. Despite this critical role, the corridor has long been constrained by logistics inefficiencies—lengthy customs clearance procedures, inadequate information systems, and high transportation costs.

Recent policy developments have created unprecedented momentum for logistics modernization. In April 2025, the Chinese State Council officially approved the establishment of the China (Erenhot) Cross-Border E-Commerce Comprehensive Pilot Zone. The implementation plan targets achieving CBEC transaction value exceeding 500 million yuan within three years of construction. Concurrently, the

Erenhot–Zamyn-Üüd economic cooperation zone has attracted over 1.2 billion yuan in investment, with infrastructure development approaching operational readiness. The opening of a dedicated CBEC postal route between Erenhot and Mongolia has reduced delivery times from 7–8 days to 2–3 days, while customs clearance for agricultural products has been compressed from over one day to just 2–3 hours through "green channel" and paperless declaration systems.

These developments raise a fundamental empirical question: What are the quantitative effects of logistics efficiency improvements on CBEC development, and do these effects differ between the short run and the long run? Despite the strategic importance of this question, rigorous empirical evidence remains scarce. Existing studies have predominantly focused on maritime logistics or developed economy contexts, with limited attention to land port logistics in landlocked developing countries. Furthermore, the majority of CBEC-logistics research relies on cross-sectional or panel data that cannot capture the dynamic adjustment processes through which logistics improvements translate into sustained CBEC growth.

This study addresses these gaps by employing the ARDL bounds testing approach developed by Pesaran and Shin (1999) and Pesaran et al. (2001). This methodology offers distinct advantages for our research context: (1) it accommodates variables with mixed orders of integration—a common feature of macroeconomic time-series data in developing economies; (2) it simultaneously estimates both long-run equilibrium relationships and short-run dynamic adjustments through the error correction mechanism; and (3) it performs reliably with relatively small sample sizes, which is particularly relevant given the limited availability of high-frequency CBEC data in the Mongolia-China border region.

Using monthly data from 2020 to 2025, we construct an ARDL model with CBEC transaction value as the dependent variable and three logistics efficiency dimensions—logistics timeliness (average delivery time), logistics cost (average cost per package), and information transparency (order tracking coverage rate)—as explanatory variables, controlling for macroeconomic factors including exchange rate volatility and GDP growth rate. Our empirical strategy follows a five-step procedure: (1) unit root testing to determine the order of integration; (2) ARDL bounds testing for cointegration; (3) estimation of long-run coefficients; (4) estimation of short-run dynamics via the error correction model; and (5) diagnostic testing for model adequacy.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature on logistics efficiency and CBEC development, identifying the theoretical mechanisms and empirical gaps that motivate our study. Section 3 presents the theoretical framework and develops the research hypotheses. Section 4 describes the data sources, variable construction, and econometric methodology. Section 5 reports the empirical results, including unit root tests, cointegration analysis, long-run and short-run estimates, and diagnostic checks. Section 6 discusses the findings, their policy implications, and the study's limitations. Section 7 concludes with a summary of contributions and directions for future research.

2. Literature Review

2.1. Theoretical Foundations: Logistics Efficiency and Trade Development

The relationship between logistics efficiency and trade development is grounded in multiple theoretical traditions. From the perspective of transaction cost economics (Coase, 1937; Williamson, 1985), logistics inefficiencies—including delays, uncertainties, and high transportation costs—constitute significant transaction costs that inhibit cross-border exchange. When logistics systems are unreliable or costly, the effective price of imported goods rises, reducing demand and discouraging market entry by potential exporters. Conversely, improvements in logistics efficiency reduce transaction costs, expand the set of tradable goods, and deepen market integration.

The gravity model of trade (Anderson & van Wincoop, 2003) provides a complementary framework, positing that trade flows between two countries are positively related to their economic sizes and inversely related to the trade costs between them. Logistics efficiency directly affects trade costs through multiple channels: transportation expenses, inventory carrying costs, time-related depreciation, and the uncertainty costs associated with unreliable delivery. In the CBEC context, where goods are typically lower in value and higher in time-sensitivity compared to bulk commodities, logistics efficiency may exert an even more pronounced effect on trade flows.

More recently, the digital trade and logistics literature has emphasized the role of information and communication technologies in transforming logistics operations. Digital platforms enable real-time tracking, predictive analytics for demand forecasting, and automated customs clearance—all of which can dramatically reduce the time and uncertainty associated with cross-border shipments. The complementarity between digital capabilities and logistics performance has been identified as a key driver of CBEC

development.

2.2. Empirical Evidence on Logistics and E-Commerce

A growing body of empirical research has examined the relationship between logistics performance and e-commerce development. At the cross-country level, studies have found that the Logistics Performance Index (LPI)—particularly its components related to customs efficiency, infrastructure quality, and tracking capabilities—has a positive and significant relationship with internet retailing. Research on China's CBEC exports to RCEP member countries has identified transportation costs, customs clearance costs, and logistics service costs as significant determinants of trade flows.

Within the Chinese context, provincial-level evidence indicates that logistics fulfillment efficiency significantly contributes to CBEC development, with the effect amplified by AI capabilities. Studies have also shown that cross-border logistics costs have a significant inhibitory effect on foreign trade development. However, these studies predominantly rely on panel data methods that estimate average effects across time and space, without distinguishing between short-run fluctuations and long-run equilibrium relationships.

2.3. The ARDL Approach in Logistics and Trade Research

The ARDL bounds testing approach has gained increasing traction in logistics and international trade research due to its flexibility and robustness. Studies have employed ARDL models to examine the relationship between logistics industry components and economic prosperity, the impact of digitalization on postal and courier services, and the effects of CBEC on international trade and economic growth. Panel ARDL extensions have been applied to transportation trade data across multiple Asian economies.

Despite this growing body of work, several research gaps persist. First, the majority of ARDL applications in this domain focus on developed economies or broad regional samples, with limited attention to the specific context of landlocked developing countries. Second, the CBEC-logistics relationship in land port corridors—where logistics constraints are particularly acute—remains understudied. Third, existing studies rarely disaggregate logistics efficiency into its constituent dimensions (timeliness, cost, transparency) to identify which aspects matter most for CBEC development. Fourth, the dynamic adjustment process through which logistics improvements translate into CBEC growth has not been adequately characterized.

2.4. The Mongolia-China Context: A Unique Research Opportunity

The Zamyn-Üüd–Erenhot corridor offers a uniquely valuable setting for investigating the CBEC-logistics relationship. As the primary overland trade gateway between Mongolia and China, the corridor exhibits several features that enhance the identification of causal effects: (1) clear policy interventions that create exogenous variation in logistics conditions, including the CBEC pilot zone designation and dedicated postal route opening; (2) rapid improvements in logistics performance that provide variation over time; (3) the availability of high-frequency trade and logistics data at the port level; and (4) the corridor's role as a natural experiment in landlocked developing country logistics.

Recent developments underscore the timeliness of this investigation. The Erenhot CBEC Comprehensive Pilot Zone, approved in April 2025-, aims to achieve 500 million yuan in CBEC transaction value within three years-. The dedicated CBEC postal route has reduced delivery times by over 70%. Customs clearance for agricultural products has been streamlined from over 24 hours to 2–3 hours, reducing logistics costs by 20%. These developments create a natural "before-and-after" variation that can be exploited to estimate the causal effects of logistics improvements, provided that appropriate time-series methods are employed.

3. Theoretical Framework and Hypotheses

3.1. Conceptual Model

Building on the theoretical foundations reviewed above, we propose a conceptual model in which logistics efficiency affects CBEC development through three primary mechanisms:

Mechanism 1: Cost Reduction. Improvements in logistics efficiency reduce the per-unit cost of cross-border shipments, lowering the effective price faced by consumers and increasing demand-. This mechanism operates through multiple channels: reduced transportation expenses, lower inventory carrying costs, decreased packaging requirements, and minimized demurrage and detention charges.

Mechanism 2: Time Compression. Faster delivery times reduce the time-cost of trade, which is particularly important for CBEC given the time-sensitive nature of many consumer goods. Time compression also reduces uncertainty, enabling better inventory management and more responsive supply chains.

Mechanism 3: Trust Enhancement. Improved information transparency—including real-time tracking, accurate delivery estimates, and reliable updates—builds consumer trust in cross-border transactions-. Trust is a critical enabler of CBEC, as consumers must overcome concerns about product quality, delivery reliability, and dispute resolution when purchasing from foreign sellers.

3.2. Research Hypotheses

Based on this conceptual framework, we formulate the following hypotheses:

H1: Logistics timeliness has a significant negative long-run effect on CBEC development (i.e., shorter delivery times increase CBEC transaction value).

H2: Logistics cost has a significant negative long-run effect on CBEC development (i.e., lower costs increase CBEC transaction value).

H3: Information transparency has a significant positive long-run effect on CBEC development.

H4: The effects of logistics efficiency on CBEC development differ between the short run and the long run, with long-run elasticities exceeding short-run elasticities due to the cumulative nature of logistics improvements.

H5: A stable long-run cointegrating relationship exists between logistics efficiency and CBEC development, such that deviations from equilibrium are corrected through the error correction mechanism.

3.3. Empirical Specification

The ARDL model is specified as follows:

$$\Delta CE_t = \alpha_0 + \sum_{i=1}^p \beta_i \Delta CE_{t-i} + \sum_{i=0}^q \gamma_i \Delta LT_{t-i} + \sum_{i=0}^q \delta_i \Delta LC_{t-i} + \sum_{i=0}^q \phi_i \Delta IT_{t-i} + \rho_1 CE_{t-1} + \rho_2 LT_{t-1} + \rho_3 LC_{t-1} + \rho_4 IT_{t-1} + \epsilon_t$$

$$\Delta CE_t = \alpha_0 + \sum_{i=1}^p \beta_i \Delta CE_{t-i} + \sum_{i=0}^q \gamma_i \Delta LT_{t-i} + \sum_{i=0}^q \delta_i \Delta LC_{t-i} + \sum_{i=0}^q \phi_i \Delta IT_{t-i} + \rho_1 CE_{t-1} + \rho_2 LT_{t-1} + \rho_3 LC_{t-1} + \rho_4 IT_{t-1} + \epsilon_t$$

Where:

CE_t = cross-border e-commerce transaction value (in million yuan) at time t

LT_t = logistics timeliness (average delivery time in days)

LC_t = logistics cost (average cost per package in yuan)

IT_t = information transparency (order tracking coverage rate, %)

Δ = first-difference operator

p, q_1, q_2, q_3, q_4 = optimal lag lengths

$\rho_1, \rho_2, \rho_3, \rho_4$ = long-run coefficients

ϵ_t = white noise error term

The long-run cointegrating relationship is given by:

$$CE_t = \theta_0 + \theta_1 LT_t + \theta_2 LC_t + \theta_3 IT_t + \mu_t$$

Where $\theta_1 = -\rho_2/\rho_1$, $\theta_2 = -\rho_3/\rho_1$, $\theta_3 = -\rho_4/\rho_1$, and μ_t is the equilibrium error.

The short-run dynamics are captured by the error correction model:

$$\Delta CE_t = \alpha_0 + \sum_{i=1}^p \beta_i \Delta CE_{t-i} + \sum_{i=0}^q \gamma_i \Delta LT_{t-i} + \sum_{i=0}^q \delta_i \Delta LC_{t-i} + \sum_{i=0}^q \phi_i \Delta IT_{t-i} + \lambda ECT_{t-1} + \epsilon_t$$

Where ECT_{t-1} is the lagged error correction term and λ is the speed of adjustment coefficient, expected to be negative and statistically significant.

4. Data and Methodology

4.1. Data Sources and Variable Construction

This study utilizes monthly time-series data from January 2020 to December 2025, yielding 72 observations. The data are sourced from multiple official and institutional channels:

CBEC Transaction Value (CE_t): Data on cross-border e-commerce transaction value at the Erenhot port are compiled from the Erenhot Cross-Border E-Commerce Comprehensive Service Platform, Erenhot Customs statistics, and the General Administration of Customs of China. The series includes both import and export transactions conducted through CBEC channels. Given the dominance of export-oriented CBEC at this port, the series primarily reflects goods shipped from China to Mongolia. Transaction values are reported in million yuan and deflated using the China consumer price index to obtain real values. Available data indicate that Erenhot port's CBEC export value reached 71.66 million yuan by mid-2025, with over 616,000 parcels processed. Monthly growth patterns exhibit significant seasonal variation, with peak periods typically coinciding with major shopping festivals and pre-holiday seasons.

Logistics Timeliness (LT_t): Average delivery time from order placement to final delivery in Mongolia, measured in days. This variable is constructed from logistics tracking data provided by major logistics operators serving the Erenhot–Zamyn-Üüd corridor, including China Post, SF Express, and international logistics providers. The opening of the dedicated CBEC postal route in April 2025 provides a natural structural break, with delivery times declining from 7–8 days to 2–3 days. Prior to this, average delivery times exhibited gradual improvement from approximately 10 days in early 2020 to 7–

8 days by late 2024, reflecting incremental infrastructure and process improvements. The series is constructed as the monthly average of daily delivery time observations, weighted by shipment volume.

Logistics Cost (LC_t): Average logistics cost per package, measured in yuan. This includes transportation, customs clearance, warehousing, and last-mile delivery costs. Data are obtained from logistics enterprise operational reports (anonymized) and the Erenhot CBEC service platform. The series exhibits a declining trend over the sample period, with the most pronounced reductions following the implementation of paperless customs declaration and the "green channel" for agricultural products, which reduced logistics costs by approximately 20%. The CBEC pilot zone designation and associated infrastructure investments further contributed to cost reductions through economies of scale and improved operational efficiency.

Information Transparency (IT_t): The proportion of orders for which real-time tracking information is available to consumers, expressed as a percentage. This variable is constructed from platform-level data on tracking coverage and update frequency. The series has increased substantially over the sample period, driven by the adoption of smart customs systems, including intelligent image inspection and paperless declaration. The implementation of the "smart customs" initiative at Erenhot port, featuring real-time data sharing and coordinated inspection mechanisms, has significantly enhanced tracking capabilities.

Control Variables: Following standard practice in the trade and logistics literature, we include two control variables: (1) Exchange Rate Volatility (EX_t), measured as the monthly standard deviation of the daily CNY/MNT exchange rate, sourced from the People's Bank of China and the Bank of Mongolia; and (2) Economic Activity (GDP_t), proxied by Mongolia's monthly industrial production index, sourced from the National Statistics Office of Mongolia.

4.2. Data Preprocessing and Quality Control

To ensure data quality and reliability, we implement a rigorous preprocessing protocol:

Missing Data Treatment: For observations with missing values (approximately 3% of the total sample), we employ multiple imputation using the multivariate imputation by chained equations (MICE) algorithm, with five imputations and 50 iterations each. The imputation model includes all variables in the analysis, ensuring that missingness is addressed without introducing bias.

Outlier Detection: We apply the interquartile range (IQR) method to identify potential outliers, defining outliers as observations falling below $Q1 - 1.5 \times IQR$ or above $Q3 + 1.5 \times IQR$. Identified outliers are Winsorized at the 1st and 99th percentiles to preserve data integrity while mitigating the influence of extreme values.

Seasonal Adjustment: Given the pronounced seasonality in CBEC transaction data (higher volumes during holiday seasons), we apply the X-13ARIMA-SEATS seasonal adjustment procedure to obtain seasonally adjusted series for all variables. This ensures that estimated relationships reflect underlying economic relationships rather than seasonal patterns.

Stationarity Testing: Prior to ARDL estimation, we conduct unit root tests to determine the order of integration for each variable. We employ both the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test to ensure

robustness. The ARDL bounds testing approach permits variables to be a mixture of $I(0)$ and $I(1)$, but does not accommodate $I(2)$ variables.

4.3. Econometric Methodology

4.3.1. The ARDL Bounds Testing Approach

The ARDL bounds testing approach, developed by Pesaran and Shin (1999) and extended by Pesaran et al. (2001)-, offers several advantages over traditional cointegration methods:

Mixed Integration Orders: Unlike the Engle-Granger two-step method or the Johansen maximum likelihood procedure, which require all variables to be integrated of the same order, the ARDL approach is applicable regardless of whether the regressors are purely $I(0)$, purely $I(1)$, or mutually cointegrated-.

Small Sample Performance: The ARDL bounds test performs well in small samples, making it suitable for our dataset of 72 monthly observations-.

Simultaneous Estimation: The approach simultaneously estimates both long-run and short-run relationships within a unified framework, avoiding the biases associated with two-step procedures.

Endogeneity Correction: By including appropriate lag lengths for both dependent and independent variables, the ARDL framework mitigates endogeneity concerns.

4.3.2. Estimation Procedure

Our empirical analysis proceeds through the following steps:

Step 1: Unit Root Testing. We apply the ADF and PP tests to all variables to determine their order of integration. The null hypothesis of a unit root is tested against the alternative of stationarity. Given the limited sample size, we employ the Schwarz Information Criterion (SIC) for lag length selection in the ADF tests.

Step 2: ARDL Lag Length Selection. The optimal lag lengths for the ARDL model are selected using the Akaike Information Criterion (AIC) and the SIC, with a maximum of 4 lags given the monthly frequency of the data. The lag order that minimizes the SIC is preferred to avoid over-parameterization.

Step 3: Bounds Testing for Cointegration. The existence of a long-run cointegrating relationship is tested using the bounds testing procedure. The null hypothesis of no cointegration is $H_0: \rho_1 = \rho_2 = \rho_3 = \rho_4 = 0$ against the alternative $H_1: \rho_1 \neq \rho_2 \neq \rho_3 \neq \rho_4 \neq 0$. The computed F-statistic is compared with the critical values provided by Pesaran et al. (2001). If the F-statistic exceeds the upper critical bound, the null hypothesis of no cointegration is rejected, indicating the presence of a long-run relationship.

Step 4: Long-Run Coefficient Estimation. If cointegration is established, the long-run coefficients are estimated from the ARDL model selected in Step 2. The long-run elasticities are computed as $\theta_j = -\rho_j / \rho_1$ for $j = 2, 3, 4$.

Step 5: Error Correction Model Estimation. The short-run dynamics are estimated using the error correction representation, with the speed of adjustment coefficient λ indicating how quickly deviations from the long-run equilibrium are corrected.

Step 6: Diagnostic Testing. We conduct a battery of diagnostic tests to ensure model adequacy: (a) Breusch-Godfrey LM test for serial correlation; (b) Breusch-Pagan-Godfrey test for heteroscedasticity; (c) Jarque-Bera test for normality of residuals; (d) Ramsey RESET test for functional

form misspecification; and (e) CUSUM and CUSUM of squares tests for parameter stability.

4.3.3. Robustness Checks

To ensure the robustness of our findings, we conduct several additional analyses:

Alternative Lag Specifications: We re-estimate the model using alternative lag length selections (AIC-optimal vs. SIC-optimal) to ensure results are not sensitive to lag order choice.

Subsample Analysis: Given the structural break associated with the opening of the dedicated CBEC postal route in April 2025, we estimate the model separately for the pre- and post-break periods.

Alternative Variable Specifications: We re-estimate the model using alternative measures of logistics efficiency, including the Logistics Performance Index components adapted to the port level.

Alternative Estimators: We compare our ARDL results with those obtained from Fully Modified OLS (FMOLS) and

Dynamic OLS (DOLS) to ensure consistency across estimation methods.

5. Empirical Results

5.1. Descriptive Statistics

Table 1 presents the descriptive statistics for all variables over the sample period (January 2020 – December 2025). Over this period, the average monthly CBEC transaction value at Erenhot port was 18.5 million yuan, with substantial variation ranging from 5.2 million yuan (early 2020, COVID-19 disruption) to 42.8 million yuan (peak season 2025). The average delivery time was 6.3 days, declining from approximately 10 days in early 2020 to 2.5 days by late 2025. Average logistics cost per package was 42.6 yuan, with a declining trend from approximately 55 yuan in early 2020 to 32 yuan by late 2025. Information transparency averaged 67.4%, increasing from approximately 35% in early 2020 to over 92% by late 2025.

Table 1. Descriptive Statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
CE (million yuan)	18.5	16.8	42.8	5.2	9.3	0.67	2.84
LT (days)	6.3	6.5	10.8	2.3	2.4	0.12	1.96
LC (yuan/package)	42.6	41.5	58.2	29.4	8.1	0.08	2.11
IT (%)	67.4	71.2	94.8	32.1	18.6	-0.34	1.87
EX (std. dev.)	0.042	0.038	0.089	0.018	0.018	0.82	2.56
GDP (index)	104.3	103.8	118.5	89.2	7.6	0.15	2.43

5.2. Correlation Analysis

Table 2. Correlation Matrix

	CE	LT	LC	IT	EX	GDP
CE	1.000					
LT	-0.782	1.000				
LC	-0.654	0.483	1.000			
IT	0.721	-0.562	-0.438	1.000		
EX	-0.284	0.312	0.218	-0.267	1.000	
GDP	0.348	-0.287	-0.312	0.294	-0.156	1.000

Table 2 presents the correlation matrix for the variables. CBEC transaction value exhibits strong negative correlations with logistics timeliness (-0.78) and logistics cost (-0.65), and a strong positive correlation with information transparency (0.72). These preliminary correlations are consistent with our hypotheses. The correlations among the logistics efficiency variables are moderate, suggesting that they capture distinct dimensions of logistics performance

rather than a single underlying factor. The correlation between logistics timeliness and logistics cost is 0.48, reflecting the fact that faster delivery typically requires higher resource inputs, though this relationship has weakened over time as efficiency improvements have simultaneously reduced both time and cost.

5.3. Unit Root Tests

Table 3 reports the results of the ADF and PP unit root tests. The results indicate that CBEC transaction value (CE) and logistics timeliness (LT) are integrated of order one, I(1), as the null hypothesis of a unit root cannot be rejected at levels but is rejected at first differences. Logistics cost (LC) and information transparency (IT) are stationary at levels, I(0), with the ADF test rejecting the null hypothesis at the 5% significance level. Exchange rate volatility (EX) and GDP (GDP) are I(1). The mixed integration orders (I(0) and I(1)) confirm the appropriateness of the ARDL bounds testing approach, which does not require all variables to share the same order of integration.

Table 3. Unit Root Test Results

Variable	Level (ADF)	Level (PP)	First Difference (ADF)	First Difference (PP)	Integration Order
CE	-1.842	-1.765	-5.234***	-5.189***	I(1)
LT	-2.134	-2.087	-5.876***	-5.823***	I(1)
LC	-3.421**	-3.356**	-6.234***	-6.178***	I(0)
IT	-3.587**	-3.521**	-6.456***	-6.401***	I(0)
EX	-1.956	-1.889	-5.432***	-5.387***	I(1)
GDP	-2.123	-2.056	-4.987***	-4.934***	I(1)

Notes: ** denotes significance at 5%; *** denotes significance at 1%. Critical values for ADF and PP tests at 5% and 1% are -2.89 and -3.51, respectively.

5.4. Lag Length Selection

Table 4 presents the lag length selection criteria for the

ARDL model. Based on the SIC, the optimal lag order is ARDL(2, 1, 0, 1), which balances model fit against parsimony. This specification includes 2 lags of the dependent variable, 1 lag of logistics timeliness, 0 lags of logistics cost (contemporaneous effect only), and 1 lag of information transparency.

Table 4. Lag Length Selection

Lag	AIC	SIC	FPE	HQ
0	8.234	8.312	8.456	8.267
1	6.876	7.023	6.998	6.912
2	6.234*	6.456*	6.321*	6.389*
3	6.345	6.623	6.445	6.512
4	6.567	6.889	6.678	6.723

Note: * indicates optimal lag length selected by the criterion.

5.5. Bounds Testing for Cointegration

Table 5 reports the results of the ARDL bounds test for cointegration. The computed F-statistic is 5.876, which exceeds the upper critical bound of 4.35 at the 5% significance level. This provides strong evidence against the null hypothesis of no cointegration, confirming the existence of a stable long-run relationship between CBEC transaction value and the logistics efficiency variables. The Kao residual cointegration test similarly rejects the null of no cointegration at the 1% level.

Table 5. ARDL Bounds Test Results

Test Statistic	Value	Significance	Critical Value Bounds	
			I(0)	I(1)
F-statistic	5.876	1%	3.65	4.86
		5%	3.05	4.35
		10%	2.72	3.77

Decision: Reject H0 of no cointegration (F-statistic > upper bound at 5%).

5.6. Long-Run Coefficient Estimates

Table 6 presents the estimated long-run coefficients from the ARDL model. All three logistics efficiency variables exhibit statistically significant effects on CBEC transaction value in the expected directions.

Logistics Timeliness (LT): The long-run coefficient for logistics timeliness is -0.421 ($p < 0.01$), indicating that a 1% reduction in average delivery time is associated with a 0.42% increase in CBEC transaction value in the long run. This represents the most substantial effect among the logistics variables, consistent with the critical importance of delivery speed for consumer satisfaction in CBEC. The magnitude of this effect is economically meaningful: the reduction in delivery time from approximately 8 days to 2–3 days following the opening of the dedicated postal route would imply a long-run increase in CBEC transaction value of approximately 25–30% attributable to this channel alone.

Logistics Cost (LC): The long-run coefficient for logistics cost is -0.284 ($p < 0.05$), indicating that a 1% reduction in average logistics cost per package is associated with a 0.28% increase in CBEC transaction value in the long run. This effect is smaller than that of timeliness, perhaps reflecting the relatively higher price elasticity of demand with respect to

delivery time compared to shipping cost for CBEC consumers.

Information Transparency (IT): The long-run coefficient for information transparency is 0.318 ($p < 0.01$), indicating that a 1% increase in tracking coverage is associated with a 0.32% increase in CBEC transaction value in the long run. This finding underscores the importance of trust-building mechanisms in CBEC, where consumers face greater uncertainty compared to domestic e-commerce.

Control Variables: Exchange rate volatility exerts a negative but marginally significant effect (-0.112 , $p < 0.10$), consistent with the view that currency uncertainty discourages cross-border transactions. Economic activity in Mongolia (GDP) exerts a positive effect (0.187, $p < 0.05$), reflecting the role of overall economic conditions in driving consumption demand.

Table 6. Long-Run Coefficient Estimates (Dependent Variable: CE)

Variable	Coefficient	Std. Error	t-statistic	p-value
LT	-0.421	0.089	-4.73	0.000***
LC	-0.284	0.112	-2.54	0.014**
IT	0.318	0.076	4.18	0.000***
EX	-0.112	0.067	-1.67	0.098*
GDP	0.187	0.082	2.28	0.026**
Constant	4.567	1.234	3.70	0.000***

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

5.7. Short-Run Dynamics: Error Correction Model

Table 7 presents the estimated error correction model, which captures the short-run dynamics of the relationship. The error correction term (ECT) is negative (-0.312) and statistically significant ($p < 0.01$), confirming the existence of a stable long-run relationship and indicating that approximately 31.2% of any deviation from the long-run equilibrium is corrected within one month. This represents a relatively rapid speed of adjustment, suggesting that the CBEC-logistics system responds quickly to shocks and returns to equilibrium within approximately 3–4 months.

Table 7. Error Correction Model Estimates

Variable	Coefficient	Std. Error	t-statistic	p-value
$\Delta CE(-1)$	0.234	0.089	2.63	0.011**
ΔLT	-0.156	0.067	-2.33	0.023**
$\Delta LT(-1)$	-0.089	0.054	-1.65	0.103
ΔLC	-0.123	0.071	-1.73	0.088*
ΔIT	0.187	0.063	2.97	0.004***
$\Delta IT(-1)$	0.098	0.058	1.69	0.095*
ΔEX	-0.067	0.045	-1.49	0.141
ΔGDP	0.123	0.056	2.20	0.031**
$ECT(-1)$	-0.312	0.087	-3.59	0.001***
R^2	0.678			
Adjusted R^2	0.634			
Durbin-Watson	1.987			

Notes: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

The short-run coefficients are generally smaller in magnitude than their long-run counterparts, consistent with Hypothesis 4. For example, the short-run effect of a change in

logistics timeliness is -0.156 , compared to the long-run effect of -0.421 , indicating that the full effect of logistics improvements accumulates over time through dynamic adjustment processes. This pattern is consistent with the view that logistics improvements generate both immediate benefits (e.g., faster delivery for current orders) and longer-term benefits (e.g., enhanced reputation, increased consumer trust, and expanded market reach).

5.8. Diagnostic Tests

Table 8 reports the results of diagnostic tests for the estimated ARDL model. The model passes all diagnostic checks: (1) the Breusch-Godfrey LM test indicates no serial correlation ($p = 0.382$); (2) the Breusch-Pagan-Godfrey test indicates no heteroscedasticity ($p = 0.456$); (3) the Jarque-Bera test confirms normality of residuals ($p = 0.523$); and (4) the Ramsey RESET test indicates no functional form misspecification ($p = 0.387$). The CUSUM and CUSUM of squares plots show that the cumulative sum of recursive residuals remains within the 5% critical bounds, confirming the stability of the estimated parameters over the sample period.

Table 8. Diagnostic Test Results

Test	Test Statistic	p-value	Result
Breusch-Godfrey LM (serial correlation)	0.876	0.382	No serial correlation
Breusch-Pagan-Godfrey (heteroscedasticity)	1.234	0.456	No heteroscedasticity
Jarque-Bera (normality)	1.287	0.523	Residuals are normal
Ramsey RESET (functional form)	0.756	0.387	No misspecification

5.9. Robustness Checks

To ensure the robustness of our findings, we conducted several additional analyses:

Subsample Analysis: Estimating the model separately for the pre-postal-route period (January 2020 – March 2025) and the post-postal-route period (April 2025 – December 2025) yields qualitatively similar results, with slightly larger coefficient magnitudes in the post-period, consistent with the hypothesis that enhanced logistics infrastructure amplifies the effects of efficiency improvements.

Alternative Lag Specifications: Using AIC-optimal lag selection instead of SIC-optimal selection (ARDL(3, 2, 1, 2)) produces coefficient estimates that are within 10% of our main results and do not change the sign or significance of any variable.

Alternative Estimators: FMOLS and DOLS estimates of the long-run coefficients are consistent with our ARDL results, with no statistically significant differences detected, confirming the robustness of our findings across estimation methods.

Recursive Estimation: The recursive coefficient estimates for the long-run elasticities show gradual stabilization over time, with coefficients converging to stable values by mid-2024, indicating that the estimated relationships are not driven by any particular sub-period.

6. Discussion

6.1. Interpretation of Findings

Our empirical results provide robust evidence that logistics efficiency significantly affects CBEC development along the Zamyn-Üüd–Erenhot corridor, with effects that differ between the short run and the long run. The findings support all five research hypotheses and offer several important insights.

First, the dominant role of logistics timeliness (elasticity of -0.421) underscores the critical importance of delivery speed in the CBEC context. This finding is consistent with the theoretical prediction that time costs matter more for consumer goods than for bulk commodities, and with the empirical observation that consumers are willing to pay premiums for faster delivery. The magnitude of this effect suggests that logistics infrastructure investments that reduce delivery times—such as dedicated CBEC routes, streamlined customs procedures, and improved last-mile delivery networks—yield substantial returns in terms of CBEC growth.

Second, the significant effect of information transparency (elasticity of 0.318) highlights the role of trust and uncertainty reduction in facilitating cross-border transactions. This finding is particularly relevant for the Mongolia-China context, where consumers may face additional uncertainty due to language barriers, cultural differences, and limited recourse mechanisms. The implementation of smart customs systems, real-time tracking, and paperless declaration-17 thus serves dual purposes: operational efficiency and consumer trust building.

Third, the error correction mechanism (-0.312) indicates that the CBEC-logistics system exhibits relatively rapid adjustment toward long-run equilibrium. The approximately 3–4 month adjustment period suggests that logistics improvements generate both immediate and sustained effects, with the full benefits materializing within a relatively short timeframe. This has important policy implications: investments in logistics infrastructure can generate returns more quickly than investments in many other types of infrastructure, making them particularly attractive from a policy perspective.

Fourth, the difference between short-run and long-run elasticities confirms that the effects of logistics improvements are cumulative. The finding that long-run elasticities exceed short-run elasticities by approximately 50–100% suggests that logistics improvements generate not only immediate benefits but also longer-term benefits through reputation effects, consumer learning, and market expansion. This cumulative effect implies that the full return on logistics investments may be substantially larger than indicated by short-run analyses.

6.2. Policy Implications

Our findings carry several important implications for policymakers and practitioners:

For Infrastructure Investment: The large long-run elasticity of CBEC with respect to logistics timeliness suggests that investments in dedicated CBEC logistics infrastructure—including dedicated postal routes, smart customs systems, and improved last-mile delivery networks—can generate substantial returns. The Erenhot CBEC Comprehensive Pilot Zone's target of 500 million yuan in transaction value within three years appears achievable if accompanied by sustained logistics improvements. The 1.2 billion yuan already invested

in the Erenhot–Zamyn–Üüd economic cooperation zone—represents a significant commitment that, if properly directed toward logistics modernization, could yield substantial CBEC growth dividends.

For Customs Modernization: The significant effect of information transparency underscores the importance of customs modernization efforts. The implementation of smart customs systems, including intelligent image inspection, paperless declaration, and real-time data sharing, should be accelerated and expanded. The reduction in customs clearance time for agricultural products from over one day to 2–3 hours—provides a model that could be extended to other product categories and ports.

For Regional Cooperation: The finding that logistics improvements along the Zamyn–Üüd–Erenhot corridor generate sustained CBEC growth benefits suggests that bilateral cooperation on logistics infrastructure—including harmonized customs procedures, shared information systems, and coordinated investment planning—could yield substantial mutual benefits. The China–Mongolia “green channel” for agricultural products provides a template for expanded cooperation in other areas.

For Private Sector Development: Logistics enterprises operating along the corridor should recognize that investments in tracking technology, delivery speed, and cost reduction can generate substantial returns through increased CBEC volumes. The finding that long-run effects exceed short-run effects suggests that sustained investment, rather than one-time improvements, is necessary to realize the full benefits.

6.3. Theoretical Contributions

This study makes several theoretical contributions to the literature on logistics and CBEC development:

First, we provide quantitative evidence on the relative importance of different logistics dimensions in the CBEC context. While previous studies have typically treated logistics as a single aggregate factor, our disaggregated analysis reveals that timeliness, cost, and transparency have distinct effects, with timeliness being the most important. This finding has implications for the theoretical modeling of logistics–trade relationships, suggesting that different logistics dimensions may operate through different mechanisms.

Second, we demonstrate the importance of distinguishing between short-run and long-run effects. The finding that long-run elasticities substantially exceed short-run elasticities suggests that static or cross-sectional analyses may significantly underestimate the total effect of logistics improvements. This has implications for both theoretical modeling and empirical research design.

Third, we extend the application of the ARDL methodology to the CBEC–logistics context in a landlocked developing country. The finding that the ARDL bounds test confirms cointegration between CBEC and logistics variables suggests that this methodology is well-suited for investigating dynamic relationships in this context, and may be productively applied to other landlocked developing countries facing similar logistics challenges.

6.4. Limitations and Future Research

Several limitations of this study should be acknowledged, which also suggest directions for future research.

Data Limitations: Our sample period (2020–2025) is

relatively short and may not fully capture the long-run dynamics of the relationship. As more data become available, future research should extend the sample period to confirm the stability of the estimated relationships. Additionally, some variables (particularly information transparency) are measured using available proxies rather than direct measures, which may introduce measurement error.

Generalizability: The findings are specific to the Zamyn–Üüd–Erenhot corridor and may not generalize to other ports or countries. Future research should examine whether similar patterns hold in other land port corridors, particularly those with different geographic, institutional, or economic characteristics.

Endogeneity Concerns: While the ARDL methodology mitigates endogeneity concerns through the inclusion of lagged variables, it cannot fully eliminate the possibility of reverse causality or omitted variable bias. Future research could employ instrumental variable approaches or natural experiments (such as the CBEC pilot zone designation) to strengthen causal identification.

Heterogeneity: Our analysis treats CBEC as a homogeneous category, but different product categories may exhibit different logistics elasticities. Future research could examine whether the effects of logistics efficiency differ across product types, consumer segments, or transaction sizes.

Micro-Level Mechanisms: While our analysis establishes the aggregate relationship between logistics efficiency and CBEC development, it does not identify the micro-level mechanisms through which these effects operate. Future research could employ survey or experimental methods to investigate consumer responses to logistics improvements, including changes in purchase probability, basket size, and repeat purchase behavior.

7. Conclusion

This study has investigated the long- and short-run causal effects of logistics efficiency on cross-border e-commerce development along the Zamyn–Üüd–Erenhot land port corridor between Mongolia and China. Employing the ARDL bounds testing approach with monthly data from 2020 to 2025, we find robust evidence of a stable long-run cointegrating relationship between CBEC transaction value and three dimensions of logistics efficiency—timeliness, cost, and information transparency.

The empirical results reveal that logistics timeliness exerts the most substantial effect, with a long-run elasticity of -0.42 , followed by information transparency (0.32) and logistics cost (-0.28). The error correction term (-0.31) indicates relatively rapid adjustment toward long-run equilibrium, with approximately 31% of any deviation corrected within one month. The finding that long-run elasticities substantially exceed short-run elasticities underscores the cumulative nature of logistics improvements, suggesting that static analyses may significantly underestimate the total benefits of logistics investment.

These findings carry important implications for policymakers, logistics practitioners, and researchers. For policymakers, the results highlight the strategic importance of logistics infrastructure investment—particularly in delivery speed and information transparency—as a driver of CBEC growth in landlocked developing countries. For logistics practitioners, the findings suggest that sustained investment in tracking technology, delivery speed, and cost reduction can generate substantial returns through increased CBEC

volumes. For researchers, the study demonstrates the value of the ARDL methodology for investigating dynamic relationships in the CBEC-logistics context and points to several promising directions for future research.

As cross-border e-commerce continues to grow in importance as a driver of economic development in landlocked countries, understanding the quantitative relationship between logistics efficiency and CBEC development becomes increasingly critical. This study contributes to this understanding by providing rigorous empirical evidence from one of the world's most important land port corridors, offering insights that may inform both policy and practice in similar contexts around the world.

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