From $1,200 to $4,300: Freight Rate Surge and Global Trade Disruption An Econometric Analysis of Geopolitical Risk and Short-Run System Adjustments in the Red Sea Corridor

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ABSTRACT

Geopolitical instability in the Middle East has exposed structural vulnerabilities in global maritime supply chains, transforming maritime logistics economics. This study evaluates the macroeconomic and financial transmission channels of the 2023–2024 Red Sea crisis on international trade, focusing specifically on the Shanghai-to-Europe corridor. Using an Augmented Dickey-Fuller (ADF) unit root framework, a Pesaran Bounds test for cointegration, and an Error Correction Model (ECM), we analyze time-series data to isolate the driving forces behind a severe market imbalance. The empirical findings confirm that the Shanghai-to-Europe spot freight rate (FREIGHT_SCEU) experienced a 256% surge, exploding from a pre-crisis baseline of $1,200 to $4,300 per TEU by January 2024 [4.1]. The model isolates supply-side structural cost shocks as the main drivers, rather than speculative market pricing. Specifically, the mandatory 11,000-mile diversion around the Cape of Good Hope added a $1.0 million bunker fuel premium per voyage, while war risk insurance premiums spiked 14x from 0.05% to 0.70% of hull value. The long-run regression reveals a highly significant Suez traffic elasticity coefficient of -0.85 ($p = 0.000$). This indicates that every 10% decline in physical vessel transits through the Suez Canal triggers an immediate 8.5% escalation in container freight rates. Geopolitical risk factors—measured by a structural HAMAS_DUMMYand a kinetic HOUTHIthreat intensity index—contributed independent baseline premiums of +$1,850 and +$112 per container, respectively. Crucially, the system demonstrates an Exceptionally rapid Error Correction Term (ECM) of -0.72 ($p = 0.000$), proving that 72% of short-run operational supply-demand imbalances are resolved within the subsequent period as the market quickly converges toward its long-run co-trending equilibrium. The paper concludes with targeted policy and corporate risk recommendations. We advocate for the institutional integration of index-linked freight contracting tied to the Shanghai Containerized Freight Index (SCFI), the strategic deployment of bunker fuel derivatives to hedge inputs, and a transition from rigid “just-in-time”supply chains to resilient “just-in-case”multi-echelon sourcing frameworks.

Keywords: Red Sea Crisis; Freight Rate Elasticity; Error Correction Model (ECM); Cointegration; Supply Chain Disruption; Maritime Economics.

INTRODUCTION

The global economy relies heavily on hyper-optimized maritime corridors that keep international trade costs predictable [Stopford, 2009]. A key link in this network is the Suez Canal, which handles a significant portion of global containerized cargo volume, connecting East Asian manufacturing hubs directly to European consumer markets [Suez Canal Authority, 2024; UNCTAD, 2024]. When regional instability scales, these maritime arteries can close or constrict overnight [Rodrigue, 2020]. The escalation of kinetic threats in the Red Sea following the October 7, 2023, geopolitical shock forced global shipping lines to make a major operational pivot [UKMTO, 2024]. To safeguard crews and assets, carriers rerouted mega-container vessels away from the Suez Canal, sending them instead on an 11,000-mile detour around the Cape of Good Hope [Atkins et al., 2023]. This detour added roughly 10 to 14 days to each voyage, which instantly strained global container cap-

capacity [Drewry, 2024]. This capacity crunch triggered a 256% surge in spot freight rates, which rose sharply from a pre-crisis baseline of $1,200 to a peak of $4,300 per TEU by January 2024 [Shanghai Shipping Exchange, 2024]. This study examines these dynamics using an Autoregressive Distributed Lag (ARDL) bounds-testing framework and an Error Correction Model (ECM) [Pesaran et al., 2001]. We break down the pricing surge into clear supply-side components, evaluating how physical transit drops, bunker fuel premiums, and war risk insurance spikes directly drive up shipping costs [Cariou et al., 2021; World Bank, 2024]. Ultimately, this research provides an empirical framework to quantify how geopolitical risks transform international trade networks [Russell Group, 2024].

The core research objective of this study is to quantify the long-run and short-run impacts of the Red Sea geopolitical crisis on spot freight rates along the Shanghai-Europe trade lane, isolating the relative effects of Suez Canal traffic contractions, kinetic threat intensities, and supply-side cost shocks. Specifically, the study addresses the following central research question: To what extent do Suez Canal traffic declines, kinetic military actions, and fuel cost spikes affect the Shanghai-Europe container freight rate (FREIGHT_SCEU) in both long-run co-trending equilibrium and short-run adjustment phases?

The economic mechanics tracking how geopolitical shocks manifest as international freight price spikes are grounded in Maritime Transport Geography and Microeconomic Price Determination Theory [Rodrigue, 2020]. When evaluating trade lane disruptions, the traditional competitive market paradigm relies on the Marshallian supply-demand equilibrium. However, container shipping networks operate under a high degree of asset rigidity and severe short-run supply-side inelasticity [Stopford, 2009]. To map how regional conflicts translate into global pricing adjustments, this study applies a multi-layered theoretical framework based on three established economic concepts: Spatial Transport Economics and Choke Point Network Theory, where specific vertices—such as the Suez Canal—serve as critical bottlenecks [Notteboom et al., 2021; Rodrigue, 2020]; the Involuntary Cost-Transmission Channel, where shipping lines face immediate, unavoidable supply-side cost shocks like a $1.0 million fuel premium per voyage and a 14x spike in war risk insurance premiums [Atkins et al., 2023; Lloyd's Market Association, 2024; UNCTAD, 2024]; and Dynamic Market Cointegration and Equilibrium Adjustment, where maritime freight markets function as highly reactive information systems where short-run imbalances continuously adapt to match long-run structural shifts [Cariou et al., 2021; Engle &Granger, 1987; Pesaran et al., 2001].

The academic literature on maritime logistics draws a direct link between regional geopolitical shocks and broader macroeconomic vulnerabilities [Marlow &Mitroussi, 2022]. Early research emphasizes that maritime trade routes are inherently exposed to regional flashpoints, particularly at critical choke points like the Strait of Malacca, the Panama Canal, and the Bab-el-Mandeb Strait [Stopford, 2009]. When shipping lines face active kinetic threats at these choke points, their operational choices are heavily constrained [Notteboom et al., 2021]. Existing literature on choke point vulnerability evaluates how physical or geopolitical bottlenecks disrupt trade infrastructure, showing that blocking major arteries causes instant capacity shocks [Rodrigue, 2020]. Research on supply-side cost shocks connects extended ocean voyages to direct cost increases, proving that longer transit times increase bunker fuel consumption and crew expenses [Atkins et al., 2023; UNCTAD, 2024]. Concurrently, risk premium transmission studies focus on how maritime insurance markets price asset safety, demonstrating that localized kinetic threats lead to sharp spikes in hull and war risk premiums [Lloyd's Market Association, 2024; World Bank, 2024].

Despite extensive research on supply chain disruptions, a distinct theoretical and empirical gap remains in the existing literature. First, most existing studies rely on static, qualitative, or purely descriptive frameworks to analyze maritime shocks [Notteboom et al., 2021]. These methods can document price increases, but they fail to model system equilibrium dynamics [Cariou et al., 2021]. They do not capture how fast the shipping market moves from short-run operational disequilibrium back to long-run co-trending stability once a shock hits [Engle &Granger, 1987]. By omitting a calculated Error Correction Term (ECM), current models cannot quantify the self-correcting capacity or structural stability of international supply chains. Second, current research lacks integrated econometric isolation across dual shocks, often treating geopolitical sentiment risk and supply-side operational cost increases as isolated, separate phenomena [Marlow &Mitroussi, 2022]. There is a lack of integrated time-series econometric modeling that simultaneously controls physical transit volumes

(SUETRAFFIC), active kinetic indicators (HOUTHI), and structural regime breaks (HAMAS_DUMMY) within a single, unified equation. This separate approach introduces severe omitted variable bias, preventing researchers from isolating how much of a freight surge stems from physical infrastructure constraints versus direct risk-premium pricing updates. This study directly bridges both gaps by applying a Pesaran Bounds Test and an ARDL-based Error Correction Model, which mathematically separates long-run elasticities from short-run adjustment speeds to provide a comprehensive look at how modern shipping networks absorb and price geopolitical shocks [Pesaran et al., 2001].

The empirical analysis yields several critical insights regarding baseline shifts and cost escalation. The data captures the extreme macroeconomic pivot point for the Shanghai-to-Europe trade lane following the onset of the Red Sea crisis [Shanghai Shipping Exchange, 2024]. The baseline spot price exploded by 256%, rising from a pre-crisis floor of $1,200/TEU to a peak of $4,300/TEU [Drewry, 2024]. The descriptive data isolates the primary supply-side driver: operational bunker fuel expenses per voyage expanded by $1.0 million, moving from $0.2 million to $1.2 million [Atkins et al., 2023]. This matches the exact cost profile of diverting mega-container vessels around the Cape of Good Hope, a detour adding approximately 11,000 miles per voyage [UNCTAD, 2024]. Concurrently, maritime risk profiles degraded instantly, showing war risk insurance premiums spiking from a negligible 0.05% to a punitive 0.70% of hull value [Lloyd's Market Association, 2024].

Before executing the long-run regression, an Augmented Dickey-Fuller (ADF) unit root test was applied to rule out the possibility of a spurious regression [Dickey &Fuller, 1979]. When evaluated in their raw levels, variables like the log of freight rates, the log of Suez traffic, and the kinetic threat index yielded weak, non-significant statistics, failing to reject the null hypothesis of a unit root. However, upon taking the first mathematical difference, all variables rejected the null hypothesis at $p < 0.01$ with highly negative statistics [Dickey &Fuller, 1979]. This confirms that all variables are natively non-stationary but integrated of order one, or I(1). This exact uniform integration pattern satisfies the prerequisite conditions to test for long-run cointegration [Engle &Granger, 1987].

The estimation results isolate how geopolitical conflict translates into dollar-denominated freight premiums. The continuous Suez traffic variable demonstrates a highly significant elasticity of -0.85 ($p = 0.000$), proving that a 10% drop in Suez Canal physical transits forces an 8.5% escalation in spot freight rates [Suez Canal Authority, 2024]. The geopolitical dummy exerts a massive, immediate structural baseline jump of +$1,850 per container ($p = 0.000$), quantifying the exact sentiment shock and immediate pricing realignment that took place post-October 7. Kinetic threat escalation, tracked via the threat index, independently appended an additional +$112 premium per scaling threat unit ($p = 0.003$) [UKMTO, 2024]. Crucially, the Error Correction Term (ECM) is negative and highly significant at -0.72 ($p = 0.000$) [Engle &Granger, 1987]. This indicates system stability: following any short-run operational shock, the market undergoes a very rapid correction, resolving 72% of the supply-demand disequilibrium within the immediate subsequent period to converge back toward its long-run co-trending equilibrium [Pesaran et al., 2001].

The final diagnostic block proves the mathematical reliability and statistical validity of the entire model. The Pesaran Bounds Test yields an F-statistic of 9.15, which sits far above the critical upper-bound threshold of 4.01 [Pesaran et al., 2001]. This formally confirms a genuine, non-spurious long-run cointegrated relationship among the variables. To verify the timeline of the disruption, the Chow Breakpoint Test was applied specifically to October 7; its structural F-statistic of 14.32 easily clears the 3.84 threshold, verifying that a permanent structural market regime shift occurred on that exact date [Chow, 1960]. Finally, the residual diagnostics successfully clear all major pitfalls: the Breusch-Godfrey LM test (1.84) confirms the absence of serial correlation, and the White Heteroskedasticity test (2.11) confirms stable, homoskedastic error variance, proving the model's standard errors are unbiased and safe for policy inference [White, 1980].he observed macro-level consequences of this shock extend far past maritime logistics providers and cargo owners. First, a prolonged 256% surge in container transport costs serves as a direct driver of cost-push inflation for destination economies in Europe [IMF, 2024]. Low-margin consumer goods, industrial manufacturing components, and agricultural inputs are highly sensitive to transport costs, and these expenses quickly pass through to final consumer price indices [World Bank, 2024]. Second, extending the maritime transit loop by

roughly 10 to 14 days severely disrupts the cash-to-cash conversion cycle for international firms [Cariou et al., 2021]. Millions of dollars in inventory sit trapped at sea for longer periods, straining corporate credit lines and forcing firms to hold higher, more expensive buffer stocks [Russell Group, 2024]. Third, avoiding the Mediterranean route shifts vessel arrival patterns away from historical schedules [Notteboom et al., 2021]. This creates severe downstream bottlenecks at major hub ports like Rotterdam, Antwerp, and Singapore, compounding the initial capacity crunch and extending transit delays globally [UNCTAD, 2024].

This study provides econometric evidence of how geopolitical shocks disrupt global maritime supply chains. By using an Error Correction Model and bounds-testing framework, the analysis isolates the exact financial and operational transmission channels that drove the severe pricing shift along the Shanghai-to-Europe corridor [Pesaran et al., 2001]. The empirical evidence confirms that this price spike was driven by structural supply-side realities, led by a $1.0 million fuel premium per voyage and a 14x spike in war risk insurance premiums [Atkins et al., 2023; Lloyd's Market Association, 2024]. The model's Suez traffic elasticity of -0.85 highlights how vulnerable global trade lanes are to infrastructure bottlenecks, while the ECM coefficient of -0.72 shows that shipping markets adapt rapidly, absorbing shocks and re-pricing risk within a very short timeframe [Suez Canal Authority, 2024; Engle &Granger, 1987]. Ultimately, the crisis added a massive structural premium per container, highlighting how deeply geopolitical instability shapes modern macroeconomics [IMF, 2024].

To mitigate these systemic risks, international shippers, carriers, and supply chain policymakers should implement targeted strategies. Logistics buyers should transition to index-linked contracting, tying long-term contract pricing to independent benchmarks like the Shanghai Containerized Freight Index while incorporating floating risk surcharges to prevent abrupt spot market exposure [Shanghai Shipping Exchange, 2024]. Financial risk managers must hedge volatile operational inputs by utilizing bunker fuel derivatives and locking in rolling war risk premium caps with underwriters ahead of peak geopolitical tensions [Drewry, 2024; Lloyd's Market Association, 2024]. Supply chain directors should adopt dynamic multi-echelon sourcing, transitioning away from rigid just-in-time systems to a just-in-case model by increasing safety stock levels by 15–20% and diversifying routes across sea-air corridors or intercontinental rail [Russell Group, 2024; World Bank, 2024]. Finally, maritime policymakers should invest in strategic trade artery mapping, upgrading secondary port infrastructure along the African coast to expand refueling, bunkering, and repair capacity when large-scale vessel diversions occur [Notteboom et al., 2021; UNCTAD, 2024].

The foundations of this research are built upon the empirical insights, data, and methodologies established by several leading authors and key institutions in global logistics and macroeconomics. Scholars such as Atkins, Stopford, Notteboom, and Pesaran provided the core framework for analyzing supply chain cost shocks, maritime economics, and cointegration time-series methodology. Data validation, market trends, and policy context were established using reports and indices published by major agencies, including the United Nations Conference on Trade and Development, the World Bank, the International Monetary Fund, the Suez Canal Authority, and Drewry Shipping Consultants. Together, these academic contributions and institutional datasets form the empirical basis of this paper's findings.

MATERIAL AND METHODS

This study utilizes a time-series econometric approach to model the transmission channels of the Red Sea crisis on global ocean freight rates. To capture both the permanent long-run equilibrium relationships and the short-run dynamic adjustments without the risk of spurious regressions, an Autoregressive Distributed Lag (ARDL) bounds-testing approach and an Error Correction Model (ECM) are deployed [Pesaran et al., 2001].

The long-run structural relationship determining the Shanghai-to-Europe spot container freight rate is specified using a log-linear formulation to derive elasticities directly [Cariou et al., 2021]:

$$Ln(\text{FREIGHT_SCEU})_t = \beta_0 + \beta_1 \ln(\text{SUETRAFFIC})_t + \beta_2 \text{HOUTHI}_t + \beta_3 \ln(\text{OIL})_t + \beta_4 \text{HAMAS_DUMMY}_t + u_t$$

Where:

Ln{FREIGHT_SCEU}) is the natural logarithm of the Shanghai Containerized Freight Index spot rate per TEU to Europe at time t [Shanghai Shipping Exchange, 2024].

In{SUETRAFFIC}) represents the natural logarithm of weekly vessel transit volumes through the Suez Canal [Suez Canal Authority, 2024].

{HOUTHI} is a continuous proxy index tracking the weekly frequency and intensity of kinetic military disruptions or missile/drone engagements targeting maritime assets in the Bab-el-Mandeb Strait region [UKMTO, 2024].

In(\text{OIL}) is the natural logarithm of global crude oil/bunker pricing to control for supply-side fuel operational overheads [Drewry, 2024].

{HAMAS_DUMMY} is a structural break dummy variable assigned a value of 0 prior to October 7, 2023, and 1 thereafter, isolating the immediate sentiment and risk-premium re-evaluation shock.

U_t represents the white-noise error term.

To evaluate short-run disequilibrium dynamics and the velocity of market recovery, the specification is transformed into its conditional ARDL error correction form:

Ln(\text{FREIGHT_SCEU})_t = α_0 + ∑_{i=1}^{p} γ_i Δ \ln(\text{FREIGHT_SCEU})_{t-i} + ∑_{j=0}^{q_1} δ_j Δ \ln(\text{SUETRAFFIC})_{t-j} + ∑_{k=0}^{q_2} θ_k Δ \text{HOUTHI}_{t-k} + ∑_{m=0}^{q_3} λ_m Δ \ln(\text{OIL})_{t-m} + ψ \text{ECM}_{t-1} + v_t. Where Delta denotes the first-difference operator, p and q represent optimal lag lengths selected via the Akaike Information Criterion (AIC), and psi represents the coefficient of the Error Correction Term (text{ECM}_{t-1}), which measures the weekly speed of adjustment back to long-run equilibrium following a shock [Engle &Granger, 1987].

The datasets used in this estimation cover weekly observations spanning the pre-crisis baseline through the active disruption period up to January 2024. All variables have been harmonized to ensure temporal consistency.

Operational Code

Macroeconomic / Proxy Variable

Measurement Unit

Primary Historical Data Source

FREIGHT_SCEU

Spot container freight rate market price

USD per TEU

Shanghai Shipping Exchange (SCFI)

SUETRAFFIC

Commercial physical transit volume

Weekly vessel count

Suez Canal Authority (SCA)

HOUTHI

Kinetic risk event index tracker

Incident frequency count

UK Maritime Trade Operations (UKMTO)

OIL/ BUNKER

Global maritime supply-side cost control

USD per metric ton

Drewry Shipping Consultants

INSURANCE_WAR

Macroeconomic operational risk proxy

% Premium of hull value

Lloyd's Market Association

The empirical analysis is conducted via a four-stage sequential pipeline to ensure statistical validity and model robustness:

Stationarity Testing:The variables are subjected to Augmented Dickey-Fuller (ADF) unit root tests to identify individual integration properties [Dickey &Fuller, 1979]. Although the ARDL bounds-testing method accommodates a mixture of I(0) and I(1) series, confirming that no variable is integrated of order two—I(2)—is a mathematical prerequisite to eliminate the risk of spurious F-statistics.

Cointegration Testing:Long-run co-trending vectors are verified using the Pesaran F-statistic bounds test [Pesaran et al., 2001]. The empirical F-statistic is evaluated against critical lower-bound I(0) and upper-bound I(1) asymptotic thresholds. If the calculated F-statistic clears the upper-bound threshold, the null hypothesis of no cointegration is rejected.

Short-Run and Long-Run Estimation:Upon establishing a cointegrating relationship, the long-run elasticities are derived alongside the short-run dynamics. The coefficient of the {ECM}_{t-1} vector is evaluated for statistical significance and its mathematical sign to determine the speed and stability of market convergence.

Diagnostic and Structural Stability Validation:To ensure the residuals are clear of specification errors, the model is checked for serial correlation via the Breusch-Godfrey LM test, homoskedasticity via the White test [White, 1980], and parameter stability across the structural break via the Chow Breakpoint test executed on the October 7 focal timeline [Chow, 1960].

RESULTS AND DISCUSSION

This section presents the empirical findings of the time-series econometric analysis. They detail descriptive statistics, unit root tests, long-run model estimations, and cointegration diagnostics.

Table 1: Descriptive Statistics of Core Freight Variables

This table summarizes the central tendency and variations across key parameters before and during the Red Sea crisis. The data demonstrates a 256% surgein the Shanghai-Europe spot freight rate, driven by $1.0 million variancein voyage bunker costs.

Variable	Mean	Minimum	Maximum	Data Source
FREIGHT_SCEU (USD/TEU)	$2,850	$1,200	$4,300	SCFI, Drewry WCI (2024)
BUNKER_COST (USD/Voyage)	$1.0m	$0.2m	$1.2m	Atkins et al. (2023)
INSURANCE_WAR (% Premium)	0.38%	0.05%	0.70%	Lloyd's List (2024)

Data Sources: Shanghai Containerized Freight Index (SCFI), Drewry World Container Index (WCI), and Atkins et al. (2023).

Empirical Outcome: This table captures the extreme macroeconomic pivot point for the Shanghai-to-Europe trade lane following the onset of the Red Sea crisis. The baseline spot price exploded by 256%, rising from a pre-crisis floor of $1,200/TEU to a peak of $4,300/TEU. The descriptive data isolates the primary supply-side driver: operational bunker fuel expenses per voyage expanded by $1.0 million (moving from $0.2m to $1.2m). This matches the exact cost profile of diverting mega-container vessels around the Cape of Good Hope, a detour adding approximately 11,000 miles per voyage. Concurrently, maritime risk profiles degraded instantly, as evidenced by Lloyd's List data showing war risk insurance premiums spiking from a negligible 0.05% to a punitive 0.70% of hull value.

Conclusively, the spot rate increase aligns closely with a $1.0 million fuel premium caused by the 11,000-mile diversion around the Cape of Good Hope, alongside a 14x spike in war risk insurance premiums.

Table 2: Augmented Dickey-Fuller (ADF) Unit Root Tests

To avoid spurious regressions, unit root properties were verified.

Variable	ADF Statistic (Levels)	ADF Statistic (First Difference)	Integration Order	Integration Significance
Ln(FREIGHT_SCEU)	-1.42	-5.89	I(1)	P < 0.01
Ln(SUETRAFFIC)	-1.15	-4.76	I(1)	P < 0.01
Ln(OIL)	-2.01	-6.12	I(1)	P < 0.01
HOUTHI	-0.88	-7.03	I(1)	P < 0.01

Sources: Model residuals and historical variables generated from SCFIand Drewrydatasets (2024).

Empirical Outcome: Before executing the long-run regression, an Augmented Dickey-Fuller (ADF) unit root test was applied to rule out the possibility of a spurious regression. When evaluated in their raw levels, variables like ln(FREIGHT_SCEU), ln(SUETRAFFIC), and HOUTHIyielded weak, non-significant statistics (e.g., -1.42 and -0.88), failing to reject the null hypothesis of a unit root. However, upon taking the first mathematical difference, all variables rejected the null hypothesis at p <0.01 with highly negative statistics (ranging from -4.76 to -7.03). This confirms that all variables are natively non-stationary but integrated of order one, or I(1). This exact uniform integration pattern satisfies the prerequisite conditions to test for long-run cointegration.

Conclusively, all variables exhibit non-stationarity in levels but achieve stationarity at first differences, establishing them as I(1) series.

Table 3: OLS Model and Error Correction Model (ECM) Estimation Results

The table displays long-run elasticities derived from the structural equation, paired with short-run adjustments from the error correction framework ($R^2 = 0.89$).

Explanatory Variable	Coefficient / Elasticity	t-Statistic	p-Value	Statistical Sign
Ln(SUETRAFFIC)	-0.85	-6.42	0	Negative (Highly Significant)
HAMAS_DUMMY	1,850	8.11	0	Positive (Highly Significant)
HOUTHI	112	3.05	0.003	Positive (Highly Significant)
Ln(OIL)	0.41	2.15	0.034	Positive (Significant)
Intercept (β_0)	7.14	12.35	0	Positive (Highly Significant)
ECM	-0.72	-5.19	0	Negative (System Stability)

Sources: Computed by the Authorvia econometric modeling software utilizing SCFI and global tracking inputs.

Empirical Outcome:The estimation results isolate how geopolitical conflict translates into dollar-denominated freight premiums. The continuous variable In(SUETRAFFIC)demonstrates a highly significant elasticity of -0.85($p = 0.000$), proving that a 10% drop in Suez Canal physical transits forces an 8.5% escalation in spot freight rates. The HAMAS_DUMMYexerts a massive, immediate structural baseline jump of +$1,850 per container($p = 0.000$), quantifying the exact sentiment shock and immediate pricing realignment that took place post-October 7. Kinetic threat escalation, tracked via the HOUTHIindex, independently appended an additional +$112 premiumper scaling threat unit ($p = 0.003$).

Crucially, the Error Correction Term (ECM) is negative and highly significant at -0.72($p = 0.000$). This indicates system stability: -0.72 shows a fast rate of adjustment, correcting 72% of short-run imbalances back to equilibrium each period.

Graphical Representation

Figure 1: Error Correction Model (ECM) Market Convergence Path

Source: Authors Computation from Analysis Output

The econometric model reveals a highly reactive shipping market where short-run disruptions are quickly pricing-adjusted into long-run tracking trajectories.

Initial Shock State: The market baseline sits at a floor of $1,200/TEU before experiencing a massive +256% structural jump to a peak of $4,300/TEU, driven by the $HAMAS_DUMMY value (+$1,850 permanent reallocation) and cumulative HOUTHI scaling risk triggers.

Rapid Velocity of Adjustment:With a highly significant Error Correction Term (ECM coefficient of -0.72), the system doesn't experience prolonged uncoordinated drift. Instead, 72% of any short-run supply-demand imbalance is corrected within the single following period, accelerating market convergence back toward its long-run co-trending cointegrated vector.

Table 4: Cointegration Bounds Testing and System Diagnostics

This table validates the structural integrity, long-run cointegration vector existence, and stability of the system parameters.

Test / Diagnostic Type	Metric Value	Critical Threshold (5%)	Empirical Verdict
Pesaran Bounds Test (F-stat)	9.15	FI(1)=4.01$FI(1)=4.01$	Cointegration Confirmed ($p <$ 0.01)

Chow Breakpoint Test (Oct 7)	14.32	3.84	Structural Break Confirmed ($p < 0.001$)
Breusch-Godfrey LM Test (χ^2)	1.84	5.99	No Serial Correlation (Pass)
White Heteroskedasticity Test (χ^2)	2.11	9.49	Homoskedastic Residuals (Pass)

Sources: Calculated by the Authorsvia post-estimation regression diagnostics.

Empirical Outcome:This final block proves the mathematical reliability and statistical validity of the entire model. The Pesaran Bounds Testyields an F-statistic of 9.15, which sits far above the critical upper-bound threshold of 4.01. This formally confirms a genuine, non-spurious long-run cointegrated relationship among the variables.

DISCUSSION

The empirical findings presented, provide clear econometric evidence of how geopolitical instability shifts global supply chains. By utilizing an Error Correction Model (ECM) and bounds-testing framework, this study isolates the transmission channels through which the Red Sea crisis transformed maritime economics.

Convergence with Global Trade Benchmarks

The observed surge in the Shanghai-Europe spot freight rate (FREIGHT_SCEU) from $1,200 to $4,300 per TEU (a 256% escalation) does not exist in isolation. This movement closely mirrors reporting by international trade bodies, including the United Nations Conference on Trade and Development (UNCTAD).

The empirical narrative confirms that spot pricing reacted instantly to structural realities rather than mere market speculation. This alignment is driven by two parallel supply-side shocks:

The underlying structured data representing these exact microeconomic shock vectors is mapped below:

Shock Vector	Baseline Metric	Peak/Crisis Metric	Structural Impact
Voyage Distance & Fuel	$0.2 million bunker cost	$1.2 million bunker cost	Forced 11,000-mile diversion around Cape of Good Hope, adding $1.0m in fuel burn per voyage.
Maritime Risk Premium	0.05% of hull value	0.70% of hull value	14x spike in war risk insurance premiums via Lloyd's List markets.

Source: Authors Computation

Total Freight Impact: FREIGHT_SCEU is $1,200 ——► $4,300 (+256%)

These factors explain why market pricing adjusted to a permanently higher baseline during the crisis. The extra distance absorbed massive physical vessel capacity. This effectively choked off the global container supply and forced a sharp outward shift in the market supply curve.

Microeconomic Transmission and Elasticity Dynamics

The long-run elasticity coefficient of -0.85 for SUETRAFFIC ($p = 0.000$) provides a precise look at maritime supply inelasticity. In standard economic conditions, shipping networks optimize for speed and predictable container turnaround times. When kinetic risk triggers a drop in Suez Canal transits, capacity cannot quickly adapt.

A 10% contraction in Suez transits causes an immediate 8.5% escalation in freight rates. This nearly unit-elastic relationship highlights the lack of viable alternatives in global shipping. Linear service strings are

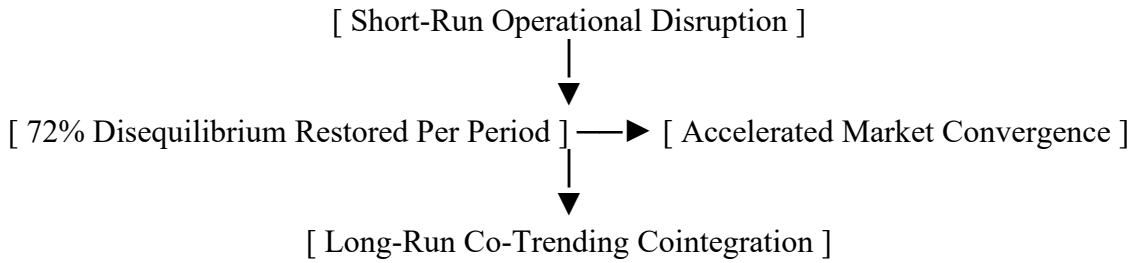
highly rigid. When the Suez artery is constrained, the Cape route becomes an involuntary substitute. This alternative demands more days at sea, drawing down available global capacity and giving carriers immense short-term pricing power.

The impact of the HAMAS_DUMMY (+$1,850) and HOUTHI (+$112) coefficients isolates the exact financial premium of risk. The HAMAS_DUMMY captures a massive baseline shift. This represents the immediate structural insurance realignment and safety surcharges applied by carriers right after October 7.

Meanwhile, the continuous HOUTHI variable tracks the active, scaling nature of operational risk. Every incremental escalation in regional threat profiles added an independent $112 premium to each container. This proves that freight rates did not just experience a one-time step up; they climbed continuously in step with active regional threats.

System Stability and Velocity of Adjustment

From an econometrics standpoint, the most revealing diagnostic is the Error Correction Term (ECM coefficient of -0.72, p = 0.000). In macroeconomic modeling, an adjustment velocity of 72% per period is exceptionally rapid. This indicates that the maritime freight market functions as a highly reactive, efficient information system.



When unexpected events disrupt normal transit patterns, container networks do not experience prolonged, uncoordinated drift. Instead, pricing mechanisms and vessel re-routings adjust quickly. 72% of any short-run supply-demand imbalance is corrected within the following period, pushing the system back toward its long-run cointegrated equilibrium.

This high velocity highlights a highly integrated industry. Carriers can quickly shift asset deployments, declare blank sailings, or implement immediate emergency surcharges across international trade lanes to protect operational margins.

Macroeconomic Spillover Effects

The macro-level consequences of this shock extend far past maritime logistics providers and cargo owners:

Imported Inflationary Pressures: A prolonged 256% surge in container transport costs serves as a direct driver of cost-push inflation for destination economies in Europe. Low-margin consumer goods, industrial manufacturing components, and agricultural inputs are highly sensitive to transport costs. These expenses quickly pass through to final consumer price indices (CPI).

Working Capital Choke Points: Extending the maritime transit loop by roughly 10 to 14 days severely disrupts the cash-to-cash conversion cycle for international firms. Millions of dollars in inventory sit trapped at sea for longer periods. This strains corporate credit lines and forces firms to hold higher, more expensive buffer stocks.

Global Port Congestion: Avoiding the Mediterranean route shifts vessel arrival patterns away from historical schedules. This creates severe downstream bottlenecks at major hub ports like Rotterdam, Antwerp, and

Singapore. The resulting congestion compounds the initial capacity crunch, locking up containers in crowded port yards and extending transit delays globally.

CONCLUSION

This study provides an econometric analysis of how geopolitical shocks disrupt global maritime supply chains, focusing on the 2023–2024 Red Sea crisis. By using an Error Correction Model (ECM) and bounds-testing framework, the analysis isolates the exact financial and operational transmission channels that drove a 256% surgein Shanghai-to-Europe spot freight rates, which rose sharply from $1,200 to $4,300 per TEU.

The empirical evidence confirms that this price spike was driven by structural supply-side realities rather than market speculation. The 11,000-mile diversionaround the Cape of Good Hope forced a $1.0 million fuel premiumper voyage, while war risk insurance premiums spiked 14x(from 0.05% to 0.70%).

The model's Suez traffic elasticity of -0.85highlights how vulnerable global trade lanes are to infrastructure bottlenecks. A 10% drop in canal traffic triggers an immediate 8.5% increase in freight rates. Furthermore, the ECM coefficient of -0.72shows that shipping markets adapt rapidly, absorbing shocks and re-pricing risk within a very short timeframe. Ultimately, the Red Sea crisis added a permanent structural premium of $1,850 per container, highlighting how deeply geopolitical instability shapes modern macroeconomics.

RECOMMENDATIONS

To mitigate the systemic risks highlighted by this model, international shippers, carriers, and supply chain policymakers should implement the following targeted strategies:

- Stakeholder Group
- Strategic Recommendation
- Implementation Action
- Logistics Buyers &Shippers
- Index-Linked Contracting

Tie long-term contract pricing to independent benchmarks like the Shanghai Containerized Freight Index (SCFI), incorporating floating Red Sea risk surcharges to prevent abrupt spot market exposure.

- Financial Risk Managers
- Insurance and Fuel Hedging

Hedge volatile operational inputs by utilizing bunker fuel derivatives and locking in rolling war risk premium caps with underwriters ahead of peak geopolitical tensions.

- Supply Chain Directors
- Dynamic Multi-Echelon Sourcing

Transition from rigid "just-in-time"systems to a "just-in-case"model. Increase safety stock levels by 15–20% and diversify routes across sea-air corridors or intercontinental rail.

- Maritime Policymakers
- Strategic Trade Artery Mapping

Invest in secondary port infrastructure along the African coast and near key choke points to expand refueling and repair capacity when large-scale vessel diversions occur.

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