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# Determinants of Türkiye's Liner Shipping Connectivity Index: Uncertainty, Trade, and Exchange Rates

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**Abstract:** *This study examines the impact of global uncertainty, foreign trade volume, and the real effective exchange rate on Türkiye's Liner Shipping Connectivity Index. It applies a partially asymmetric NARDL model to quarterly data for 2010Q1-2025Q3 period. The results show that global uncertainty is positively associated with liner shipping connectivity in both the short and long run. Import volume emerges as the dominant long run determinant of connectivity, with import contractions exerting a stronger negative effect than the positive effect generated by expansions. Export expansion affects liner shipping connectivity only over longer horizons while real appreciation provides statistically weak evidence of a positive effect on connectivity. These findings indicate Türkiye's maritime connectivity is shaped by asymmetric and horizon dependent mechanisms beyond trade volume alone. Overall, the results suggest that liner shipping rigidity, carrier adjustment behavior, import dependence, supply chain resilience and Türkiye's strategic transit position are important factors in explaining maritime connectivity dynamics. They also suggest that policy priorities should include stable import related cargo flows, service continuity, port efficiency and readiness for route reconfiguration within changing global liner shipping networks.*

**Keywords:** Liner Shipping Connectivity Index, Global Uncertainty, Trade Volume, Exchange Rates, Asymmetry

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## 1. Introduction

Maritime transport forms the main physical channel of international merchandise trade as over 80% of global goods trade by volume is carried by sea (United Nations Conference on Trade and Development [UNCTAD], 2023). For emerging economies dependent on trade, efficient and regular liner shipping services are one of the structural determinants of economic integration and competitiveness. The Liner Shipping Connectivity Index (LSCI), developed by UNCTAD, measures how strongly a country is connected to regular liner shipping networks. It is constructed from six elements: scheduled ship calls, deployed capacity, regular liner services, liner shipping companies, largest ship size and direct country connections (UNCTAD, 2026). A higher LSCI value indicates better global market access, lower effective transport costs and stronger integration into liner shipping networks and global production networks (UNCTAD, 2013; UNCTAD, 2017). Therefore, understanding the determinants of LSCI is fundamental for countries that seek to improve trade competitiveness and port infrastructure.

Türkiye is strategically important for maritime shipping due to its location at the intersection of Europe, Asia and the Middle East. The sustainability of ports for combined transport and the enhancement

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of their capabilities increasingly support Türkiye’s competitiveness in international trade (Cesur, 2020: 44). Although Türkiye’s foreign trade volume has expanded substantially over the past two decades, its LSCI has followed an upward trend with notable fluctuations. This suggests that connectivity performance cannot be explained solely by trade growth and may also reflect structural and macroeconomic factors (Turkish Statistical Institute [TurkStat], 2026; UNCTAD, 2026). From a theoretical perspective, uncertainty is one of the relevant factors as it may affect liner shipping through demand fluctuations, operational risk and route reconfiguration. Another important factor is exchange rate as it may influence connectivity through trade demand and cost channels by changing relative prices. Existing studies focusing on Türkiye have mainly explained maritime performance through uncertainty, exchange rate movements, foreign trade and liner shipping connectivity by using proxy indicators such as container traffic, container handling volume and port activity (Açık, 2020; Açık et al., 2019; Atacan et al., 2022; İpekçi & Sözen, 2025). However, direct evidence on the macroeconomic determinants of Türkiye’s LSCI remains limited. This leaves the dynamics of the index underexplored.

This study aims to fill this gap by estimating short run and long run effects of World Uncertainty Index (WUI), both export and import volume indices and the real effective exchange rate (REER) on Türkiye’s LSCI over the period 2010Q1-2025Q3. To account for possible nonlinear adjustment patterns, the study employs a partially asymmetric nonlinear autoregressive distributed lag (NARDL) framework that allows trade volume and exchange rate changes to affect maritime connectivity differently depending on the direction of the shock.

The study adds to the existing literature in three respects. First, although previous studies have examined maritime connectivity and related port performance indicators, country specific time series evidence on the determinants of Türkiye’s LSCI remains limited. Therefore, this study focuses directly on Türkiye’s LSCI within a quarterly time series framework. Second, it jointly examines world uncertainty, export volume, import volume and REER. It integrates uncertainty, trade volume and macroeconomic price channels within a single empirical model. Third, by applying a partial asymmetric NARDL model, it separates expansionary and contractionary movements in trade volumes and the REER while treating WUI as symmetric. This allows the analysis to identify whether Türkiye’s maritime connectivity reacts differently to trade and exchange rate expansions or contractions.

The remainder of the paper is organized as follows. Section 2 explains the theoretical background. Section 3 presents the literature review. Section 4 describes the dataset and methodology. Section 5 reports and discusses the empirical results. Section 6 concludes with policy implications and directions for future research.

## 2. Theoretical Background

Theoretically, heightened uncertainty is expected to adversely affect economic agents' decision-making processes and it leads to a contraction in aggregate demand. As uncertainty increases, foreign trade demand, order flows and cargo throughput are expected to decrease, leading shipping lines to service cancellations, capacity adjustments or network reconfiguration (Crotti et al., 2022; Pan et al., 2022; Sağlam et al., 2021). However, uncertainty can influence the LSCI through two opposing channels. While demand contraction implies a negative effect, network reconfiguration and route diversification may generate a positive effect. Therefore, the net effect of WUI on LSCI is treated as an empirical question.

The LSCI should be distinguished from port throughput or container handling volume. Port throughput measures the volume of container traffic handled, which may include loaded containers, empty containers, repositioning flows and transshipment movements. In major transshipment centers, empty and transshipped containers can account for a substantial share of total handling (World Bank, n.d.). Therefore, high handling volume may not directly imply stronger liner shipping network integration. LSCI captures a country’s supply side position within these networks through components that are schedule based (Hoffmann et al., 2024). Accordingly, the studies relying on container traffic, port activity or cargo throughput are included as close proxies of the LSCI, not as its direct equivalents.

The LSCI is not only a trade volume indicator but also represents a country's position within the maritime network. Therefore, external shocks should be interpreted through network reconfiguration as well as demand contraction. According to the modern logistics approach, uncertainty can trigger resilience-oriented transformation, and flexibility in port logistics is crucial under increased uncertainty (Russell et al., 2022: 94). The Covid-19 pandemic, geopolitical conflicts and other disruptions have also increased attention to adaptive mechanisms such as buffer stocks, supplier diversification and strategic capacity reservations (Gou et al., 2025: 451). Similarly, geopolitical risks and geoeconomic fragmentation have increased the emphasis on supply chain resilience, while nonaligned connector countries have gained importance for de-risking (Gopinath et al., 2024). Within this framework, de-risking refers to the re-structuring of sourcing patterns through reshoring and friend-shoring (Cerdeiro et al., 2024: 5). This interpretation is supported by evidence indicating that global economic uncertainty may increase port activity during heightened uncertainty and in the long term (İpekçi & Sözen, 2025: 2020).

World uncertainty and geopolitical shocks may increase route costs and operational risks, leading carriers to route changes, port call adjustments and network reconfiguration. For example, the 2024 Suez Canal disruptions, a geographical crisis that triggered a broader rise in global uncertainty, caused container ships to reroute via the Cape of Good Hope, and by the second week of February 2024, 586 container vessels had re-routed (UNCTAD, 2024: 4, 11). Since transshipment port selection is partly determined by strategic location, strategically positioned nodes may become relatively more important when transit cargo flows are relocated. There is some evidence supporting this interpretation. For example, as the Cape Route became a substitute for Suez Canal transits, longer sailing distances led shipping lines to deploy additional vessels to preserve service frequency, while port-call adjustments rendered transshipment containers handled by Eastern Mediterranean and Red Sea ports relatively footloose (Yap & Yang, 2024:1). As Türkiye is a node that connects Europe, Asia and Northern Africa in the East Mediterranean, its geostrategic location and transshipment capacity may provide a potential basis for benefiting from such reallocations (Moschovou & Kapetanakis, 2023: 727). However, these channels are not directly observed in this study. Therefore, they are proposed as plausible interpretations consistent with the estimated relationship rather than directly tested mechanisms.

Within this framework, the positive relationship between uncertainty and maritime connectivity can also be understood from a network diversification perspective at the service level. Similar to financial investors managing asset exposure, shipping lines may respond to heightened uncertainty by broadening route and port-call combinations instead of concentrating services on a single corridor. During periods of market stress, hedging activity between oil futures and liner shipping companies increases and is accompanied by stronger portfolio diversification benefits (Maitra et al., 2020: 31). Under such conditions, disruption management may require operational reconfiguration of service networks, including port omission, speed adjustment and alternative route decisions (Asghari et al., 2023: 627-628). Taken together, these findings suggest that market stress in liner shipping can generate risk-management responses at both financial and operational levels. Türkiye's position at the intersection of Europe, Asia and Northern Africa may therefore support additional service calls and connectivity when global uncertainty is elevated.

International trade is another important determinant of maritime shipping connectivity. Theoretically, when a country's exports and imports increase, its LSCI is expected to rise accordingly. Since demand for maritime transport is primarily derived from raw material imports and manufactured goods trade, the overall trajectory of the global economy is the main determinant of shipping capacity requirements (Stopford, 2009: 140). As international trade expands, it stimulates demand for inbound loaded containers, port handling operations, vessel calls and liner service capacity. It also drives expansion among carriers, cargo owners, terminal operators, third-party logistics firms and freight forwarders (Notteboom et al., 2022: 3). Sustained increases in export and import volumes may lead liner service providers to adjust capacity, vessel deployment and service structure according to perceived demand, thereby strengthening a country's LSCI over time (Fugazza & Hoffmann, 2017: 16). Since the LSCI is operationalized through carrier presence, deployed twenty-foot equivalent units (TEU) capacity, number of vessels, service frequency, shipping options and maximum vessel size, sustained increases in export and import volumes may strengthen the LSCI by expanding the operational basis of liner services (Wilmsmeier & Hoffmann, 2008). Therefore, higher export and import volumes are expected to positively affect a country’s LSCI.

The expected positive relationship between international trade and the LSCI may weaken in the short run due to capacity adjustment constraints in liner shipping. Since capacity control is difficult, capacity is generally added in large blocks, liner services involve high fixed costs and unused capacity cannot be stored (Notteboom, 2004). This is consistent with the planning structure of liner shipping, where tactical decisions determine the service network and operational decisions are limited to cargo acceptance and routing within that structure (Agarwal & Ergun, 2008: 177). Also, once a ship is assigned to a route, it generally remains there for the entire planning period, and weekly decisions affect subsequent shipping capacities (Wang et al., 2014: 49). Therefore, trade-volume changes may first be absorbed within existing deployment mechanisms before being reflected in broader LSCI adjustment. Consequently, while export and import volume fluctuations are expected to influence the LSCI over longer horizons, their immediate effects may remain statistically weak.

Exchange rate movements can influence maritime shipping connectivity through the cost structure of liner services. Container freight rates incorporate several cost components. These include port and channel charges, terminal handling costs, cargo manipulation costs and currency adjustment factors. It means that exchange rate changes form part of the broader cost environment faced by shipping lines (Oblak et al., 2016). However, this cost channel does not necessarily operate uniformly across all contexts.

Exchange rate movements may also shape maritime shipping connectivity through trade demand. Real appreciation, for instance, tends to stimulate import demand, which raises the need for containerized liner services. This aligns with the view that shipping is a derived demand and maritime transport volumes are conditioned by world trade (Cariou, 2020: 5). At the network level, this demand channel also includes capacity and service adjustments accompanying shifts in seaborne trade. Accordingly, trade changes induced by exchange rates may be reflected in ship carrying capacity, liner service configuration, port performance and port capacity requirements (UNCTAD, 2017: 16). Empirical evidence also shows that exchange rate movements can affect loaded port cargo throughput and maritime export volumes through freight flows and liner service requirements (Chi & Cheng, 2016; Kim, 2016). Therefore, the REER-LSCI relationship can be understood through cost-side and demand-side maritime channels rather than a purely direct volume effect.

## 3. Literature Review

In the literature, proxy variables are generally used instead of the LSCI when examining the effects of uncertainty on maritime trade. The most common proxies are container throughput, port traffic, dry bulk cargo and tanker freight indexes. Açık (2020) examined Turkish ports over 2004–2019 and found that negative WUI shocks positively affected exported and imported container volumes. Bai (2021), using global tanker freight data for 2002–2019, showed that global economic policy uncertainty (GEPU) shocks had a statistically meaningful effect on tanker freight rates. Drobetz et al. (2021) analyzed global dry bulk freight rates over 1991–2018 and found that geopolitical risk (GPR) shocks had a positive but diminishing effect, while economic policy uncertainty (EPU) shocks reduced trade demand and dry bulk freight rates. Sağlam et al. (2021) studied 21 European countries over 2005–2018 and reported that the WUI significantly affected port throughput. Akpa (2022), directly using LSCI for 16 G7, BRICS and MINT economies over 2006–2021, found that global trade disruptions affected developing countries more strongly than developed countries. Atacan and Açık (2023) examined 15 developing countries, including Türkiye, over 2000–2020 and found that positive GPR shocks generally reduced container traffic, whereas Türkiye showed a positive response. Yap and Yang (2024) showed that geopolitical tensions on Asia–Europe and Asia–Mediterranean routes led shipping companies to adjust capacity, investments, sailing routes and port calls. Cai (2025) analyzed Shanghai Port over 2000–2022 and found that global economic uncertainty directly affected container volume. İpekçi and Sözen (2025) examined Turkish ports and reported that rising global economic uncertainty increased port activity, suggesting that Türkiye’s logistics infrastructure may become more prominent as a transit hub under uncertain conditions. Thus, the uncertainty literature does not point to a single uniform effect. While some studies emphasize demand contraction and operational risk channels, the findings focused on Türkiye suggest that uncertainty may also generate a positive effect through transit hub dynamics and network reconfiguration.

There are few studies directly investigating the effects of trade flows on maritime connectivity by using the LSCI; instead, most studies use proxies such as container throughput or cargo throughput, which also reflect maritime connectivity. Syafi'i et al. (2005) analyzed Indonesia over 1982–2002 and found that export volumes had stronger positive effects on container throughput than import volumes. Makhecha (2016) examined major ports in the Hamburg–Le Havre range over 1995–2015 and showed that export and import values were the most significant determinants of container throughput, with positive and linear effects. Rashed (2016) studied Antwerp Port and the EU Hamburg–Le Havre region over 1990–2015 and found that exports and imports were the main determinants of container demand and port connectivity. Büyükakın, et al. (2025) analyzed the Mediterranean Corridor over 2005–2024 and reported that improvements in the foreign trade balance increased container port throughput. Guo et al. (2025), using data for 43 Chinese ports in 2022, found that total exports and imports positively affected port cargo throughput and maritime connectivity, although these effects varied spatially. Fang et al. (2026) examined 55 Chinese ports over 2018–2023 and showed that import and export volumes had positive effects in the global model, but their impact was highly spatially sensitive. Canbay et al. (2026) directly used the LSCI for ASEAN-5 countries over 2006–2021 and found a strong relationship between export dynamics and the LSCI, with causality from export volume to the LSCI in Indonesia and the Philippines. Overall, the literature agrees that trade volume is a basic source of derived demand for maritime transport, but it also shows that the relative importance of exports and imports depends on the country, port system, spatial structure and the indicator used.

Exchange rates are basic determinants of many economic variables, including maritime shipment, and several studies use exchange rates as a factor affecting shipping performance and connectivity. Kim and Lu (2016) analyzed South Korean ports over 2008–2013 and found that the REER had positive statistically significant effects on container throughput and transshipment cargo. Gosasang et al. (2018) examined Bangkok Port in Thailand over 2000–2015 and showed that exchange rates affected port traffic and could be used for long-term forecasting of inbound and outbound container throughput. Açık et al. (2019) studied Turkish ports over 2004–2018 and found that the effect of exchange rates on container handling volume varied over time, while extreme exchange rate increases had significant positive effects on container volumes. Haris (2019) analyzed Belawan International Container Terminal in Indonesia over 2006–2018 and reported that exchange rate changes in Malaysia and Thailand positively affected container traffic in Belawan. Atacan et al. (2022) examined Türkiye over 2006–2021 and found that increases in the real exchange rate negatively affected both export and import container numbers, while the LSCI positively affected both. Thalagala et al. (2025) studied Sri Lankan ports over 1994–2023 and found that exchange rates positively and significantly affected container-throughput growth. These mixed findings indicate that exchange rate effects depend on context. In some cases, currency movements increase container and transit cargo throughput, while in others they create negative pressure on trade volume and connectivity. Therefore, the REER should be considered not as a uniformly positive and negative determinant, but as a macroeconomic channel whose effect depends on the balance between import demand, export competitiveness and shipping cost adjustments.

Taken together, the literature can be grouped into three main channels. The first channel links uncertainty and geographical disruptions to maritime indicator through demand shocks, operational risks and network adjustment. The second channel emphasizes the role of trade volumes as the main source of derived demand for liner shipping services, although the relative importance of exports and imports differs across countries and port systems. The third channel focuses on exchange rates as macroeconomic factors that affect maritime activity through both trade demand and operational costs. Compared with these studies, this paper combines uncertainty, export volume, import volume, and the REER within an asymmetric framework for Türkiye's LSCI.

## 4. Dataset and Methodology

### 4.1. Dataset

This study estimates the effects of the World Uncertainty Index (WUI), export volume index, import volume index and the real effective exchange rate (REER) on Türkiye's Liner Shipping Connectivity Index (LSCI). The dataset is quarterly and covers the period 2010Q1–2025Q3. The dependent variable is Türkiye's LSCI, obtained from the UNCTAD database. The LSCI is indexed relative to the average value of 2023Q1, which serves as the reference point with a base value of 100. The first independent variable is the WUI, taken from the Economic Policy Uncertainty database and compiled by Ahir et al. (2022). The second and third independent variables are Türkiye's export and import volume indices for goods, obtained from the International Monetary Fund (IMF) database. These series measure price-adjusted quantity changes in exports, free on board (FOB), and imports, cost, insurance and freight (CIF), with 2010 as the base year. The fourth independent variable is Türkiye's Consumer Price Index (CPI) based REER, obtained from the Electronic Data Delivery System (EVDS) of the Central Bank of the Republic of Türkiye (CBRT). All variables are log-transformed before the analysis, with no additional normalization beyond the original base years used by the data providers. The transformed series are denoted as *LNLSCI, LNWUI, LNEXPVOLIND, LNIMPVOLIND* and *LNREER.*

**Table 1.** Summary of the Variables

| Abbreviation | Description | Source | Adjustment |
|---|---|---|---|
| LNLSCI | Türkiye's Liner shipping Connectivity Index | UNCTAD Database | Natural log |
| LNWUI | World Uncertainty Index | PolicyUncertainty.com (Ahir et al., 2022) | Natural log |
| LNEXPVOLIND | Türkiye's Export Volume Index of Goods | IMF Database | Natural log |
| LNIMPVOLIND | Türkiye's Import Volume Index of Goods | IMF Database | Natural log |
| LNREER | Türkiye's Real Effective Exchange Rate | EVDS of TCMB | Natural log |

### 4.2. Methodology

In this study, the nonlinear autoregressive distributed lag (NARDL) framework developed by Shin et al. (2014) is used to examine the dynamics between the variables. Its main advantage over traditional cointegration methods is the ability to capture asymmetric effects in the short and long run by decomposing shocks into positive and negative components. It also allows the simultaneous estimation of short and long term coefficients and is applicable when variables have mixed integration orders, specifically I(0) and I(1) (Allen & McAleer, 2021: 16). In addition, the error correction mechanism enables the analysis of the speed of adjustment toward long-run equilibrium (Nkoro & Uko, 2016: 79).

The integration properties of the data are first assessed using Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests to ensure that all variables are either I(0) or I(1). To ensure that the results of these unit root tests are not biased by an omitted structural break, an additional Zivot-Andrews (ZA) test is performed, which accounts for a single endogenously determined break. Given the limited quarterly sample size, the break date identified by the ZA test is evaluated through the test's own framework and post estimation stability diagnostics rather than by adding deterministic dummy variables to avoid further loss of the model's degrees of freedom. Following these initial checks, a VAR model is estimated to select the optimal lag length.

To conduct the partial asymmetric NARDL test, the selected explanatory variables are decomposed into their positive and negative partial sum processes, given in equation (1). In the equation, $x_t \in \{LNEXPVOLIND_t, LNIMPVOLIND_t, LNREER_t\}$, while $LNWUI_t$ is retained in its symmetric form.

$$x_t^+ = \sum_{j=1}^{t} max\left(\Delta x_j, 0\right),\; x_t^- \sum_{j=1}^{t} min\,(\Delta x_j, 0) \tag{1}$$

The long run relationship is estimated by using Pesaran et al. (2001) bounds test approach. Accordingly, the bounds testing results are interpreted together with the ZA unit root test evidence and CUSUM/CUSUMSQ stability diagnostics. Since the ZA results do not require redefining the baseline specification with structural break dummies, no additional deterministic dummy is included. The non-linear dynamics and asymmetric responses to shocks are captured through the NARDL empirical formulation presented in equation (2). It incorporates the relationship between the dependent and independent variables within an error correction framework.

$$\begin{aligned} LNLSCI = \beta_0 &+ \beta_1 LNLSCI_{t-1} + \beta_2 LNWUI_{t-1} + \beta_3^+ LNEXPVOLIND_{t-1}^+ \\ &+ \beta_3^- LNEXPVOLIND_{t-1}^- + \beta_4^+ LNIMPVOLIND_{t-1}^+ \\ &+ \beta_4^- LNIMPVOLIND_{t-1}^- + \beta_5^+ LNREER_{t-1}^+ + \beta_5^- LNREER_{t-1}^- \\ &+ \sum_{k=1}^{p-1} \delta_{1k}\, \Delta LNLSCI_{t-k} + \sum_{k=0}^{q-1} \delta_{2k}\, \Delta LNWUI_{t-k} \\ &+ \sum_{k=0}^{w-1} (\delta_{3k}^+ \Delta LNEXPVOLIND_{t-k}^+ + \delta_{3k}^- \Delta LNEXPVOLIND_{t-k}^-) \\ &+ \sum_{k=0}^{y-1} (\delta_{4k}^+ \Delta LNIMPVOLIND_{t-k}^+ + \delta_{4k}^- \Delta LNIMPVOLIND_{t-k}^-) \\ &+ \sum_{k=0}^{z-1} (\delta_{5k}^+ \Delta LNREER_{t-k}^+ + \delta_{5k}^- \Delta LNREER_{t-k}^-) + \varepsilon_t \end{aligned} \tag{2}$$

In equation (2), $\beta_i$ denotes the long-run, $\delta_{jk}$ denotes the short-run coefficients where $j$ indexes the regressor group and $k$ the lag order and $\varepsilon_t$ is the error term. The optimal lag lengths are determined by the Schwarz Information Criterion (SIC) and indicated as *p*, *q*, *w, y* and *z,* respectively. The lag structure is selected according to the SIC, which is preferred because it penalizes model complexity more strongly and therefore supports a more parsimonious specification for the limited quarterly sample. Dynamic multipliers are calculated according to Shin et al. (2014). Through the analysis of both short- and long-run dynamics, this model examines how fluctuations in the explanatory variables influence the response variable. Error Correction Term (ECT) is vital for the NARDL method. It should be both negative and significant to validate the long-run relationship. Asymmetry in both short and long run is tested via Wald tests. They impose linear restrictions to compare the impacts of positive and negative shocks (Greene, 2018).

## 5. Results and Discussion

### 5.1. Results

The descriptive characteristics of the log-transformed series are presented in Table 2 below as a preliminary step to empirical analysis. The descriptive statistics show that the variables show a balanced structure as their mean and median values are close to each other and they are normally distributed according to Jarque-Bera test results except *LNWUI*. Although *LNWUI* deviates from normality due to its high skewness and kurtosis values, the main variables such as connectivity and foreign trade volumes constitute a reliable base for the empirical analysis.

**Table 2.** Descriptive Statistics

| | LNLSCI | LNWUI | LNEXPVOLIND | LNIMPVOLIND | LNREER |
|---|---|---|---|---|---|
| **Mean** | 5.4350 | 10.0848 | 5.0000 | 4.8610 | 4.7630 |
| **Median** | 5.4292 | 10.0132 | 4.9993 | 4.8558 | 4.7944 |
| **Maximum** | 5.7589 | 11.5793 | 5.3757 | 5.1041 | 5.1442 |
| **Minimum** | 5.1206 | 9.3833 | 4.5208 | 4.4398 | 4.2600 |
| **Std. Dev.** | 0.1385 | 0.4237 | 0.2296 | 0.1373 | 0.2474 |
| **Skewness** | 0.1136 | 1.1118 | -0.0986 | -0.2921 | -0.2031 |
| **Kurtosis** | 3.2636 | 4.7891 | 1.9326 | 2.9862 | 1.6994 |
| **Jarque-Bera** | 0.3180 | 21.3834 | 3.0925 | 0.8967 | 4.8729 |
| **Probability** | 0.8529 | 0.00002 | 0.2130 | 0.6386 | 0.0874 |

It is crucial to determine the stationarity level of the series before the application of the NARDL model although it allows estimating cointegration between the variables with mixed integration order, none of them should be I(2). Accordingly, ADF, PP and ZA unit root tests results are given in Table 3:

**Table 3.** ADF, PP and ZA Unit Root Test Results

| | | Level | | | | First Difference | |
|---|---|---|---|---|---|---|---|
| | | **ADF** | **PP** | **ZA** | **Break Date** | **ADF** | **PP** |
| | | | | **With Intercept** | | | |
| **LNLSCI** | t-Stat. | -0.4509 | -0.5505 | -3.4953 | 2022Q4 | -6.5856*** | -6.6047*** |
| **LNWUI** | t-Stat. | -2.4432 | -2.6869* | -4.2782 | 2020Q4 | -8.6168*** | -8.6134*** |
| **LNEXPVOLIND** | t-Stat. | -1.2712 | -1.9128 | -4.0304 | 2021Q2 | -9.4331*** | -23.4604*** |
| **LNIMPVOLIND** | t-Stat. | -3.3304** | -3.3005** | -6.9486*** | 2018Q3 | -10.2639*** | -13.0139*** |
| **LNREER** | t-Stat. | -1.3642 | -1.3403 | -2.5420 | 2017Q4 | -10.3100*** | -10.3396*** |
| | | | | **With Trend and Intercept** | | | |
| **LNLSCI** | t-Stat. | -1.4598 | -1.756 | -3.6775 | 2020Q1 | -6.5258*** | -6.5461*** |
| **LNWUI** | t-Stat. | -2.8651 | -3.1658 | -4.0852 | 2021Q4 | -8.6716*** | -8.6707*** |
| **LNEXPVOLIND** | t-Stat. | -6.2574*** | -6.2657*** | -4.8432* | 2021Q2 | -9.4456*** | -24.1373*** |
| **LNIMPVOLIND** | t-Stat. | -5.0204*** | -5.0204*** | -7.2093*** | 2018Q3 | -10.2209*** | -12.9312*** |
| **LNREER** | t-Stat. | -2.422 | -2.3576 | -3.9646 | 2021Q4 | -10.3143*** | -10.4409*** |

**Note:** * denotes 10%, ** denotes 5% and *** denotes 1% significance level.

The unit root results show that *LNLSCI, LNWUI* and *LNREER* are I(1) at the 5% significance level, as the ADF, PP and ZA tests fail to reject the unit root null at level but reject it at first difference. Since *LNLSCI* remains non-stationary at level even with the 2020Q1 structural break in the ZA test with intercept and trend, no endogenous dummy variable is included. *LNIMPVOLIND* is I(0), as the tests reject the unit root null at level. *LNEXPVOLIND* presents mixed results at level but becomes stationary at first difference in all specifications. Therefore, the variables have mixed integration orders and can be used in the NARDL framework. Dummy variables that are specific to events such as the Suez Canal crisis are not included because alternative specifications weakened the main coefficients and increased the risk of over-parameterization as the number of the available quarterly samples is limited. Therefore, structural disruptions are addressed through the ZA unit root test and stability diagnostics, while the baseline model is kept parsimonious.

Accordingly, a VAR model is estimated to determine the maximum lag length under SIC. Table 4 indicates that the lowest value of SIC is obtained at lag 1, so the maximum lag length is determined as 1 for the NARDL model.

**Table 4.** Lag Length Criteria Results under the VAR model

| Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|
| **0** | -390.1046 | NA | 0.5683 | 13.6243 | 13.8019 | 13.6934 |
| **1*** | -199.4200 | 341.9173 | 0.0018* | 7.9110 | 8.9767* | 8.3261* |
| **2** | -175.1971 | 39.2577 | 0.0019 | 7.9378 | 9.8916 | 8.6989 |
| **3** | -156.9558 | 26.4183 | 0.0026 | 8.1708 | 11.0128 | 9.2779 |
| **4** | -127.9355 | 37.0259 | 0.0025 | 8.0322 | 11.7623 | 9.4852 |
| **5** | -91.14561 | 40.5957* | 0.0019 | 7.6257* | 12.2439 | 9.4246 |

**Note:** * indicates the lowest information criteria value.

Following the determination of the maximum lag length, the BDS test is employed to detect possible nonlinear dependence and hidden patterns within the series. This test provides supplementary evidence that the relationship among the variables may not be fully captured by a purely linear specification. Therefore, the BDS results are interpreted as supportive diagnostic evidence for considering an asymmetric framework.

**Table 5.** BDS Independence Test Results

| Variable | Dimension 2 | Dimension 3 | Dimension 4 | Dimension 5 | Dimension 6 |
|---|---|---|---|---|---|
| **LNWUI** | 0.0355*** | 0.0302 | 0.0070 | 0.0258 | 0.0432** |
| **LNEXPVOLIND** | 0.1404*** | 0.2481*** | 0.3179*** | 0.3657*** | 0.3973*** |
| **LNIMPVOLIND** | 0.1179*** | 0.1950*** | 0.2412*** | 0.2641*** | 0.2792*** |
| **LNREER** | 0.1640*** | 0.2780*** | 0.3542*** | 0.3972*** | 0.4162*** |

**Note:** (***) and (**) denote the rejection of the null hypothesis of i.i.d. residuals at the 1% and 5% significance levels, respectively.

According to the test results, while *LNEXPVOLIND, LNIMPVOLIND* and *LNREER* exhibit strong non-linearity, the *LNWUI* variable failed to reject the null hypothesis in most dimensions. In addition, *LNWUI* was initially modeled as an asymmetric component; however, the resulting coefficients lacked statistical significance and the Wald test did not support the asymmetry. Therefore, to avoid unnecessary parameter proliferation in a limited sample, a partial asymmetric NARDL model was preferred where *LNWUI* is kept symmetric while the remaining variables are decomposed into asymmetric components.

Before proceeding with the bounds test, a series of diagnostic checks were performed to validate the model's consistency. These findings are reported in Table 6 and the structure stability is further depicted through the CUSUM and CUSUMSQ graphics in Figure 1.

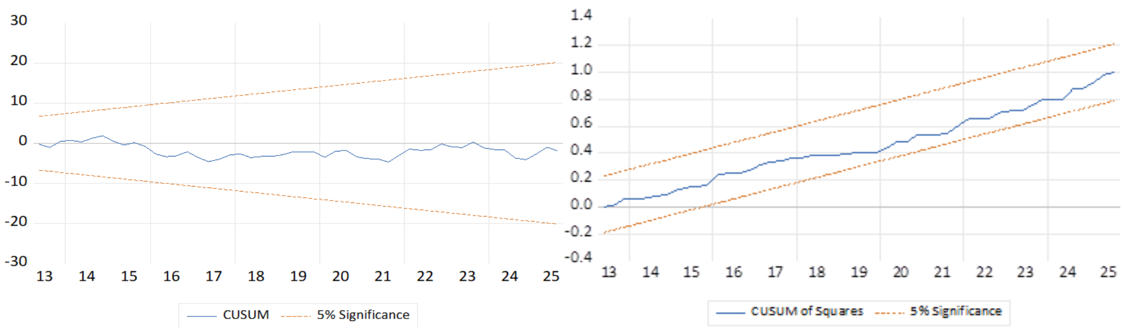
**Table 6.** Diagnostic Test Results

| Test | Statistics |
|---|---|
| Jarque-Bera normality test | 1.790958 |
| Breusch-Godfrey LM test (Obs.*$R^2$) | 0.749157 |
| Breusch-Pagan-Godfrey test (Obs.*$R^2$) | 6.403414 |
| Ramsey RESET test (F-statistic) | 0.057559 |
| $R^2$ | 0.982962 |

**Note:** * denotes 10%, ** denotes 5% and *** denotes 1% significance level.

Diagnostic test results and 0.98 $R^2$ value indicate that the model does not have basic econometric problems such as non-normality, autocorrelation, heteroskedasticity and specification error. Also, as CUSUM and CUSUMSQ graphs are within the 5% significance bands, the model is proven to be robust and structurally stable.

**Figure 1.** CUSUM and CUSUMSQ Results




Following the confirmation of the model’s structural stability, the results of the bounds test conducted to examine the long-term cointegration relationship among the variables are presented in Table 7 below.

**Table 7.** Bounds Test Results

| Test Statistic | Value | k |
|---|---|---|
| **F-statistic** | 6.3544 | 7 |
| **Significance** | **I(0) Bound** | **I(1) Bound** |
| **10%** | 2.044 | 3.104 |
| **5%** | 2.373 | 3.540 |
| **1%** | 3.129 | 4.507 |

The bounds test results show that the estimated F-statistics value of 6.3544 is above the I(1) bound at all significance levels so the null hypothesis of “no levels relationship” is rejected and the long-run relationship among the variables is accepted. The short-run and error correction term (ECT) coefficients estimated by the NARDL model are presented in Table 8:

**Table 8.** Short-Run and ECT Results

| Variable | Coefficient | Std. Error | t-statistic |
|---|---|---|---|
| **D(LNWUI)** | 0.0140 | 0.0068 | 2.0429** |
| **D(LNEXPVOLIND_POS)** | -0.0336 | 0.0567 | -0.5930 |
| **D(LNEXPVOLIND_NEG)** | 0.0453 | 0.0581 | 0.7795 |
| **D(LNIMPVOLIND_POS)** | 0.1894 | 0.0676 | 2.8030*** |
| **D(LNIMPVOLIND_NEG)** | 0.0057 | 0.0714 | 0.0796 |
| **D(LNREER_POS)** | 0.1109 | 0.0658 | 1.6852* |
| **D(LNREER_NEG)** | -0.0244 | 0.0513 | -0.4758 |
| **ECT** | -0.3119 | 0.0453 | -6.8818*** |

**Note:** * denotes 10%, ** denotes 5% and *** denotes 1% significance level. The optimal lag structure (1, 0, 1, 0, 0, 1, 0, 0) is determined by the SIC.

The short-term results indicate that the ECT is negative and statistically significant at the 1% level. The ECT coefficient is -0.3119 and it shows that approximately 31% of the short-run deviations from the long-run equilibrium are corrected within one quarter. This indicates a moderate speed of adjustment toward the long-run equilibrium.

The coefficient of *D(LNWUI)* is positive and statistically significant at the 5% level. The coefficient value of 0.0140 indicates that a 1% increase in the WUI increases the LSCI by 0.0140% in the short run.

Although the magnitude of the effect is small, this result indicates a positive statistical association between uncertainty and Türkiye's LSCI in the short run.

The short-run coefficients of both *D(LNEXPVOLIND_POS)* and *D(LNEXPVOLIND_NEG)* are statistically insignificant. This result indicates that export volume changes do not generate an immediate response in the LSCI. Therefore, while import expansion affects Türkiye's LSCI in the short run, export side changes do not appear to create statistically significant short-term effects.

Regarding trade volume variables, the positive component of import volume is statistically significant at the 1% level, while the negative component is statistically insignificant. The coefficient of *D(LNIMPVOLIND_POS)* is 0.1894. It indicates that a 1% increase in import volume increases the LSCI by 0.1894% in the short run. In contrast, short-run import contractions do not produce a statistically significant effect on the LSCI.

Lastly, the coefficient of *D(LNREER_POS)* is positive and statistically significant only at 10% level. The coefficient value of 0.1109 indicates that a 1% increase in Türkiye's REER increases the LSCI by 0.1109% in the short-run. However, this result should be interpreted cautiously because the significance level is weak. The negative REER component is statistically insignificant. This result indicates that real depreciation does not produce a clear short-run effect on LSCI.

**Table 9.** Long-Run Results

| Variable | Coefficient | Std. Error | t-statistic |
|---|---|---|---|
| **LNWUI** | 0.0560 | 0.0234 | 2.3914** |
| **LNEXPVOLIND_POS** | 0.3266 | 0.1434 | 2.2775** |
| **LNEXPVOLIND_NEG** | 0.1550 | 0.1206 | 1.2859 |
| **LNIMPVOLIND_POS** | 0.4274 | 0.1314 | 3.2514*** |
| **LNIMPVOLIND_NEG** | 0.8521 | 0.1237 | 6.8898*** |
| **LNREER_POS** | 0.3282 | 0.1147 | 2.8630*** |
| **LNREER_NEG** | 0.0162 | 0.1172 | 0.1378 |
| **C** | 4.5644 | 0.2400 | 19.0169*** |

**Note:** * denotes 10%, ** denotes 5% and *** denotes 1% significance level.

The long-run results presented in Table 9 show that WUI has a positive and statistically significant effect on the LSCI. The coefficient indicates that a 1% increase in the WUI increases the LSCI approximately by 0.0560% in the long run. The long run effect is considerably larger than the short-run coefficient. This result indicates that the positive association between uncertainty and Türkiye's maritime connectivity is stronger in the long run.

The positive component of export volume is statistically significant at 5% level while the negative component is statistically insignificant. A 1% increase in export volume increases the LSCI by approximately 0.3266% in the long run. This result indicates that export expansion affects the LSCI only when the increase is sustained over time, whereas export contractions do not generate a statistically significant inverse effect.

Import volume is found to be the strongest long run determinant of the LSCI. Both the positive and negative components of the variable are statistically significant at 1% level. A 1% increase in import volume is associated with a 0.4274% increase in the LSCI, whereas a 1% decrease in import volume is associated with a 0.8521% decline in the LSCI. Since the negative partial sum variable captures decreases in import volume, the positive coefficient of LNIMPVOLIND_NEG should be interpreted as evidence that import contractions reduce LSCI in the long run. The larger magnitude of this coefficient indicates that Türkiye's LSCI is more sensitive to import contractions than to import expansions.

Finally, the long-term REER results show that only the positive component is statistically significant. A 1% increase in the REER increases the LSCI by approximately 0.3282% while the negative component remains statistically insignificant. This finding suggests that real appreciation supports Türkiye’s LSCI in the long run, whereas real depreciation does not produce a statistically meaningful effect.

In the NARDL framework, the Wald test is essential for determining whether the differences between the coefficients of positive and negative shocks are statistically significant as it formally validates the presence of asymmetry. The short-run and long-run test results are presented in Table 10.

**Table 10.** Wald Test Results

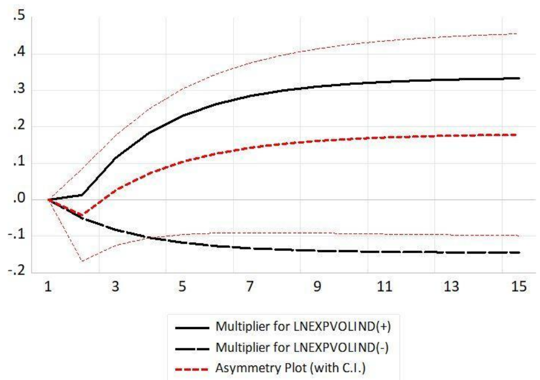
| Variable | F-Statistics |
|---|---|
| **LNEXPVOLIND (Short-Run)** | 0.2472 |
| **LNIMPVOLIND (Short-Run)** | 5.1440** |
| **LNREER (Short-Run)** | 3.1373* |
| **LNEXPVOLIND (Long-Run)** | 1.3826 |
| **LNIMPVOLIND (Long-Run)** | 11.9947*** |
| **LNREER (Long-Run)** | 3.1373* |

**Note:** * denotes 10%, ** denotes 5% and *** denotes 1% significance level.

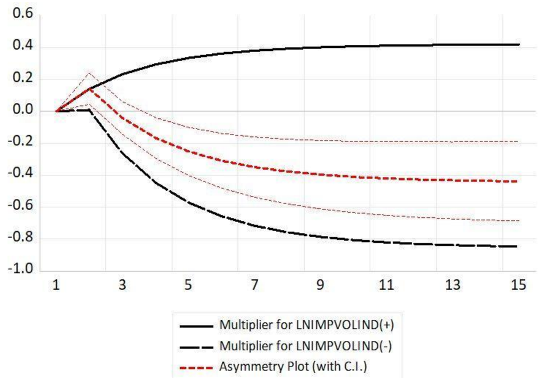
Short-run Wald test results reveal a distinct asymmetry for import volumes. This result indicates that LSCI is sensitive to surges but resilient to contractions. However, exports do not show a significant dependency in direction. Also, REER exhibits only marginal asymmetry and this suggests that it has a statistically weak but significant influence in the short-run. Overall, the short-run REER results should be interpreted cautiously, as the evidence is weak and limited to real appreciation. The long-run Wald test also shows that asymmetry is not universal, as the coefficient difference between positive and negative component of export volume is not statistically significant, although export volume is retained in decomposed form due to the preliminary evidence of nonlinear dependence obtained from BDS independence test presented in Table 5. Conversely, import volumes demonstrate robust long-run asymmetry, where the negative impact of trade contractions significantly overweighs the positive influence of expansions on Türkiye’s LSCI. The REER still shows marginal evidence of asymmetry so it is clear that the import channel is the primary driver of the asymmetry whereas exports remain structurally symmetric over the long-run.

**Figure 2.** Dynamic Multiplier Graphs from the NARDL Model

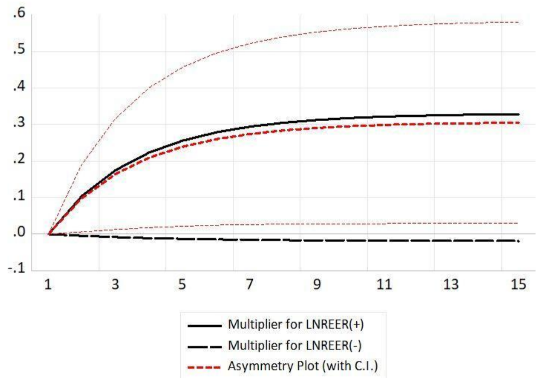
**(2a)** Export Volume



**(2b)** Import Volume




**(2c)** Real Effective Exchange Rate




The NARDL multiplier graphs given in Figure 2 also confirm that the LSCI is significantly more responsive to contraction in import volumes whereas the asymmetric structure for the REER remains relatively limited. Although the trajectories for positive and negative export shocks visually deviate, the discrepancy is not statistically significant. It indicates the lack of robust directional asymmetry in the export channel.

### 5.2. Discussion

The positive effect of the WUI on the LSCI in both the short and long run indicates that uncertainty does not necessarily weaken maritime connectivity in Türkiye's case. Contrary to conventional expectation, this result is consistent with resilience-oriented mechanisms such as supplier diversification, strategic redundancy, alternative routing and network reconfiguration (Crotti et al., 2022; Gou et al., 2025; Pan et al., 2022; Russell et al., 2022; Sağlam et al., 2021). It is also consistent with the view that geoeconomic fragmentation and de-risking strategies increase the importance of nonaligned connector countries (Cerdeiro et al., 2024; Gopinath et al., 2024). Therefore, the positive WUI coefficient should be interpreted as a positive statistical association that is consistent with possible route diversification and logistical substitution mechanisms rather than direct evidence of these channels. Empirical evidence showing that geopolitical risk may increase container traffic in Türkiye and uncertainty may increase port activity also supports this interpretation (Atacan & Açık, 2023; İpekçi & Sözen, 2025: 2020).

The trade results indicate that the LSCI response is both asymmetric and horizon-dependent. In the short run, LSCI reacts only to import expansion, while export changes and import contractions remain insignificant. This suggests that short-run trade shocks are largely absorbed through vessel utilization, cargo routing and existing service structures rather than immediate network changes (Agarwal & Ergun, 2008; Notteboom, 2004; Wang et al., 2014). In the long run, export expansion becomes significant, supporting the view that sustained export growth can justify capacity expansion and stronger carrier commitment. This delayed effect may also be related to Türkiye’s export logistics structure. Since merchandise exports are generally recorded on *free on board* (FOB) basis, export growth may not immediately reflect the international freight service component or lead carriers to adjust liner services (UNCTAD, 2021; UN Comtrade, 2026). In addition, trade imbalances are a key source of empty container repositioning and liner network design should account for empty container flows (Meng & Wang, 2011; Song & Carter, 2009). Therefore, export growth may improve LSCI only when it persistently supports more balanced cargo flows and justifies adjustments in service frequency, capacity allocation and port calls. Turning to imports, the long-run significance of both import components is consistent with the derived-demand nature of maritime transport (Fugazza & Hoffmann, 2017; Notteboom et al., 2022; Stopford, 2009). In Türkiye’s liner shipping context, inbound loaded containers may constitute an important commercial basis for carriers’ port-call decisions, whereas export cargo may partially function as a backhaul opportunity for container reuse or repositioning. Therefore, when import demand contracts, carriers’ financial incentive to call at Turkish ports may weaken, reducing port calls, service frequency and ultimately LSCI. However, the two import responses are also asymmetric with import contractions producing the larger effect. This indicates that falling import volumes weigh on Türkiye's LSCI more heavily over the long run than rising volumes lift it. Therefore, the stronger long-run sensitivity to import contractions should be interpreted as a Türkiye-specific structural result, while previous studies broadly support the role of trade volumes in container throughput, port connectivity and maritime network performance (Guo et al., 2025; Makhecha, 2016; Rashed, 2016).

The REER findings suggest a limited asymmetric pattern. It also operates mainly through real appreciation. Although the positive REER component is significant across both horizons, the depreciation component is not statistically significant. The Wald test confirms asymmetry only at the 10% level. Therefore, this result should be interpreted cautiously. Since an increase in REER represents real appreciation, the findings suggest that appreciation may support the LSCI by lowering the cost of imports in domestic currency and increasing trade-induced demand for containerized liner services. This interpretation is consistent with the view that exchange rates affect maritime transport through two channels: cost-side and demand-side. However, the weak asymmetry evidence indicates that the REER effect should be treated as a secondary rather than dominant empirical mechanism (Cariou, 2020; Chi & Cheng, 2016; Kim, 2016; Oblak et al., 2016; UNCTAD, 2017).

Overall, the findings indicate that Türkiye’s LSCI is shaped by asymmetric and horizon-dependent mechanisms. In the short run, connectivity responds mainly to uncertainty, import expansion and weakly to REER appreciation, while effects of the exports remain statistically insignificant. Over the long run, the pattern becomes wider and stronger. Uncertainty, export expansion, import movements and REER appreciation all matter. Therefore, Türkiye’s maritime connectivity should not be interpreted as a mechanical outcome of trade volume growth alone. It also reflects liner shipping rigidity, carrier adjustment behavior, route reconfiguration driven by uncertainty, Türkiye’s strategic location and macroeconomic price conditions.

## 6. Conclusion

This study examines the determinants of liner shipping connectivity in Türkiye by estimating short and long run effects of world uncertainty, export volumes, import volumes and the REER on the LSCI over the period 2010Q1-2025Q3. It uses a partial asymmetric NARDL framework and the analysis shows that Türkiye’s LSCI is shaped not only by trade volume growth, but also by asymmetric macroeconomic mechanisms dependent on the horizon.

The results show that Türkiye’s LSCI is shaped by asymmetric and horizon-dependent effects. In the short run, connectivity responds mainly to import expansions and weakly to real appreciation, while export movements and import contractions are insignificant. In the long run, uncertainty, export growth, import movements and real appreciation affect LSCI, with import volume emerging as the dominant determinant. The stronger role of import contractions indicates an import-driven maritime structure, while real appreciation supports connectivity by lowering import costs. The positive effect of uncertainty may reflect route diversification, supply-chain resilience and Türkiye’s strategic location, although these mechanisms are not directly measured in the empirical model. Overall, Türkiye's maritime connectivity depends on trade dynamics, import dependence, exchange-rate conditions and its role in global network reconfiguration.

These findings offer several policy implications. First, Türkiye's maritime connectivity policy should recognize the central role of stable cargo flows, particularly import flows associated with intermediate and capital goods, in sustaining container demand and port utilization. Given the stronger long run effect of import contractions, temporary and targeted incentives such as port fee reductions, priority berthing, transshipment support or service-continuity arrangements could help maintain carriers' incentives to call at Turkish ports when import related cargo flows weaken. Second, exchange rate conditions should be considered as part of the broader maritime connectivity environment, although the asymmetry related to the REER should be interpreted cautiously due to its relatively weak statistical support. Third, the positive association between LSCI and global uncertainty suggests that Türkiye may benefit from strengthening its readiness for route reconfiguration and supply chain adjustment during periods of global disruption. Investments in transshipment capacity, port efficiency and digital customs procedures would support such readiness. Because the study does not directly measure connector-economy mechanisms, this remains a cautious policy inference rather than a finding established by the empirical results. Therefore, policies aimed at Türkiye's LSCI should go beyond volume expansion in trade and focus on attracting carrier services, maintaining service continuity and enhancing the country's strategic position within changing global maritime networks.

This study is subject to several limitations. First, the analysis focuses on one country only, which restricts the extent to which the findings can be generalized internationally. Second, the quarterly sample, constrained by the availability of LSCI data, limits the degrees of freedom for more complex specifications. Third, although major structural disruptions such as the COVID-19 pandemic and the Russia–Ukraine war are acknowledged, they are not included as separate dummy variables in order to preserve parsimony. Fourth, potential omitted variable and endogeneity concerns cannot be fully ruled out in a single country time series framework. Future studies may extend this framework to panel data which covers strategically positioned emerging economies to examine whether the import-driven connectivity pattern and positive uncertainty effects are specific to Türkiye or reflect a broader tendency among connector economies. Port-level data, cargo composition and bilateral trade flows could also provide a more detailed understanding of the mechanisms identified in this study.

## Declarations and Disclosures

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