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Analysis of Maritime Transportation Sector Through Econometric Modelling Concerning Relationship Between Foreign Trade and Freight Transportation in Türkiye

Cemre Gürses, Dilek Temiz, Ömer Yurtseven, Zehra B. Kanık*, Aytaç Gökmen

Çankaya Üniversitesi, Uluslararası Ticaret ve Finansman Bölümü, Merkez Kampüs, Eskişehir Yolu 29. Km, Yukarıyurtçu Mahallesi Mimar Sinan Caddesi No:4 06790, Etimesgut/ANKARA/TÜRKİYE, e-mail: cemregurses@gmail.com; dilektemiz@cankaya.edu.tr; yurtseven@cankaya.edu.tr; zbkanik@cankaya.edu.tr; agokmen@cankaya.edu.tr

* Corresponding author

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ABSTRACT

The main objective of this study is to investigate the effect of freight transportation on foreign trade in the Turkish maritime transportation sector. Data gathered from the Turkish Statistical Institute and the Ministry of Transport and Infrastructure's official websites, between the years 2013 and 2023, were utilized and time series analysis was conducted. The Industrial Production Index was used as a proxy for economic expansion. This research used five variables, all shown in logarithmic form (Export, Import, Volume, Handling, and Index). Unit root tests were done to examine the stationarity of the series. Regression analysis was conducted utilizing the Ordinary Least Squares (OLS) method to ascertain the short-term direction of the relationship between the variables. The findings from the Toda-Yamamoto causality test align with those derived from OLS and affirm that within the maritime sector, sea freight transportation exerts a positive impact on foreign trade, particularly in the short term.

1 Introduction

The global logistics market size was estimated at 10.68 trillion US dollars in 2022, and the development of the e-commerce industry further contributed to the growth of the logistics sector. As the e-commerce industry expanded, the demand for logistics services also increased. With the increasing demand, it is expected that the global logistics market size will reach approximately 18.23 trillion US dollars by 2032 [1].

As per findings outlined in the Transportation and Tourism Panel Target 2023, a report by the Scientific and Technological Research Council of Türkiye (TUBİTAK), approximately 80% of global trade happens through maritime transportation. Compared to alternative modes of transport, this mode boasts a 14-fold cost advantage over air transport, a 3.5-fold advantage over railway transport, and a 7-fold cost advantage over road transport. Particularly notable in maritime transport is the ability to efficiently move large quantities of industrial raw materials, serving as essential production inputs, in single shipments between relevant target ports [2].

Maritime transportation, which plays a significant role in the globalization of trade, is commonly utilized for the transportation of large-volume, low unit-price, and time-sensitive cargoes [3]. Maritime transportation involves such activities as loading, handling, and ensuring the security of goods onto a sea vessel, thereby facilitating their transportation to their destination [4]. The role of maritime transport in international transport poses the question of whether there is a relationship between freight transport and foreign trade. With the advent of e-commerce and containerization, maritime transportation has also become a significant mode contributing to the development of multimodal transportation [5].

The reason for selecting Turkey as a case study is that the country is geographically situated peninsula at the crossroads of Europe, Asia, and Africa, hence holds a significant position in terms of maritime transportation. Maritime transportation plays a great role in Türkiye's foreign trade and emerges as a sector with potential for further development. In 2022, approximately 86.58% of the volume of goods transported worldwide was carried by naval means. In Turkey, around 92.22% of the volume of goods for imports and approximately 80.08% for exports were transported by naval means in 2022. Maritime transportation holds a significant share of the logistics sector monetarily, positioning the maritime sector as the most strategic sector in global trade [1]. In this study, the relationship between maritime imports and exports, economic growth and maritime freight transportation is investigated with the utilization of three econometric models that were put forward specifically. To this end, three econometric models were developed for the study.

The study is divided into four sections. After Introduction, the second section presents a comprehensive review of the relevant literature. The third section thoroughly explores Türkiye's maritime transportation sector. The fourth section explains the application of the empirical analysis in Turkey. The paper concludes with summary, conclusions, limitations and suggestions for further research.

2 Literature Review

De Langen et al. (2007) conducted research aimed at evaluating indicators of port performance and introduced original metrics for assessing port efficacy. Their study proposed a new model encompassing factors like employment and value-added within port operations, complementing existing performance measures. The suggested model unveiled potential indicators crucial for bolstering port visibility and enhancing the port industry [6].

Jacks and Pendakur (2008) delved into the impact of logistics sector advancements on global trade dynamics through a gravity model analysis, focusing on 19th-century trade and freight data from England. They concluded that the surge in global trade during this era was primarily attributed to income growth-driven convergence rather than maritime transport, shedding light on the period's commercial dynamics [7].

Ateş and Işık (2010) investigated the connection between logistics sector advancements and Türkiye's export performance, establishing a causal relationship between logistics, exports, and economic growth. While short-term correlations between logistics and exports were inconclusive, a Granger causality link from the logistics sector to exports emerged in the long run. Additionally, a one-way causality relationship was observed from logistics sector revenues to industrial production and a bidirectional link to gross national product, underlining a long-term interdependence between the logistics industry and exports [8].

Ateş et al. (2010) advocated proactive legal frameworks, entrepreneurial support, and technological integration to leverage Türkiye's strategic geographical position and enhance its maritime influence. They emphasized the pivotal role of rail connections in bridging ports with inland regions, especially amid Türkiye's burgeoning container traffic, urging capacity improvements to meet growing demands [9].

Psaraftis and Kontovas (2010) explored the interplay between economic and environmental aspects of maritime transportation, proposing policies to mitigate environmental impacts. They highlighted the potential for achieving economically and environmentally sustainable outcomes in maritime transport through strategic trade-offs, underscoring the sector's pivotal role in global trade and sustainable development [10].

Korkmaz (2012) investigated the correlation between ship movements in Turkish ports and industrial production indices and total trade volumes through regression analysis. Positive significant relationships were found between increased shipping activity and both industrial production and total trade, underscoring the maritime sector's economic significance [11].

Harlaftis and Kostelenos (2012) scrutinized maritime transport's impact on Greece's 19th-century economy, revealing a robust relationship between maritime earnings and the country's foreign trade, highlighting maritime transport's pivotal role in economic development [12].

Köseoğlu and Mercangöz (2012) examined the repercussions of the 2008 global financial crisis on Türkiye's maritime sector, employing ISTFIX and BDI data to assess sector performance amid global economic shifts. Their study unveiled a structural shift in 2008, indicating a symbiotic relationship between maritime transport and the global economy [13].

Grzelakowski (2013) analyzed the influence of two global regulatory systems on the maritime transport sector and global trade, assessing their efficacy and efficiency. Despite challenges and diminished impacts, the study underscored the sector's resilience and adaptability, even amidst turbulent regulatory environments [14].

Morrissey and O'Donoghue (2013) quantified maritime transport's contribution to Ireland's economy through input-output analysis, revealing significant impacts on production sub-sectors, underscoring maritime's integral role in Ireland's economic landscape [15].

Bentaleb et al. (2015) aimed to develop a new performance measurement framework for port systems, leveraging existing research to design a multi-criteria hierarchical model. The proposed model addressed performance evaluation gaps in multimodal transportation, offering insights for future port system enhancements [16].

Erol and Dursun (2016) investigated the market structure of non-regular liner maritime transport, highlighting its operation under free market conditions. Their analysis of factors influencing demand and supply dynamics underscored the sector's sensitivity to global economic trends and freight market dynamics [17].

Pascali (2017) examined factors shaping globalization for England in the late 19th century and its impact on economic development, emphasizing maritime transport's pivotal role in driving international trade patterns and economic disparities [18].

Deran and Erduru (2018) compared the financial performance and development of Türkiye's roads and maritime freight transportation sectors, revealing disparities in liquidity, financial structure, profitability, and asset utilization [19].

Tunalı and Akarçay (2018) explored the link between industrial production and maritime transport in Turkey, uncovering a positive correlation between industrial output and maritime activity [4].

Eryüzlü (2019) investigated global maritime trade dynamics and Türkiye's foreign trade relations, highlighting Türkiye's position as a significant player influenced by and influencing global maritime trade [20].

Akbulaev and Bayramli (2020) studied the relationship between maritime transport development and economic growth in Caspian Sea-bordering countries, illustrating how maritime projects fostered sustainable economic growth in the region [21].

Arabacı and Yücel (2020) investigated the logistics sector's impact on economic growth, emphasizing its positive effects on various economic facets, including balance of payments, income distribution, employment, and small-scale business development, thereby contributing to enhanced living standards [22].

Temiz Dinç and Karamelikli (2021) examined the short and long-term relationships between maritime transport and foreign trade volume, as well as the linear and nonlinear characteristics of these relationships. Using data from Turkey between 2004 and 2018, linear relationships were analyzed with the ARDL model, while nonlinear relationships were analyzed with the NARDL model. The results showed that the short-term asymmetry and long-term symmetry models are statistically valid [5].

3 An Overview of Türkiye's Maritime Transportation Sector

Türkiye's maritime sector holds significant economic importance within the state, serving as a crucial link between Asia and Europe. With key water passages like the Bosporus and the Dardanelles, Turkey enjoys a strategic geographical advantage for maritime activities. Given its geopolitical positioning, Turkey assumes a pivotal global role in maritime transport, serving as a major transit hub for international sea trade and boasting well-developed port facilities to support its maritime activities. Turkey possesses numerous large and contemporary ports, which serve as significant hubs for the country's foreign trade and transit cargo transportation.

In Turkey, maritime transportation had the largest share in both imports and exports in terms of the value of transported goods over the past 10 years. In 2022, the Gross Domestic Product (GDP) of Turkey increased by 5.6%. Compared to the previous year's chained volume index, exports of goods and services increased by 9.1% in 2022, while imports increased by 7.9%. Goods and services exports decreased by 3.3% in the fourth quarter of 2022 compared to the same quarter of the previous year according to the chained volume index, while imports increased by 10.2% [23].

In Turkey, the volume of cargo handled in ports decreased by 4.0% compared to the previous year, reaching 521,079,804 tons in 2023. The container handling volume increased by 1.5%, reaching 12,556,401 TEUs, with most cargo being transported in 40' and 20' containers. The quantity of cargo involved in foreign trade decreased by 0.6%. There was a 9.8% decrease in export shipments and a 5.0% increase in import discharges. Most of the handled cargo consisted of foreign trade goods. The number of containers involved in foreign trade increased by 2.4%, reaching 9,741,352 TEUs. The number of loaded containers for export purposes increased by 0.2% to 2,497,310 units. When examining the volume of cargo handled by cargo types, it was observed that liquid bulk cargo decreased by 2.0% and general cargo decreased by 15.0%. The number of vehicles transported on regular Ro-Ro lines related to foreign countries decreased by 3.0%, reaching 698,133 units. Most vehicles transported on international Ro-Ro lines were carried on routes connected to Europe [1].

4 Research Method

The study used EViews13 package program to analyze monthly data between January 2013 and May 2023. Maritime freight statistics used in econometric analyses were obtained from the Turkish Statistical Institute (TUIK), Ministry of Transport and Infrastructure E-Maritime websites. The Industrial Production Index was used to measure economic growth. This data set was obtained from the Central Bank of the Republic of Türkiye. In the analyses, variables were used in logarithmic form. The causality relationship between the variables used in the econometric models was tested with the Toda-Yamamoto causality test. The analysis started by performing unit root tests. Then, appropriate lag lengths were determined. Identification tests of the econometric models to be used in the study were performed to obtain the best model. In addition, regression analysis was performed using the Ordinary Least Squares (OLS) method to determine the short-term sign of the relationship between the variables. This study focused on examining the relationship between maritime import and export, economic growth and maritime freight transportation for Turkey filling a gap in the literature. The study was conducted to close this gap and to emphasize the importance of maritime trade for the country.

4.1 Dataset and Econometric Model

The following variables, LNEXPORT (maritime export) represents the number of exports made by sea, LNIMPORT (maritime import) represents the number of imports made by sea, LNINDEX represents the industrial Production Index figures used to represent economic growth, LNVOLUME (Marine Trade Volume) represents the total amount of exports and imports made by sea, LNHANDLING (Maritime cargo handling) represents the cargo transportation made by sea, were chosen for the analyses. In the equations, $\beta1$, α1, θ1 are constant terms, $\beta2$, α2, θ2, $\beta3$, α3, θ3 represent the estimated coefficients of the variables used in the analysis and μt, et, Ɛt represent the error terms. The definitions and abbreviations of the variables employed in the study are summarized in Table 1.

Table 1 Variables used in the model

Variables	Description
LNEXPORT	Marine Export (Thousand US $)
LNIMPORT	Marine Import (Thousand US $)
LNVOLUME	Marine Trade Volume (Thousand US $)
LNHANDLING	Maritime cargo handling (Tons)
LNINDEX	Industrial production index (2015:100)

The study estimates the following three models:

Model 1:
LNEXPORT =
$$\beta 1 + \beta 2 LNHANDLING + \beta 3 LNINDEX + \mu t \quad (1.1)$$

Model 2:
LNIMPORT =
$$\alpha 1 + \alpha 2 LNHANDLING + \alpha 3 LNINDEX + et \quad (1.2)$$

Model 3:
LNVOLUME =
$$\theta 1 + \theta 2 LNHANDLING + \theta 3 LNINDEX + \varepsilon t \quad (1.3)$$

4.1.1 Unit Root Tests

To examine the causality dimension of the relationship between variables, the Toda-Yamamoto causality test was chosen [27]. The existence of multiple advantageous situations played an effective role in the selection of this test. One of these is that it offers a much easier method for estimating the VAR model developed for the purpose of investigating Granger Causality Tests. In this test, which consists of two separate stages, first the optimal lag length is determined, and the maximum degree of integration (dmax) is determined for the series taken as the basis for the application. The appropriate lag length is determined for the VAR model using criteria such as SC, Akaike and Hannan-Quinn. Thus, by determining the optimal lag length k and the maximum integration degree dmax, an improved VAR model that includes the lag length k+dmax can be used. When the second stage is reached, Wald tests of the obtained VAR model will be applied, and inferences will be made from the accepted or true truths and falsehoods of the obtained propositions depending on causality [27]. Therefore, unit root tests were first performed in the study. To assess the stationarity of the series, conventional unit root tests including the Augmented Dickey-Fuller Test (ADF) [24], Kwiatkowski, Phillips, Schmidt, Shin (KPSS) [25], and Elliott, Rothenberg & Stock (ERS) Point Optimal Test [26] were employed. The results of the ADF unit root test are displayed in Table 2. The numbers in parentheses denote the lag lengths estimated using the Schwarz (SC) information criterion.

When Table 2 is examined, it is seen that at the 5% significance level, according to the ADF test results, the series contained a unit root at the level and are not stationary. These non-stationary series were made stationary by taking the first difference. In this context, according to the ADF unit root test, the maximum degree of integration (d_{max}) of the variables was determined as 1.

To reinforce the stationarity of the first difference of the series, the KPSS unit root test was applied. The results of the KPSS test are presented in Table 3.

According to Table 3, as the LM test statistics for the variables' degrees exceed the critical values of the KPSS test at the 5% significance level, it was determined that they are non-stationary and possess unit roots. However, the results obtained from the first-degree difference of the variables indicate stationarity. These findings from the KPSS test corroborate those from the ADF unit root test. The maximum cointegration degree (d_{max}) according to the KPSS test was estimated as 1.

Furthermore, the ERS Point Optimal unit root test, developed by Elliott, Rothenberg, and Stock 1996, was employed in this study. The primary hypothesis in the ERS test posits the presence of a unit root in the series. If the Pt statistic calculated for the ERS test falls below its critical value, the unit root hypothesis is rejected. The results of the ERS unit root test are presented in Table 4.

Table 2 ADF Unit Root Test Results

Variable	ADF	P-value	Constant-Trend	Result
LNEXPORT	-2.129497 (1)	0.2336	constant	not stationary
LNIMPORT	-1.299325 (1)	0.6285	constant	not stationary
LNVOLUME	-2.336204 (1)	0.4111	constant, trend	not stationary
LNHANDLING	-1.486681 (2)	0.5371	constant	not stationary
LNINDEX	-1.962955 (2)	0.3029	constant	not stationary
DLNEXPORT	-9.853259 (2)	0.0000	constant	stationary
DLNIMPORT	-11.21814 (1)	0.0000	constant	stationary
DLNVOLUME	-11.41058 (1)	0.0000	constant	stationary
DLNHANDLING	-8.963397 (3)	0.0000	constant	stationary
DLNINDEX	-7.826176 (2)	0.0000	constant	stationary

* A p-value > 0.05 indicates unit root is detected (not stationary); otherwise, it means there is no unit root (stationary). The "D" used in front of the variables indicates the first difference.

Table 3 KPSS Test Results

Variable	LM-Stat	Constant, Trend	Asymptotic Critical Value (5%)	Result
LNEXPORT	0.725736 (1)	Constant, Trend	0.146000	not stationary
LNIMPORT	0.982714 (1)	Constant, Trend	0.146000	not stationary
LNVOLUME	0.961515 (1)	Constant, Trend	0.146000	not stationary
LNHANDLING	0.191666 (1)	Constant, Trend	0.146000	not stationary
LNINDEX	0.168636 (1)	Constant, Trend	0.146000	not stationary
DLNEXPORT	0.024587 (1)	constant	0.463000	Stationary
DLNIMPORT	0.107448 (1)	constant	0.463000	Stationary
DLNVOLUME	0.071827 (1)	constant	0.463000	Stationary
DLNHANDLING	0.015396 (1)	constant	0.463000	Stationary
DLNINDEX	0.017874 (1)	constant	0.463000	Stationary

Table 4 ERS Point Optimal Unit Root Test Results

Constant and Trend			
Variable	P_t	**Critical Value (%5)**	**Result**
LNEXPORT (4)	9.675795	5.645000	Unit root available
LNIMPORT (1)	13.32725	5.645000	Unit root available
LNVOLUME (1)	9.960490	5.645000	Unit root available
LNHANDLING (4)	6.504146	5.645000	Unit root available
LNINDEX (2)	8.719609	5.645000	Unit root available
DLNEXPORT (1)	0.094641	5.644800	Unit root does not exist
DLNIMPORT (1)	1.442024	5.644800	Unit root does not exist
DLNVOLUME (1)	1.470756	5.644800	Unit root does not exist
DLNHANDLING (3)	1.344727	5.644800	Unit root does not exist
DLNINDEX (1)	0.821910	5.644800	Unit root does not exist
LNEXPORT (1)	5.810971	3.125000	Unit root available
LNIMPORT (1)	6.453791	3.125000	Unit root available
LNVOLUME (1)	7.112171	3.125000	Unit root available
LNHANDLING (1)	37.03355	3.125000	Unit root available
LNINDEX (1)	13.72393	3.125000	Unit root available
DLNEXPORT (1)	0.030051	3.124400	Unit root does not exist
DLNIMPORT (1)	0.442097	3.124400	Unit root does not exist
DLNVOLUME (1)	0.438289	3.124400	Unit root does not exist
DLNHANDLING (3)	0.418601	3.124400	Unit root does not exist
DLNINDEX (1)	0.226453	3.124400	Unit root does not exist

*The values in parentheses are determined by the SC, which refers to lag lengths.

The outcome of the ERS unit root test reveals that the series are non-stationary at the level, whereas their differences exhibit stationarity. This finding from the ERS test aligns with the results obtained from other conventional unit root tests. Consequently, based on all unit root tests conducted in this study, the maximum cointegration degree of variables (d_{max}) was determined to be 1. Since the probability values of the first differences of the variables are smaller than the critical values of the variables, it can be stated that the maximum cointegration degree (dmax) of the variables is 1.

4.1.2 Number of Lags

The second stage of the Toda-Yamamoto Causality Test [28] involves determining the suitable lag number. The appropriate number of lags should be identified through information criteria and descriptive tests. To conduct the Toda-Yamamoto test, the maximum integration degree (d_{max}) of the series should not surpass the optimal lag number (k) of the model [27]. The lag length utilized in the model was determined via VAR analysis and is reported in Table 5.

Table 5 Determining the Optimum Lag-Length in the VAR Model

Model 1: *LNEXPORT = β1 + β2LNHANDLING + β3LNINDEX + µt*				
Lag	**FPE**	**AIC**	**SC**	**HQ**
0	1.10e-06	-5.850665	-5.134210	-5.176281
1	1.45e-07	-7.899253	-6.948419	-7.116703
2	7.82e-08	**-8.019099***	**-7.354890***	**-7.649386***
3	7.46e-08	-7.948050	-7.191004	-7.611713
4	6.62e-08*	-7.927702	-7.098375	-7.645296
5	7.13e-08	-7.918051	-6.814850	-7.487985
6	7.30e-08	-7.887612	-6.582027	-7.381375
7	6.87e-08	-7.872770	-6.434621	-7.360181
8	7.65e-08	-7.862034	-6.121409	-7.173182
Model 2: *LNIMPORT = α1 + α2LNHANDLING + α3LNINDEX + et*				
Lag	**FPE**	**AIC**	**SC**	**HQ**
0	2.12e-06	-4.552164	-4.481339	-4.523410
1	1.06e-07	-7.550462	-7.267162	-7.435446
2	5.91e-08	**-8.138210***	**-7.635785***	**-7.930281***
3	5.95e-08	-8.124786	-7.416536	-7.837245
4	5.88e-08*	-8.131560	-7.217486	-7.764408
5	5.91e-08	-8.135664	-7.002465	-7.675599
6	6.38e-08	-8.062450	-6.716775	-7.516122
7	6.20e-08	-8.096369	-6.538220	-7.463780
8	7.09e-08	-7.968594	-6.197970	-7.249743
Model 3: *LNVOLUME = θ1 + θ2LNHANDLING + θ3LNINDEX + Ɛt*				
Lag	**FPE**	**AIC**	**SC**	**HQ**
0	1.36e-06	-4.991207	-4.920382	-4.962452
1	9.64e-08	-7.640852	-7.357552	-7.525835
2	4.82e-08	**-8.348302***	**-7.838550***	**-8.133047***
3	4.93e-08	-8.331969	-7.603719	-8.024429
4	4.77e-08*	-8.324325	-7.427577	-7.974499
5	4.89e-08	-8.314850	-7.191650	-7.864785
6	5.30e-08	-8.247335	-6.901660	-7.701008
7	4.91e-08	-8.328349	-6.770200	-7.695759
8	5.61e-08	-8.202317	-6.431693	-7.483466

*Indicates the lag length selected by the information criteria (based on a 5% significance level). **FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 6 Autocorrelation LM Test Results

Lag	LM-Stat	Prob.
Model 1: ***LNEXPORT = β1 + β2LNHANDLING + β3LNINDEX + μt***		
Lag	**LM-Stat**	**Prob.**
1	10.19817	0.3347
2	12.24577	0.1998
3	5.836651	0.7561
4	7.865847	0.5477
5	8.704946	0.4649
Model 2: ***LNIMPORT = α1 + α2LNHANDLING + α3LNINDEX + et***		
Lag	**LM-Stat**	**Prob.**
1	10.91076	0.2819
2	9.604641	0.3834
3	3.465196	0.9430
4	7.312667	0.6046
5	10.79808	0.2898
Model 3: ***LNVOLUME = θ1 + θ2LNHANDLING + θ3LNINDEX + Ɛt***		
Lag	**LM-Stat**	**Prob.**
1	12.58007	0.1825
2	12.49398	0.1869
3	4.577867	0.8694
4	5.808870	0.7589
5	8.902176	0.4464

Table 7 White Heteroscedasticity Test Results

Models	Test Statistics	Probability
Model 1	99.13296	0.2302
Model 2	103.8869	0.4847
Model 3	105.8743	0.4304

*The H_0 hypothesis in the variance test is "there is no variance".

In the study, the lag length was determined based on the AIC, SC, and HQ information criteria. The lag length was consistently determined as 2 for all three models. It is anticipated that the selected lag number has successfully passed the identification tests. Initially, the LM test was employed to assess the presence of autocorrelation issues in the determined lag number. Table 6 presents autocorrelation LM test results.

Upon examining the probability values in Table 6, it is observed that the null hypothesis concerning the absence of autocorrelation issues was accepted at the 5% significance level for all three models, specifically at the 2nd lag length.

Subsequently, the White Heteroscedasticity Variance Test was conducted to identify potential heteroscedasticity problems following the autocorrelation test. The outcome of this test is displayed in Table 7.

Based on this result, it is concluded that there is no heteroscedasticity issue in the error terms at the 5% significance level. Consequently, it is inferred that there are no autocorrelation or heteroscedasticity problems in the VAR analysis conducted with a lag length of 2.

Subsequently, the stability of the 2-lag VAR model was examined. Figure 1 shows the position of the inverse roots of the AR (Autoregressive) characteristic polynomial of the anticipated model within the unit circle and provides insights into the stationarity of the model.

As depicted in Figure 1, the absence of any inverse roots of the AR characteristic polynomial outside the unit circle signifies that the constructed VAR model possesses a stable structure. Therefore, it has been concluded that the optimal number of lags (k) is 2.

Model 1 **Model 2** **Model 3**

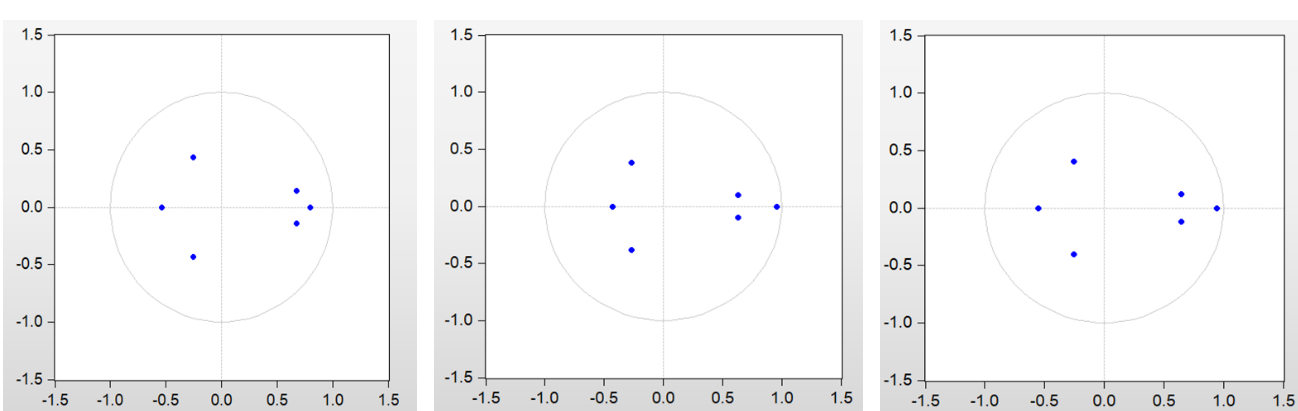

Figure 1 Inverse Roots of AR Characteristic Polynomial

Table 8 Toda-Yamamoto Causality Test Results

	Direction	X^2 Test Statistics	Probability	Decision*
Model 1	**LNHANDLING → LNEXPORT**	16.14041	0.0011	Causality
	LNEXPORT → LNHANDLING	3.976683	0.2640	No Causality
	LNEXPORT → LNINDEX	8.035841	0.0453	Causality
	LNINDEX → LNEXPORT	6.323434	0.0969	No causality**
	LNHANDLING → LNINDEX	25.76536	0.0000	Causality
	LNINDEX → LNHANDLING	21.44230	0.0001	Causality
Model 2	**LNHANDLING → LNIMPORT**	19.45172	0.0002	Causality
	LNIMPORT → LNHANDLING	5.421900	0.1434	No Causality
	LNIMPORT → LNINDEX	1.337817	0.7202	No Causality
	LNINDEX → LNIMPORT	14.65157	0.0021	Causality
	LNHANDLING → LNINDEX	20.55535	0.0001	Causality
	LNINDEX → LNHANDLING	21.11062	0.0001	Causality
Model 3	**LNHANDLING → LNVOLUME**	19.72072	0.0002	Causality
	LNVOLUME → LNHANDLING	5.747255	0.1246	No Causality
	LNVOLUME → LNINDEX	1.522988	0.6770	No Causality
	LNINDEX → LNVOLUME	13.18717	0.0042	Causality
	LNHANDLING → LNINDEX	24.20222	0.0000	Causality
	LNINDEX → LNHANDLING	19.99247	0.0002	Causality

*According to %5 significance level. ** There is a causality running from the Industrial Production Index to exports in the maritime industry according to the %10 significance level.

According to the Toda-Yamamoto Causality Test Results presented in Table 8, the relationships between the proposed variables in the study are as follows:

- LNHANDLING ↔ LNINDEX: This indicates a bidirectional causality between freight transportation made by sea and economic growth. In the study, economic growth was represented by the industrial production index.
- LNEXPORT → LNINDEX: This suggests a causality from marine export to economic growth.
- LNINDEX → LNIMPORT and LNINDEX → LNVOLUME: These imply a causality from economic growth to marine import and marine trade volume
- LNHANDLING → LNEXPORT, LNHANDLING → LNIMPORT, and LNHANDLING → LNVOLUME: These indicate a causality from freight transportation made by sea to marine trade volume.
- There is no causality from marine trade volume to freight transportation made by sea in Turkey.

Based on the analysis findings, it can be concluded that marine import export, marine trade volume, and economic growth are influenced by freight transportation made by sea. Additionally, economic growth affects freight transportation made by sea, and developments in economic growth also impacts on marine trade volume in Turkey.

4.1.3 OLS estimates

The study conducted a regression analysis utilizing the OLS (Ordinary Least Squares regression) technique to ascertain the direction of the relationship between the variables in the short term. Initially, the lag length was determined as 8 based on the SC criterion. The final model was attained by eliminating irrelevant variables from the models.

In the estimation equation in Table 9, the lag lengths were determined as 2 for DLNEXPORT, 3 for DLNHANDLING and 1 for DLNINDEX. When the specification tests of this equation are performed, it is seen that there is no autocorrelation problem, there is no ARCH problem, but the error terms are not normally distributed. There is also the problem of varying variance. It was excluded from the evaluation because the estimation results may not be reliable.

In the estimation equation in Table 10, the lag lengths are determined as 1 for DLNIMPORT and DLNINDEX. DLNHANDLING itself is used in the model. When specification tests of this equation are made, it is seen that there is no autocorrelation problem, no ARCH problem, error terms are normally distributed and there is no problem of varying variance. In this respect, it can be said that the hypothesis tests are reliable. According to OLS estimation results, the effect of DLNHANDLING, DLNINDEX and DLNINDEX (-1) on

Table 9 OLS Results- Dependent Variable: DLNEXPORT

Variable	Coefficient	t-Statistic	Prob.
DLNEXPORT (-1)	-0.693134	-7.777901	0.0000
DLNEXPORT (-2)	-0.197938	-2.445305	0.0160
DLNHANDLING	0.014536	0.077687	0.9382
DLNHANDLING (-1)	-0.325003	-1.483499	0.1408
DLNHANDLING (-2)	-0.465342	-2.552388	0.0120
DLNHANDLING (-3)	-0.426478	-2.650973	0.0092
DLNINDEX	0.843249	7.582721	0.0000
DLNINDEX (-1)	0.444025	3.130370	0.0022
C	0.004300	0.557092	0.5786
R-squared	0.630425	Jarque-Bera	5.9549 P= 0.0409
Adjusted R-squared	0.604027	Breusch-Godfery Ser. Corr. (4 lag)	0.192489 P=0.9419
Schwarz criterion	0.083570	ARCH (4 lag)	1.080788 P= 0.3695
F-statistic	23.88137	White	3.919561 P= 0.0004
Prob(F-statistic)	0.000000		

Table 10 OLS Results- Dependent Variable: DLNIMPORT

Variable	Coefficient	t-Statistic	Prob.
C	-0.000447	-0.065083	0.9482
DLNIMPORT (-1)	**-0.475497**	**-5.918381**	**0.0000**
DLNHANDLING	**0.483497**	**3.445557**	**0.0008**
DLNINDEX	**0.511316**	**5.122075**	**0.0000**
DLNINDEX (-1)	**0.311436**	**3.049218**	**0.0028**
R-squared	0.565290	Jarque-Bera	2.2995 P= 0.3167
Adjusted R-squared	0.550554	Breusch-Godfery Ser. Corr. (4 lag)	1.332317 P= 0.2622
Schwarz criterion	-2.168374	ARCH (4 lag)	0.217669 P= 0.9281
F-statistic	38.36133	White	0.355146 P= 0.8400
Prob(F-statistic)	0.000000		

DLNIMPORT is positive at 5% significance level. In other words, the effect of freight transportation made by sea and economic growth on marine import is positive in the short run.

$$DLNHANDLING\uparrow \rightarrow DLNIMPORT\uparrow$$

$$DLNINDEX\uparrow \rightarrow DLNIMPORT\uparrow$$

Table 11 OLS Results-Dependent Variable: DLNVOLUME

Variable	Coefficient	t-Statistic	Prob.
C	-0.000494	-0.080395	0.9361
DLNVOLUME (-1)	**-0.556268**	**-7.432920**	**0.0000**
DLNHANDLING	**0.338897**	**2.695852**	**0.0080**
DLNINDEX	**0.648749**	**7.352218**	**0.0000**
DLNINDEX (-1)	**0.352137**	**3.622051**	**0.0004**
R-squared	0.744308	Jarque-Bera	2.4261 P=0.2972
Adjusted R-squared	0.732250	Breusch-Godfery Ser. Corr. (4 lag)	1.301174 P= 0.2739
Schwarz criterion	-2.389632	ARCH (4 lag)	1.349971 P= 0.2558
F-statistic	53.43682	White	0.997524 P= 0.4118
Prob. (F-statistic)	0.000000		

In the estimation equation presented in Table 11, lag lengths are determined as 1 for DLNVOLUME and DLNINDEX, while DLNHANDLING is utilized as is in the model. Upon conducting specification tests for this equation, it is observed that there are no issues with internal correlation, ARCH, or normally distributed error terms, and there are no indications of varying variance. Therefore, it can be concluded that the hypothesis tests are reliable.

According to the OLS estimation results, the impact of DLNHANDLING, DLNINDEX, and DLNINDEX (-1) on DLNVOLUME is statistically significant at the 5% significance level, with a positive effect. This suggests that in the short term, freight transportation made by sea and economic growth have a positive effect on marine trade volume.

$$\text{DLNHANDLING}\uparrow \rightarrow \text{DLNVOLUME}\uparrow$$

$$\text{DLNINDEX}\uparrow \rightarrow \text{DLNVOLUME}\uparrow$$

The estimation outcomes from both the Toda-Yamamoto causality test and OLS analysis in the study mutually reinforce each other. It is evident that freight transportation made by sea significantly influences marine trade volume, with this effect being positive in the short term.

5 Discussion and conclusions

This study examined the relationship between maritime imports and exports, economic growth, and maritime transportation. These relationships were investigated using three different econometric models in EViews13. The models included variables such as maritime export (LNEXPORT), maritime import (LNIMPORT), industrial production index (LNINDEX), maritime trade volume (LNVOLUME), and maritime cargo handling (LNHANDLING).

Unit root tests (ADF, KPSS, ERS) were used to assess the stationarity of the series, and it was determined that all series were stationary in their first differences. Additionally, the Toda-Yamamoto causality test was used to identify the causal relationships between the variables. The results showed that maritime transportation had a bidirectional effect on economic growth and maritime trade volume and that maritime exports affected economic growth. Furthermore, it was found that maritime imports and trade volume also vary depending on economic growth. The OLS regression analysis results revealed that maritime transportation and economic growth have had positive effects on maritime imports. Specifically, it was concluded that economic growth and maritime transport volume increased maritime imports in the short term.

The Toda-Yamamoto causality test, and the forecast results from Ordinary Least Squares (OLS) mutually supported each other in the study. In the maritime sector, freight transportation by sea indeed influenced foreign trade, as represented by the Industrial Production Index. Additionally, a causal relationship was found between exports in the maritime industry and economic growth, and from economic growth to imports and foreign trade volume in the maritime sector. Moreover, causality was found between maritime freight transportation and foreign trade variables, indicating the significant influence of freight transportation on maritime trade.

Four major studies contributed significantly to the literature by examining the role of maritime transport in economic and sustainable growth from both methodological and outcome-based perspectives. Fratila et al. (2021) employed panel data analysis to demonstrate the positive impact of investments in maritime transport on economic growth within the EU, emphasizing the need for green investments for environmental sustainability. Bugarčić et al. (2023) explored horizontal collaboration in logistics, showing how cost reduction and environmental sustainability can be achieved through shared resources, thus enhancing competitive advantages. Li et al. (2023) studied the integration of maritime transport into supply chains, highlighting how digitalization and automation improve efficiency and environmental performance. Transarya (2023) examined the future role of maritime transport in global trade, focusing on sustainable practices and technological innovations. Collectively, these studies have contributed to literature by methodologically addressing sustainability and economic impacts in the maritime sector. This study will investigate the bidirectional effects of maritime transportation on economic growth and trade volume.

This study specifically examined the bidirectional effects of maritime transportation on economic growth and trade volume. It has particularly identified how maritime exports influence economic growth, and how economic growth, in turn, affects maritime imports and trade volume. Additionally, the study concluded that in the short term, economic growth and maritime transport volume increase maritime imports. It supports previous studies and underscores the significant impact of maritime transportation on foreign trade.

Despite its contributions, the study faced limitations related to the data sources' availability and the model's assumptions. The analysis relied on monthly data, potentially overlooking short-term fluctuations and seasonal variations. Moreover, the study's findings may be sensitive to the chosen econometric approach and model specifications, suggesting the need for robustness checks and sensitivity analyses in future research.

For future studies, analyzing data from other OECD countries could provide valuable insights into the impact of maritime freight transportation on international trade among nations. Future research could explore the long-term effects of maritime freight transportation on foreign trade, considering dynamic relationships over extended periods. Additionally, investigating the impact of external factors such as global economic trends and geopolitical events on maritime trade dynamics would provide valuable insights. Furthermore, comparative studies across different countries' maritime sectors could offer a broader perspective on the subject.

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