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THE IMPACT OF TRANSPORTATION EXPENDITURES ON FOREIGN TRADE VOLUME IN TÜRKİYE: AN ECONOMETRIC ANALYSIS

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ABSTRACT

This study endeavors to conduct a comprehensive empirical investigation into the impact of transportation expenditures on Türkiye's foreign trade performance, within the context of its strategic geographical positioning and geopolitical significance. The research is structured around the following core inquiries: To what extent do transportation expenditures influence Türkiye's foreign trade volume? What is the nature and direction of the relationship between transportation investments and foreign trade dynamics? Focusing on the Turkish economy over the 1980–2024 period, the study incorporates control variables such as the real exchange rate, interest rates, and relevant dummy variables. Methodologically, it employs the Fourier Autoregressive Distributed Lag (Fourier ADL) model and the Fourier Toda–Yamamoto causality test to capture potential structural breaks and non-linearities over time. Empirical findings indicate that expenditures across all modes of transportation exert a statistically significant positive effect on foreign trade volume. Notably, a bidirectional causal relationship is established between expenditures in road and maritime transport and foreign trade volume, suggesting mutual reinforcement. The expansion of trade volume is likely to incentivize the adoption of new and more efficient transportation modalities, thereby fostering reciprocal growth in logistics and transport sectors. Moreover, the reduction of transportation costs is contingent upon the integration of advanced technological systems and the implementation of efficient supply chain management practices. In this regard, the development of a resilient and modern transportation infrastructure emerges as a pivotal factor in enhancing Türkiye's trade capacity, which, in turn, facilitates the evolution of sophisticated multimodal transport systems and comprehensive logistics networks.

Keywords: Transportation Expenditures, Foreign Trade Volume, Fourier Time Series Analysis, Turkish Economy
Jel Classification: B23, F31, L91

TÜRKİYE'DE ULAŞTIRMA HARCAMALARININ DIŞ TİCARET HACMİ ÜZERİNDEKİ ETKİSİ: EKONOMETRİK BİR ANALİZ

ÖZ

Bu çalışma, Türkiye'nin stratejik coğrafi konumu ve jeopolitik önemi doğrultusunda, ulaştırma sektörünün dış ticaret performansı üzerindeki etkilerini kapsamlı biçimde analiz etmeyi amaçlamaktadır. Araştırma, şu temel sorulara odaklanmaktadır: Türkiye'de ulaştırma harcamalarının dış ticaret hacmine etkisi nedir? Türkiye'nin ulaştırma harcamaları ile dış ticaret hacmi arasındaki ilişki nasıldır? Çalışma Türkiye ekonomisinde 1980-2024 yılları kapsamında reel döviz kuru, faiz oranı ve kukla değişkenleri içeren kontrol değişkenler ışığında ulaştırma harcamaları ve dış ticaret hacmi arasındaki ilişkiyi Fourier Otoregressif Gecikmesi Dağıtılmış Model (Fourier ADL) ve Fourier Toda-Yamamoto Nedensellik Testi ile ele almıştır. Çalışma sonucunda her bir ulaştırma türüne ait harcamaların dış ticaret hacmini arttırdığı tespit edilmiştir. Ayrıca karayolu ve denizyolu ulaştırma harcamaları ile dış ticaret hacmi arasında çift yönlü nedensellik ilişkisi elde edilmiştir. Dış ticaret hacmindeki artış, yeni ulaştırma yöntemlerini teşvik ederek

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lojistik ve ulaştırma faaliyetlerini karşılıklı olarak destekleyecektir. Taşımacılık maliyetlerinin düşürülmesi ise modern sistemlerin kullanımı ve etkin tedarik zinciri yönetimine bağlıdır. Güçlü bir ulaşım altyapısı dış ticaret hacmini artıracak; bu artış taşımacılık sistemleri ve ulaşım ağlarının gelişimini hızlandıracaktır.

Anahtar Kelimeler: Ulaştırma Harcamaları, Dış Ticaret Hacmi, Fourier Zaman Serileri Analizi, Türkiye Ekonomisi
Jel Sınıflandırması: B23, F31, L91

1. INTRODUCTION

Transportation encompasses the processes of safely and timely moving goods from one location to another, including activities such as packaging, labeling, and distribution, all of which are integral to achieving cost-efficiency and profit maximization. The concept of transportation dates back to the early 1900s both globally and in Türkiye, with the production of transportation services in Türkiye beginning in the late 1970s. Furthermore, due to its strategic geographic location and geopolitical significance, Türkiye is an important participant in international commerce. The contribution of Türkiye's transportation sector to foreign trade performance has become increasingly significant, particularly in light of the country's geographical positioning and the evolving dynamics of global commerce. The goal of the research is to thoroughly investigate how Türkiye's international trade efficiency is affected by the transportation industry. The following basic issues in science are looked at in this context: What influence do transportation costs have on the amount of international trade? What effect do these costs have on Türkiye's capacity to engage in trade? What is the basis of the link among foreign trade developments and infrastructure savings? To ensure analytical precision, the study disaggregates the transportation sector into its main modes road, air, maritime, and rail and models the relationship between each transportation type and foreign trade volume separately. In addition to the disaggregated models by mode of transportation, the study incorporates several control variables to enhance its contribution to literature. These comprise the real exchange rate, the rate of interest, and dummy variables which represent the impact of the COVID-19 pandemic along with major earthquakes that took place during the research time. The relationship between Türkiye's transport sector and global trade has been the focus of plenty of empirical and theoretical studies, yet there remain a limited econometric analysis accessible. By performing an economic evaluation, the present research aims to fill the hole in the literature while deciding which type of transportation ought to be created next so as to enhance Türkiye's performance in commerce abroad.

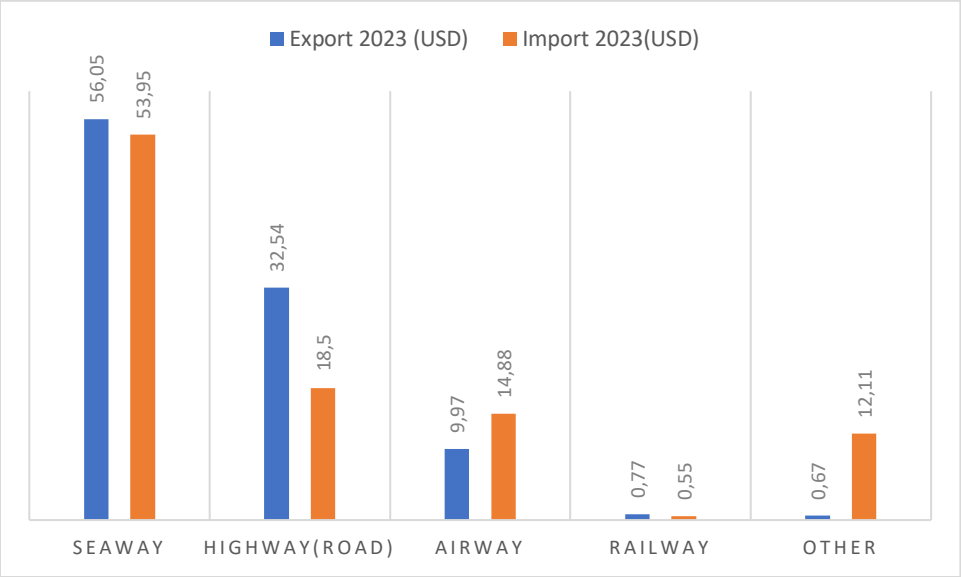
The beginning of the research first covers the transportation industry, its origins, the concept of global commerce, and the relationship between transportation costs and global trade. The connections among other control variables which could have a bearing on global trade are additionally taken into consideration by the model. A description of Türkiye's foreign commerce architecture based on different transportation modalities is subsequently provided. Previous research on these variables and how they interact has been addressed in the literature review sections. The dataset and methods utilized during the research are discussed in the fourth section, and the outcomes are given in the fifth chapter. A part of the paper on findings and suggestions follows at the conclusion of the research.

The transportation sector is a strategic field that ensures efficient management of the supply chain through activities such as transportation, storage, inventory management, order processing, and distribution. Technological advancements have enhanced process automation and traceability, offering faster, more reliable, and cost-effective solutions. With increasing complexity driven by globalization, the demand for specialized professionals in transportation planning has risen. Moreover, a robust transportation infrastructure contributes to competitive advantage, customer satisfaction, and economic growth (Akkan, 2022, p. 206). With the onset of the Industrial Revolution and the subsequent globalization process, the significance of transportation has steadily increased, transforming it especially under the influence of advancing technologies into a critical determinant of business success in the modern era. Accordingly, the efficient management of transportation activities has emerged as a strategic necessity in contemporary business environments (Karagöz, 2012, p.33). Owing to its strategic geographical position, substantial foreign trade volume, and active engagement in international political and commercial relations, Türkiye continues to evolve as a key player in the transportation sector. The country's maritime advantage, stemming from being surrounded by seas on three sides, facilitates the growth of maritime transport, while its well-developed terrestrial infrastructure supports the expansion of road and rail transportation. The logistics hub initiatives launched in 2006 aim to enhance efficiency and safety in freight and passenger transportation. With its natural resources and expanding infrastructure, Türkiye is solidifying its place within global transportation networks and maintains robust trade relations with numerous regions, particularly Europe (Bozdağlıoğlu and Keşir, 2022, p. 2).

On the other hand, the foundations of international trade were established through the cooperative interactions of civilizations with diverse social, political, and economic structures. Commerce in this manner started as barter and gradually evolved to the transfer of goods and amenities via the utilization of cash, precious metals, and foreign currencies (Fauvelle, 2025, p. 5). The mutually beneficial exchange of goods and amenities between a country and the remainder of the globe is known as foreign trade in a narrow sense. A country's global trade quantity is the total amount of what it purchases and sells throughout a particular period of time. A surplus in trade is witnessed by a country when the total worth of sales is more than the total worth of purchases; a trade shortfall is encountered when purchases are bigger than sales. It is frequently acknowledged that global trade has an important effect on the way the transport sector grows (Han and Li, 2022, p. 3). The intensification of commercial interaction between countries heightens the importance of transportation activities and assigns a strategic position to the sector in terms of the efficient movement of traded goods. As foreign trade expands, the transportation sector not only generates added value and increases its share in the economy but also emerges as both a facilitator and carrier of international commerce (Senquiz-Diaz, 2021, p. 12).

Regarding the link among global commerce and the logistics industry, Türkiye has positioned itself as a country demonstrating continuous progress in freight and passenger transportation as well as in logistics services (Koca, 2021, p. 43).

Figure 1: Percentages of Exports and Imports by Modes of Transport in Türkiye (2023)



Source: Foreign Trade Logistics Report 2024

According to the data presented in Figure 1, maritime transport holds the largest share in Türkiye's exports, accounting for 56% of the total. This is followed by road transport with 32.5%, air transport with 10%, and rail transport with only 0.77%. This distribution clearly indicates Türkiye's limited efficiency and utilization of rail transportation in export activities. On the other hand, a similar pattern is observed in import activities. Maritime transport again dominates with a 54% share, followed by road transport at 18.5%, and air transport at 14.88%.

In Türkiye, the transportation sector and foreign trade exhibit a mutually reinforcing and simultaneous development. Transportation is one of the fundamental components of foreign trade, and the increase in trade volume directly influences the demand for transportation services. This growth enhances the quality and efficiency of transport-related services, thereby contributing to the sustainability of foreign trade (Kaplan, 2019, p. 36).

The real exchange rate is one of the variables of control taken into consideration in the present investigation whereas evaluating the connection among the value of global business and the cost of transportation. Given full substitution among local and foreign goods, traditional global trade concept suggests a decrease in the real exchange rate enhances the balance of trade by increasing exports and reducing imports (Özmen, 2014, p. 8). The effect typically materializes if all of the elasticities of prices for demand for both imports and exports surpass one, pursuant to the Marshall-Lerner criteria. Due to the J-curve hypothesis, exchange rate amortization may first affect the balance of trade but ultimately enhance it due to insufficient short-term elasticities (Krugman et al., 2015, p. 518). However, if supply elasticity is low or if production heavily depends on imported inputs, exchange rate depreciations may negatively affect exports as well (Hepaktan, 2009, p. 40). With the emergence of global supply chains, imports have increasingly become a prerequisite for exports, complicating the relationship between exchange rate fluctuations and trade performance (Özmen, 2014, p. 56). Thus, this relationship is subject to periodic, asymmetric, and structural variations (Iyke and Ho, 2017, p. 381).

An increase in exports depends on the capacity of domestic producers to meet rising demand; otherwise, a depreciation in the exchange rate will not translate into higher export volumes. In this context, the price elasticity of export supply plays a decisive role in determining foreign trade performance. In the case of Türkiye, the export-led growth model adopted after 1980 has exacerbated the structural current account deficit due to the country's dependence on imports (Kartal, 2019, p. 248; Sağlam and Uzun, 2020, p. 56). Although recent exchange rate fluctuations have provided Turkish exporters with a competitive advantage, they have also increased production costs, thereby constraining trade performance. Therefore, for Türkiye, designing policy frameworks that can stabilize the exchange rate–foreign trade nexus is of critical importance.

The interest rate is a further control variable which is examined in the present investigation. Rising interest rates may attract greater hot money (or portfolio investment) inflows primarily a consequence of the country's restrictive monetary regulations, that may increase foreign exchange reserves and lead the worth of the national currency to appreciate (Agenor et al., 1997, p. 820). As a consequence, an elevated currency is expected to have a detrimental effect on the balance of trade by reducing exports and boosting imports. The flexibility (responsiveness) of import and export products to exchange rate shifts indicates the extent that a country's international commerce is impacted by these alterations (Göçer and Elmas, 2013, p. 140).

The dummy variables incorporated in the study represent the effects of the COVID-19 pandemic and the major earthquakes that have profoundly impacted both the economic and social life of Türkiye. During the pandemic, the balance between supply and demand was disrupted; moreover, support packages aimed at protecting public health often excluded foreign trade activities, thereby hindering the recovery of trade, which is considered a fundamental driver of national economies, and causing a significant contraction (Ateş, 2024, p. 246; Çatuk and Aydın, 2021, p. 444). This period witnessed critical disruptions in access to healthcare services and food products, which in turn led to substantial interruptions in global supply chains. Labor-intensive sectors such as agriculture and food production were particularly affected by the pandemic. Furthermore, the literature emphasizes that developing and less developed countries were considerably impacted by export restrictions implemented during the pandemic (Espitia et al., 2020, p.925). Examining the impact of COVID-19 on Türkiye's foreign trade reveals that compared to 2019, exports declined by approximately 18%, 41%, and 40% in March, April, and May 2020, respectively, marking the lowest export levels in the past three years. Due to the relatively delayed arrival of the pandemic in Türkiye, exports increased by around 10% in March 2020 compared to the same month in 2019. However, by the second quarter, particularly in April, the effects of COVID-19 became more pronounced, with exports decreasing by roughly 15% compared to March. A similar trend was observed on the import side, with the most significant declines occurring in April and May. Imports fell by 25% to 13.56 billion USD in April and by 27% to 13.39 billion USD in May. Although imports also decreased, they remained at higher levels relative to exports, resulting in an increased trade deficit for Türkiye (TOBB, 2020, p. 147).

The impacts of earthquakes on foreign trade can manifest in various ways. Earthquakes may adversely affect foreign trade due to the damage inflicted on infrastructure and production facilities, resulting in production losses, logistical disruptions, and increased costs (Eğilmez, 2023). Additionally, a decline in consumer confidence can reduce export demand. For instance, the 1999 earthquakes led to a decrease in GDP and a rise in inflation (Aktürk and Albeni, 2002,

p. 8), while the February 2023 Kahramanmaraş earthquakes caused a 6.4% decline in exports (Habertürk, 2023). Therefore, robust crisis management is essential to mitigate the economic impacts of such disasters. Earthquakes can damage critical infrastructure, including ports, roads, and airports, thereby negatively affecting foreign trade. The Kahramanmaraş-centered earthquake, which impacted 10 provinces in Türkiye, disrupted transportation networks, impeding the delivery of aid and goods. This situation caused disturbances in supply chains and escalated costs. Interruptions in production reduced the volume of goods while increasing logistics and insurance costs (Demirci Orel and Akkan, 2018, p. 93). Moreover, the economic burden of earthquakes raises public expenditures, exerting pressure on exchange rates, which can further widen the foreign trade deficit (Şen, 2023, p. 22). Consequently, measures aimed at disaster risk reduction are crucial for ensuring the sustainability of foreign trade.

The subsequent section of the study provides a detailed overview of the modes of transportation involved in Türkiye's foreign trade.

2. THE STRUCTURE OF TÜRKİYE'S FOREIGN TRADE BY MODES OF TRANSPORTATION

Maritime transport accounts for more than approximately 80% of Türkiye's total foreign trade shipments (Foreign Trade Logistics Report, 2024, p. 3). It is especially preferred for the economical and efficient transportation of heavy and bulky goods such as crude oil, iron and steel, automotive products, and container shipments. Türkiye's geographic position, being surrounded by three seas the Black Sea, Aegean Sea, and Mediterranean Sea renders maritime transport strategically significant. Furthermore, the presence of international waterways such as the Bosphorus and Çanakkale Straits places Türkiye in a pivotal position within global trade routes. In regard to monetary value, automobiles, agricultural machinery, bikes, motorbikes, and other motorized vehicles, in addition to the associated parts, parts, and devices, were the top export goods transported via sea in 2023. These products collectively accounted for 53.49% of Türkiye's maritime exports in 2023 (Foreign Trade Logistics Report, 2024, p. 6).

The busiest ports in Türkiye's foreign trade include Mersin, serving as the gateway to the Middle East and Africa; Alsancak, as the export hub of the Aegean region; Ambarlı on the European side of Istanbul, which is crucial for container transportation; and the ports of Haydarpaşa and Derince, which play critical roles in the trade of the Marmara region (Foreign Trade Logistics Report, 2024, p. 7). Türkiye's port operations and transportation sector have developed significantly in recent years, supported by port modernization projects and new investments. However, bureaucratic procedures in customs, infrastructure challenges, and environmental regulations occasionally impact the efficiency of transportation (Foreign Trade Logistics Report, 2024, p. 8). In summary, maritime transport holds an indispensable position in Türkiye's foreign trade due to its transport volume, cost advantages, and geographical location.

Among alternative maritime transportation methods that have gained popularity in recent years, Roll-on/Roll-off (Ro-Ro) shipping stands out (Foreign Trade Logistics Report, 2024, p. 11). Ro-Ro shipping, a specialized maritime transport where wheeled vehicles such as trucks, buses, and cars board and disembark vessels under their own power, offers substantial time and cost advantages by enabling rapid loading and unloading processes. The ability to transport vehicles together with their cargo reduces transshipment costs while ensuring safe transport. Ro-Ro shipping is particularly significant for Türkiye's foreign trade with European countries.

Regular Ro-Ro services operate between Türkiye and countries such as Italy (Trieste), France, and Ukraine, serving as a strategic solution to overcome bureaucratic barriers encountered in road transportation, such as visa and transit permits. Key ports facilitating Ro-Ro transport include Pendik, Ambarlı, Yalova, and Mersin. Türkiye's geographical position, connecting Europe, the Middle East, and North Africa, enhances the effectiveness of Ro-Ro transportation, which emerges as a vital transport mode supporting the sustainability and competitiveness of Türkiye's foreign trade (Foreign Trade Logistics Report, 2024, p. 12).

Another mode of transportation, road transport, remains a widely used method both domestically and internationally in Türkiye, and is frequently preferred by exporters due to its door-to-door service. In 2023, 32.5% of Türkiye's exports and 18.5% of its imports were carried out via road transport (Foreign Trade Logistics Report, 2024, p. 13). This trend is largely influenced by the country's high transport capacity, which has resulted in a supply-demand imbalance favoring supply. The preference for road transport in domestic shipments can be attributed to several factors, including a more developed road network compared to other modes of transportation, the ability to complete shipments without transfers, and a well-established vehicle fleet (Foreign Trade Logistics Report, 2024, p. 14). From the perspective of foreign trade, road transport holds strategic importance due to Türkiye's unique geographical position, lying on key international road corridors and serving as a critical junction between continents. This relevance is maintained not only along the east-west axis but also increasingly along the north-south axis, supported by the growing number of ports. Türkiye's international road transport connections include border crossings with Bulgaria (Kapıkule, Hamzabeyli, and Dereköy), Georgia (Sarp, Türkgözü, and Aktaş), Iraq (Habur and Üzümlü), Iran (Gürbulak, Kapıköy, and Esendere), Nakhchivan (Dilucu), Syria (Karkamış, Cilvegözü, Öncüpınar, Nusaybin, and Akçakale), and Greece (Pazarkule and İpsala). Due to political and security reasons, border crossings with Armenia (Akyaka, Alican) and some Syrian road border gates (Yayladağ, Mürşitpınar, etc.) are effectively non-operational. Heating systems, equipment, mechanical devices and instruments, nuclear power plants, and their components and parts were the most significant goods got by roadway in 2023 in terms of import and export volume. These products accounted for 59.4% and 64.4% of road transport exports and imports respectively (Foreign Trade Logistics, 2024, p. 15).

In 2023, 9.9% of Türkiye's exports and 14.8% of its imports were transported by air (Foreign Trade Logistics Report, 2024, p. 17). Air transport has recently become one of the most preferred and rapidly growing modes of transportation due to its speed and reliability. Over the past decade, it has been the fastest-growing form of transportation worldwide. The urgency brought about by globalization, combined with increasingly challenging transportation routes due to geographical constraints, are among the primary reasons for the rapid development of air transport. The globalization of the world economy and customers' increasing expectations for faster and more reliable deliveries have led to a greater reliance on air transport for products with short shelf lives. This has intensified competition in the cargo and express transport sectors and contributed to the growth of air freight services. Despite having the highest unit costs of any method of transportation, air travel is now developing more quickly due to global rivalry. The widespread utilization of air transportation is made feasible by the existence of modern airports, innovative cars, increased abilities, and smart storage systems (Foreign Trade Logistics Report, 2024, p. 19).

In 2023, the most significant product group in terms of air-transported exports by dollar value consisted of pearls, precious stones, metals, and coins. This product group accounted for 53% of Türkiye's air freight exports in 2023. Additionally, the top 10 product groups collectively represented 90% of air-transported exports in the same year (Foreign Trade Logistics, 2024, p. 21).

Finally, the mode of transportation examined is rail transport. In Türkiye, the share of rail transport in foreign trade shipments both exports and imports have never exceeded 1% over the years. In 2023, 0.7% of exports and 0.5% of imports were carried by rail. Globally, the saturation of road transport capacity and increasing environmental awareness have led to a greater emphasis on rail transport, especially over the last three decades. As of the inventions that changed the course of civilization and significantly contributed to the development of today's world, railroad service continues to have a growing effect on development and evolution on an international level. Considering the needs of security, ecology, power, and the economy, it has grown more and more important in the transportation industry (Foreign Trade Logistics Report, 2024, p. 22). Among the global transport networks established in parallel with the growth of international trade, international rail corridors have become unrivaled for transporting bulk goods not only within countries but also between countries and even continents—due to their safety, low construction costs, long service life, minimal land use, environmental friendliness, and independence from petroleum (Foreign Trade Logistics Report, 2024, p. 23). Rail transport is widely regarded as the greenest mode of transportation and the largest environmentally friendly mass transit system. Türkiye's geopolitical position, connecting East to West and Asia to Europe, places it at a crucial crossroads for global trade, offering access to many markets with extensive foreign trade volumes due to its strategic location. Türkiye could serve as the hub for regional transport activity because of its perfect geography, which offers quick travel to Eastern Europe, Central Asia, the Middle East, and North Africa. In the transportation of both passengers and cargo, Türkiye's highways are important. Railroads will be encompassed into these passageways, which will provide uninterrupted instruct hyperlinks among countries and significantly improve the railroad sector (Foreign Trade Logistics Report, 2024, p. 24). In order to ensure connectivity among nations, it is essential to develop prevalent facilities operational norms, and rules. Investments and policies should also be made to minimize moments eliminated at borders, eliminate obstacles on railway passageways, and finish lacking relationships. At present, the rapid growth of the global economy, combined with environmental sensitivities often being overlooked, has led to serious ecological problems. The COVID-19 pandemic has further raised "green" awareness, prompting both national and international initiatives, and accelerating previously initiated efforts. In spite of that, on December 11, 2019, the European Union unveiled the "European Green Deal" strategy, which seeks to make Europe the continent's initial attempt to reach zero emissions of carbon by 2050. Regarding the impact of this deal on logistics and transportation sectors, the foremost issue is the obligation to transport goods produced with low emissions and energy using vehicles with the lowest possible emissions. The implementation and widespread adoption of these measures require the restructuring of the logistics and transportation sector with a renewed focus on prioritizing rail transportation (Foreign Trade Logistics, 2024, p. 25).

3. LITERATURE REVIEW

In this section of the study, the findings of previous research examining the relationship between transportation expenditures and foreign trade are discussed, along with how the present study differs from them. Martinez-Zarzoso et al. (2003), in their article, analyzed the impact of road and maritime transportation costs on exports for 76 ceramic firms in Spain for the year 1999. Their findings indicated that long distances and inadequate infrastructure in transportation expenditures hinder exports and pose a challenge for the country's foreign trade. Unlike this study, which focuses solely on the export side of foreign trade and considers only road and maritime transport channels in the analysis, the current research differs in both scope and results. The study differs from the current study in that it covers a single sector (ceramics) and a single export direction (from Spain to other countries).

Utilizing data from five Latin American nations within the structure of the European Union, Martinez-Zarzoso and Suarez-Burguet (2005) employed a spatial gravity model to examine the connection between imports and transportation sector expenditures. Based to their results, imports frequently result in higher transportation costs in areas with less geographical dependence, but spatial proximity reduces the cost of transportation related to imports. On the contrary together, the present research looks at the way transportation costs influence the value of international trade through different transportation methods. Examining import flows between Latin American countries and EU countries, using the panel gravity model, and regional policies aimed at reducing trade costs can be highlighted as different aspects of the current study.

Hummels (2007) developed a model to analyze how U.S. imports between 1975 and 2004 were influenced by ad valorem tariffs in ocean and air transport. According to his outcomes, air travel had a far greater impact on global commerce than marine travel. The key distinction from our study lies in the focus on how changes in trade patterns, following the imposition of tariffs, vary according to the mode of transportation. Although both studies use time series analysis, Hummels's research differs in its emphasis on how changes in transportation costs specifically affect imports. While the link between the decrease in transportation costs and foreign trade was addressed with a macro focus in the study, the relationship between the increase in transportation expenditures and foreign trade was addressed with a micro focus in the current study, which created a difference.

Uslu (2018) investigated the connection from interest rates, commerce abroad, and currency rates in the Turkish economy between January 1989 and June 2018. The long-term cointegration estimation revealed that exchange rate increases led to higher exports and lower imports, with the effect on exports being stronger than on imports. Moreover, changes in interest rates were found to have no statistically significant impact on either exports or imports. These results partially align with the expectations of the present study, particularly in the way exchange rates are theorized to positively influence trade, whereas interest rate changes tend to have a dampening effect.

Tang and Abosedra (2019) evaluated the relationship between the logistics performance index (LPI) and exports and growth in 23 Asian countries for the period 2010-2016. The results showed that improvement in logistics performance significantly supports exports and economic growth. While the study examines the relationship between logistics performance index and export and growth in Asian countries using panel data method, the current study reveals the effect

of road and maritime expenditures on foreign trade volume in Türkiye using long-term time series and causality analysis.

İncekara used the Toda-Yamamoto causality analysis in his 2020 paper to investigate the connection among Türkiye's exports and transportation spending from 1960 to 2018. The analysis discovered a reciprocal causal connection among exports and transportation expenses, which was also anticipated by the present research. This finding implies that as exports increase, countries such as Türkiye are likely to expand and diversify their transportation infrastructure to support growing trade activities. The study in question is a more specialized version of the current study. It examines the impact of transportation expenditures on Türkiye's exports. It examines this impact by considering the transportation sectors as a whole, without any distinction.

Kuştepeli et al. (2021) looked at the way transportation improvements impacted Türkiye's economic development and foreign commerce between 1970 and 2005. Using conventional time series methods, the authors concluded that while exports had a short-term effect on road infrastructure expenditures, no statistically significant relationship was found between road infrastructure investment, economic growth, and foreign trade in the long run. The fact that the study did not yield the expected results in terms of a single mode of transportation for foreign trade distinguishes it from the present study.

Bozdağlıoğlu and Keşir (2022) aimed to determine the effect of the transportation sector on foreign trade. Their study utilized monthly data spanning from January 2000 to December 2020. A VAR model was constructed using variables such as Türkiye's foreign trade, various modes of transport, and the industrial production index, followed by variance decomposition and impulse-response analyses. The econometric findings demonstrated that foreign trade is closely associated with all modes of transportation and with industrial production. Although the structure and forecasting process of the model used in their research differ from those in the present study, the expectations align.

Shao et al. (2023) tested the relationship between logistics performance index and exports using the gravity model for Singapore and found that logistics performance had a positive impact on exports. While they present evidence on the link between logistics efficiency and trade volume in Singapore, they do not directly address the impact of transportation expenditures or mode-based expenditures.

Yurdakul (2023) examined the contribution of Türkiye's maritime transport infrastructure to foreign trade performance and showed that port investments increase trade volume in parallel with economic growth. This study differs from this one in that it focuses not only on maritime transport but also takes a holistic approach and applies advanced time series analysis techniques.

Bahtiyar and Güdenoğlu utilized time-varying causality analysis via monthly data from 1994 to 2021 in their 2023 cardboard to look at the relationship among currency rates and global trade in the Turkish economy. Due to their studies, competitive exchange rate regulations fail to result in long-term benefits for global trade. In terms of results, their study diverges from the expectations of the present research. The study focuses only on exchange rate and foreign trade data and does not include transportation expenditures or logistics factors.

Çetin and Saygın (2024) evaluated the relationship between the transportation sector and foreign trade within the context of the Turkish economy. Their study addressed Türkiye's transport performance, the distribution of transportation modes, current statistics, and the sector's potential. Although the primary objective of their research partially overlaps with that of the

current study, differences exist in the model design, applied methodology, and expected outcomes.

In their study, Shetshova et al. (2025) used a structural gravity model, which includes road and transportation costs along with interregional trade data for 267 different European regions, based on 2013 data. They concluded that the policy increased interregional real exports by an average of 0.03% in the targeted regions. While Shetshova et al. (2025) examines transportation infrastructure investments in EU regions with the gravity model, current study evaluates transportation expenditures in Türkiye with time series and causality analysis.

4. DATA SET AND METHOD

The study examines the impact of transportation expenditures on the volume of foreign trade. This relationship is evaluated through a model based on several control variables, as outlined in the introduction. The table below presents the variables used in the analysis along with their respective data sources.

Table 1: Data Set

Variable	Abbreviation	Source
Foreign Trade Volume (exports + imports)	lnft	Electronic Data Delivery System of the Central Bank of the Republic of Türkiye
Road Transportation Expenditures	lnrote	General Directorate of Highways Statistical Data
Air Transport Expenditures	lnate	State Airports Authority Annual Reports
Maritime Transport Expenditures	lnmte	Ministry of Transport and Infrastructure Annual Foreign Trade Logistics Reports
Railway Transportation Expenditures	lnrate	Republic of Türkiye State Railways Directorate Statistical Data
Interest Rate	ir	Central Bank of the Republic of Türkiye Electronic Data Distribution System (Annual Interest Rate Applied to Bank Deposits in TRY)
Real Exchange Rate	lnrer	Central Bank of the Republic of Türkiye Electronic Data Delivery System (Consumer Price Index-Based Real Exchange Rate)
COVID-19 Pandemic	COVID19d	Pelit and Irmak (2022), Yıldırım (2021), Hayakawa and Mukunoki (2021), Tekoğlu (2020)
Earthquakes	earthd	Özsalman and Yıldırım (2024), Bardakçı and Demirtaş (2023), Aktürk and Albeni (2002)

Table 1 presents the abbreviations of the variables used in the study along with their data sources. The annual frequency of the data constitutes one of the main limitations of the study. Data from the years 1980 to 2024 were used for the analysis. The natural logarithms of foreign trade volume, transportation-related expenditure, and real exchange rate variables were taken. Since foreign trade volume and transportation expenditures are dollar-based, currency conversion was applied prior to the analysis. The interest rate variable, being a rate, was used in its original form. The dummy variable COVID19d was included in the model with a value of 1 for the years 2020, 2021, and 2022, and 0 for other years. These years were also confirmed by the studies

referenced in Table 1. Another dummy variable, *earthd*, was created for the major earthquakes experienced in Türkiye between 1980 and 2024 (1999, 2003, 2011, 2020, 2023), assigned a value of 1 for those years and 0 for the others, and included in the model accordingly.

The main model of the study is presented in the equation below.

$$lnft_t = \beta_0 + \beta_1 lnrote_t + \beta_2 lnate_t + \beta_3 lnmte_t + \beta_4 lnrate_t + \beta_5 ir_t + \beta_6 lnrer_t + \beta_7 COVID19d_t + \beta_8 earthd_t + \varepsilon_t \quad (1)$$

lnft represents the dependent variable, foreign trade volume; *lnrote, lnate, lnmte, lnrate, ir, lnrer, COVID19d,* and *earthd* represent the independent variables corresponding to road transportation expenditures, air transportation expenditures, maritime transportation expenditures, railway transportation expenditures, interest rate, real exchange rate, the COVID-19 pandemic dummy variable, and the earthquake dummy variable, respectively. The coefficients of the variables are denoted by β_i, and ε_t represents the error term of the model.

The econometric analysis process begins with testing the stationarity of the series. Analyses conducted with non-stationary series produce spurious results. Therefore, it is inevitable to subject the series to unit root tests. Traditional unit root tests such as the Augmented Dickey-Fuller (ADF) (1981), Phillips-Perron (PP) (1988), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (1992), and Dickey-Fuller generalized least squares (DF-GLS) (1996) neglect structural breaks occurring in the series. However, using traditional unit root tests in analyses conducted in countries experiencing structural breaks reduces the reliability of the results obtained. Tests that allow for structural breaks, such as Zivot-Andrews (1992) and Lumsdaine-Papell (1997), detect structural breaks endogenously, i.e., prior to testing. To overcome these issues, Enders and Lee (2012a), building on Gallant's (1981) Fourier functions, developed a unit root test based on the Lagrange Multiplier (LM) and the DF-GLS methods of Rodrigues and Taylor (2012) by incorporating Fourier terms into the model. The fundamental difference that distinguishes unit root tests using Fourier functions from traditional unit root tests is that the former use low-frequency components and allow for smooth transitions. In other words, the dates, numbers, and forms of structural breaks are not predetermined in Fourier-based unit root tests; instead, trigonometric terms are added to the model (Yurtkuran, 2021, p.67). The traditional ADF test is formulated as follows:

$$\Delta y_t = \alpha(t) + \beta t + \theta y_{t-1} + \sum_{i=1}^{p} \vartheta_i \Delta y_{t-i} + \varepsilon_t \quad (2)$$

α(t) represents the deterministic term; p is the appropriate lag length; β, θ, and ϑ are coefficients; and ε_t denotes the error terms. Lagged values of Δy_t are included in the model to eliminate the autocorrelation problem. In such a structure, the deterministic term cannot be estimated properly, which may cause issues when θ=1 (Enders and Lee, 2012b). To resolve these issues, Fourier functions are incorporated into the model. Because Fourier-based approaches capture the smooth transitional character of structural fractures and include them into the model without the need for previous identification, they were chosen for this investigation. Because they involve pre-determining breakpoints or concentrate on time-frequency analysis, other methods like wavelet analysis and Markov regime-switching models were judged less appropriate for this

study's long-term macroeconomic series containing several shocks. However, because of their parametric structure and simplicity of integration with econometric tests, Fourier techniques provide a more appropriate framework for evaluating the link between transportation costs and international commerce.

The model for the Fourier ADF unit root test, which includes a single frequency and trigonometric terms, is expressed in Equation 3.

$$\Delta y_t = \alpha_1 + \delta t + \alpha_k \sin\left(\frac{2\pi kt}{T}\right) + \beta_k \cos\left(\frac{2\pi kt}{T}\right) + \sum_{i=1}^{p} \sigma_i \Delta y_{t-i} + \theta y_{t-1} + \varepsilon_t \quad (3)$$

In Equation 3, k represents the frequency value for which the sum of squared residuals (SSR) is minimized; t denotes the trend; T is the number of observations; and p indicates the appropriate lag length. To determine whether the series contains a unit root, the significance of the coefficient θ is examined. The obtained value is compared with the critical values from Enders and Lee (2012b), and a decision is made regarding the presence of a unit root in the series.

After the stationarity test, a cointegration test was conducted to examine the long-term relationship among the series. Traditional cointegration tests such as Engle and Granger (1987) and Johansen and Juselius (1990) ignore structural breaks. Therefore, the results obtained using these methods may contain high margins of error. In subsequent years, cointegration tests that endogenously account for structural breaks were developed to address these shortcomings. A key feature of these tests is that the dates, structures, and number of structural breaks must be known in advance. However, Banerjee et al. (2017), in their study, incorporated trigonometric terms into the model using Fourier functions and developed the Fourier Autoregressive Distributed Lag (ARDL) cointegration method, which allows for smooth transitions rather than abrupt structural breaks. The most important distinguishing feature of this test compared to traditional methods is the inclusion of low-frequency components of the Fourier expansion in the model. As a result, there is no need to know or determine the number or timing of structural breaks in advance. The model used for this method is expressed in Equation 4.

$$\Delta y_t = \alpha_0 + \alpha_1 \sin\left(\frac{2\pi kt}{T}\right) + \alpha_2 \cos\left(\frac{2\pi kt}{T}\right) + \alpha_3 \Delta y_{t-1} + \alpha_4 \Delta x_{t-1} \sum_{i=1}^{p} \alpha_5 \Delta y_{t-i} + \sum_{i=1}^{r} \alpha_6 \Delta x_{t-i} + u_t \quad (4)$$

In Equation 4, the constant term is denoted by α_0, the coefficients by α_1, α_2, α_3, α_4, α_5, and α_6, and the error term by u_t. The single frequency is represented by k, the total number of observations by T, and the trend by t. Banerjee et al. (2017) utilized the Akaike Information Criterion (AIC) to determine the appropriate lag lengths p and r. After obtaining the optimal frequency, the presence of a long-term cointegration relationship among the variables is assessed based on the significance of the coefficient α_3. If the null hypothesis H_0: $\alpha_3 = 0$ holds, there is no cointegration among the series. However, under the alternative hypothesis H_a: $\alpha_3 < 0$, a cointegration relationship exists. The calculated t-statistic is then compared with the critical values provided by Banerjee et al. (2017). If the calculated value exceeds the critical value, it indicates the presence of a cointegration relationship among the series.

Following the cointegration test, the Dynamic Ordinary Least Squares (DOLS) method was employed to estimate the long-run model. Stock and Watson (1993) developed the DOLS

estimator to address the biases and endogeneity problems inherent in the ordinary least squares method. Accordingly, DOLS provides robust and consistent long-run estimates in the presence of endogeneity and autocorrelation issues. For the implementation of this estimator, the series are required to be stationary at first differences. Moreover, the DOLS method benefits from Monte Carlo simulations, yielding reliable results even in datasets with heterogeneous structures and a limited number of observations (Mark and Sul, 2003, p. 654). The models formulated for the DOLS long-run estimator are presented in Equations 5 and 6.

The coefficients in Equation 6 are derived from $E(v_t' z_T')$ and $\beta = (B' \otimes I_{k_t})\delta$' (Stock and Watson, 1993, p. 790).

$$\hat{\delta}_{OLS} = \left[(\sum_t z_t z_t') \otimes I_{k_t}\right]^{-1} \left[\sum_t (z_t \otimes I_{k_t})(\Delta^{d-I+1} y_t')\right] \quad (5)$$

$$\Delta^{d-I+1} y_t' = \left(z_t' \otimes I_{k_t}\right)\delta + v_t' \quad (6)$$

The final stage of the empirical analysis involves testing the causal relationships among the variables. The Granger causality method, introduced by Granger (1969), is based on the VAR framework, and when the series are non-stationary, their first differences are taken. However, differencing the series may lead to a loss of long-term information. To address this issue, Toda and Yamamoto (TY) (1995) developed an alternative Granger causality approach. While both tests are considered conventional causality methods, they do not account for structural breaks in the data. In response, Enders and Jones (2016) extended the Granger method, and Nazlıoğlu et al. (2016) modified the TY causality approach by incorporating Fourier functions, allowing structural shifts to be included in the model. In the model proposed by Nazlıoğlu et al. (2016), as specified in Equation 7, the assumption of time-invariant intercept terms is relaxed, thereby enabling structural changes to be explicitly captured within the framework.

$$y_t = \alpha(t) + \beta_1 y_{t-1} + \cdots + \beta_{p+dmax} y_{t-(p+dmax)} + \varepsilon_t \quad (7)$$

In Equation 7, structural changes in, y_t and β are represented by the intercept term $\alpha(t)$, which is modeled as a function of time. The coefficient matrices, endogenous variables, and white noise error terms are denoted by y_t and ε_t respectively. In models employing Fourier functions, neither the timing, form, nor the number of structural breaks is predetermined. The specification constructed to incorporate Fourier terms into the model is presented in Equation 8.

$$\alpha(t) = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k} \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} \alpha_{2k} \cos\left(\frac{2\pi kt}{T}\right) \quad (8)$$

In Equation 8, the number of frequencies is denoted by *n*, the number of observations by *T*, and the frequency value by *k*. A large value of *n* may lead to stochastic parameter variation and cause an overfitting problem. Therefore, employing a single Fourier frequency in the model can effectively eliminate this issue, regardless of the number, timing, or form of structural breaks (Nazlıoğlu et al., 2016). The specified model is presented in Equation 9.

$$\alpha(t) = \alpha_0 + \alpha_{1k} \sin\left(\frac{2\pi kt}{T}\right) + \alpha_{2k} \cos\left(\frac{2\pi kt}{T}\right) \quad (9)$$

The Fourier TY causality test with a single frequency is specified in Equation 10. Similar to the standard TY causality approach, the null hypothesis in the Fourier TY method states that there is no causal relationship between the series.

$$\alpha(t) = \alpha_0 + \alpha_{1k} \sin\left(\frac{2\pi kt}{T}\right) + \alpha_{2k} \cos\left(\frac{2\pi kt}{T}\right) + \beta_1 y_{t-1} + \cdots + \beta_{p+dmax} y_{t-(p+dmax)} + \varepsilon_t \quad (10)$$

Unlike alternatives such as Bai-Perron break tests, Markov-switching, or wavelet methods, the Fourier ADL and Fourier Toda-Yamamoto approaches flexibly model smooth structural shifts without prior breakpoint identification, making them well suited to this study's long-term trade–transport context.

5. FINDINGS

Before proceeding with the analyses, the basic descriptive statistics and correlation analysis of the series used in the study are presented in the tables below.

Table 2: Descriptive Statistics and Correlation Matrix of The Variables (N=44)

	lnft	**lnrote**	**lnate**	**lnmte**	**lnrate**	**ir**	**lnrer**
lnft	1						
lnrote	0.729***	1					
	(0.000)						
lnate	0.675***	0.988***	1				
	(0.000)	(0.000)					
lnmte	0.592***	0.974***	0.980***	1			
	(0.000)	(0.000)	(0.000)				
lnrate	0.623***	0.952***	0.940***	0.970***	1		
	(0.000)	(0.000)	(0.000)	(0.000)			
ir	-0.053	-0.580***	-0.662***	-0.683***	-0.568***	1	
	(0.727)	(0.000)	(0.000)	(0.000)	(0.000)		
lnrer	0.123*	0.115*	0.028*	0.137*	0.327**	-0.290*	1
	(0.077)	(0.052)	(0.085)	(0.068)	(0.028)	(0.053)	
Mean	27.343	20.131	16.832	26.852	13.035	42.067	4.496
Std. deviation	3.182	4.384	4.190	3.604	2.108	29.344	0.210
Minimum	20.527	10.825	9.453	20.900	9.155	7.054	3.917
Maximum	33.063	26.617	22.854	32.175	17.422	99.843	4.850
Skewness	-0.286	-0.490	-0.356	-0.021	0.309	0.475	-0.627
Kurtosis	2.530	2.066	1.618	1.620	2.425	2.074	2.964
Jarque-Bera	1.028	3.430	4.530	3.573	1.333	3.298	2.955
(Probability)	(0.598)	(0.180)	(0.104)	(0.167)	(0.513)	(0.192)	(0.228)

Notes: Asterisks indicate statistical significance at the 1%, 5%, and 10% levels. P-values are in parentheses. *Covid19d* and *earthd* variables are not in the list because they are dummy variables.

The correlation analysis revealed that all coefficients are statistically significant. The highest correlation was observed between road transport expenditures and air transport expenditures (0.988), followed by air and sea transport expenditures (0.980). The lowest correlation was found between air transport expenditures and the real exchange rate (0.028). The relationship between foreign trade volume and interest rate was negative, with a weak correlation coefficient of –0.053. Among the variables, the real exchange rate exhibited the least variability. The Jarque-Bera statistics and corresponding probability values indicate that all series under consideration are normally distributed.

At this stage of the study, the stationarity properties of the series were identified using the Fourier ADF test results.

Table 3: Fourier ADF Unit Root Test Results

Variables	t-stat	Optimal Lag	Frequency	Min SSR
lnft	-1.84	0	3	2.677
lnrote	-0.78	1	1	1.955
lnate	-1.93	2	2	0.816
lnmte	-1.46	0	1	0.783
lnrate	-2.13	0	1	4.282
ir	-1.75	3	2	8.263
lnrer	-0.90	2	1	3.997
Δlnft	**-6.44*****	**0**	**3**	**2.364**
Δ lnrote	**-4.77*****	**1**	**1**	**1.673**
Δlnate	**-6.93*****	**1**	**1**	**0.779**
Δlnmte	**-5.68*****	**1**	**1**	**0.692**
Δlnrate	**-7.49*****	**0**	**2**	**4.197**
Δir	**-5.91*****	**2**	**2**	**7.724**
Δlnrer	**-4.89*****	**2**	**1**	**3.473**

Notes: *** denotes significance at the 1% level. For frequencies 1, 2, and 3, the critical values from Enders and Lee (2012b) at the 1%, 5%, and 10% significance levels are as follows: (-4.42, -3.81, -3.49); (-3.97, -3.27, -2.91); and (-3.77, -3.07, -2.71 respectively.

Following the test results, it was observed that the variables become stationary not at their level values but after first differencing, based on the frequency levels corresponding to the lowest sum of squared residuals and optimal lag lengths. Therefore, the variables can be considered stationary at the I(1) level. In the subsequent stage, the Fourier ADL method was employed to examine the cointegration relationship among the variables. The results of this analysis are presented in Table 4.

Table 4: Fourier-ADL Cointegration Test Results

Model I- ADL (1,1,1,1,1,1)	$t_{ADL}^{F}(\hat{k})$	$\hat{k}$	**AIC**
lnft=f(lnrote,ir, lnrer, COVID19d, earthd)	-5.811***	1	-2.073
Model II- ADL (1,1,2,2,1,1)	$t_{ADL}^{F}(\hat{k})$	$\hat{k}$	**AIC**
lnft=f(lnate,ir, lnrer, COVID19d, earthd)	-4.609*	2	-1.366
Model III- ADL (2,2,2,2,1,1)	$t_{ADL}^{F}(\hat{k})$	$\hat{k}$	**AIC**

lnft=f(lnmte,ir, lnrer, COVID19d, earthd)	-6.044***	1	-3.885
Model IV- ADL (2,2,2,2,1,1)	$t_{ADL}^{F}(\hat{k})$	$\hat{k}$	**AIC**
lnft=f(lnrate,ir, lnrer, COVID19d, earthd)	-5.227**	3	-6.805
Critic Values	1%	5%	10%
	-5.33	-4.63	-4.27

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Within the scope of the four different model specifications examined, the Fourier ADL cointegration test indicates the presence of a long-run cointegration relationship among the series. The DOLS estimation results related to the identified cointegration relationships are presented.

Table 5: DOLS Model Predict Results (Long Term)

Dependent Variable: lnft	Model I	Model II	Model III	Model IV
Variables				
Constant	2.632***	3.085***	1.445***	
	[3.783]	[4.117]	[3.884]	
lnrote	0.446**	-	-	-
	[2.011]			
lnate	-	0.538**	-	-
		[1.973]		
lnmte	-	-	0.644***	-
			[4.559]	
lnrate	-	-	-	0.175**
				[1.995]
ir	-0.016***	-0.118***	-0.126***	-0.105***
	[4.279]	[3.915]	[4.107]	[3.607]
lnrer	1.005**	0.883	0.912**	-0.461*
	[1.994]	[1.293]	[2.035]	[1.804]
COVID19d	-2.099*	-0.776**	-0.193***	-0.335***
	[1.807]	[2.226]	[4.901]	[3.192]
earthd	-0.578***	-0.493	-0.225*	-0.172*
	[6.092]	[1.325]	[1.844]	[1.914]
CC	0.033***	0.118***	0.077***	0.224***
	[3.903]	[4.107]	[3.149]	[4.309]
SS	0.018**	0.096***	0.104***	0.173**
	[2.166]	[4.336]	[3.771]	[2.225]

Notes: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. t-statistics for the coefficients are reported in square brackets [ ].

The long-run impact of transportation expenditures on foreign trade volume is presented in Table 5. The models constructed for four different modes of transport indicate that expenditures in each mode positively affects foreign trade volume. Among them, maritime transport expenditures exhibit the strongest effect: a 1% increase in maritime transport spending leads to a 0.644-unit rise in foreign trade volume. Conversely, railway transport has the weakest impact, with a 1% increase in railway expenditures resulting in a 0.175-unit increase in trade volume. In

all four models, the interest rate is statistically significant and exerts a negative effect on foreign trade volume. Although higher interest rates may stimulate imports, they also cause a notable decline in exports, leading to an overall reduction in trade volume during the years examined. In contrast, the real exchange rate exerts a direct and positive effect on trade volume, except in the maritime transport model, where it is found to be negative. This may be due to the fact that goods transported by sea are often produced using imported inputs, thereby potentially reducing net trade volume. Additionally, the effects of the COVID-19 pandemic and major earthquakes were found to negatively influence foreign trade volume through their impact on expectations. The strongest coefficients were observed in the model examining the relationship between road transport and foreign trade. Furthermore, in the context of the Fourier-type long-run estimations, the statistical significance of both sine and cosine terms indicates the overall robustness and stability of the estimated coefficients. Finally, the causal relationships among the variables were examined in the findings section, and the results are presented in Table 6.

Table 6: Fourier Toda-Yamamoto Causality Test Results

Direction of Causality	Fourier Number	Test Statistics	Asymptotic Probability Value	Boostrap Probability Value	Causality Finding
lnrote→lnft	1	3.286	0.079*	0.077*	✓
lnft→lnrote	1	3.816	0.052*	0.056*	✓
lnate→lnft	1	4.129	0.043**	0.048**	✓
lnft→lnate	2	1.785	0.322	0.316	×
lnmte→lnft	2	3.507	0.059*	0.057*	✓
lnft→lnmte	1	2.973	0.086*	0.090*	✓
lnrate→lnft	3	1.667	0.405	0.413	×
lnft→lnrate	3	1.744	0.303	0.298	×
ir→lnft	1	0.673	0.612	0.635	×
lnft→ir	2	0.851	0.542	0.537	×
lnrer→lnft	3	6.003	0.007***	0.009***	✓
lnft→lnrer	2	8.561	0.000***	0.000***	✓
COVID19d→lnft	1	0.933	0.511	0.508	×
lnft→ COVID19d	1	0.724	0.586	0.589	×
lnft→earthd	2	1.819	0.283	0.280	×
earthd→lnft	1	0.693	0.597	0.601	×

Notes: Due to the large number of variables included in the model, considering all possible directions of causality would require 36 pairwise tests based on the combination of 9 variables taken 2 at a time. Therefore, only the causality results between the dependent variable and the independent variables are presented on a model-by-model basis. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

As shown in Table 6, the asymptotic and bootstrap probability values from the causality test indicate the presence of a bidirectional causal relationship between road and maritime transport expenditures and foreign trade volume. In addition, a unidirectional causality was detected from air transport expenditures to foreign trade volume. Regarding the control variables,

a bidirectional causal link was found between the real exchange rate and foreign trade volume. No causality was observed among the other variables.

Although the literature review presented studies with both similarities to and differences from the current analysis, the empirical findings of this study both statistically and economically are largely consistent with the results of Bozdağlı and Keşir (2022), and Çetin and Saygın (2024) İncekara (2020) and Uslu (2018). What distinguishes this study is the incorporation of distinct transportation channels through expenditure variables in the econometric model, along with the selected control variables. Moreover, to the best of our knowledge, there exists no prior study applying Fourier-type time series analysis to data structures involving these specific variables, indicating that the methodology employed also contributes to the originality of the study.

The study's conclusions show that while shocks like pandemics and significant earthquakes influence this connection in diverse ways, transportation spending boosts the amount of international trade. Due to the container problem and growing freight costs, global supply chain interruptions and logistical bottlenecks, especially during the COVID-19 epidemic, hindered the timely transportation of commodities and momentarily impeded international commerce flows. Despite higher transportation investment, this resulted in drops in the volume of international commerce. Similar to this, major natural catastrophes like earthquakes seriously damaged transportation infrastructure, limiting regional output and export potential as well as causing supply-side bottlenecks. These outcomes align with comparable discoveries in the literature. For instance, COVID-19 decreased trade volume through both supply-side and demand-side shocks, according to Hayakawa and Mukunoki (2021) for Asian nations and Pelit and Irmak (2022) for Türkiye. According to Bardakçı and Demirtaş (2023), Türkiye's international trade performance suffered as a result of the damages to the transportation infrastructure following the earthquake. On the other hand, research carried out within the European Union by Shetshova et al. (2025) highlighted that investments in transportation lower trade costs and eventually boost regional commerce. This comparison shows that transportation investment in Türkiye continues to boost the amount of international commerce over the long term, even in the face of temporary delays during times of crisis.

Therefore, it is crucial to take into account both long-term trends and processes like demand shocks, supply bottlenecks, and logistical disruptions that occur during times of crisis when analyzing the effect of transportation spending on international commerce. Future studies that examine transportation investment from the standpoints of crisis management and resilience would be extremely helpful to policymakers in this regard.

6. CONCLUSION

6.1. Policy Implications

Türkiye's geographic location and strategic importance make the relationship between transportation and foreign trade even more critical. Situated at the crossroads of Europe and Asia and connected by land, sea, and air routes, Türkiye holds a significant advantage in transportation activities. The smooth and efficient functioning of these processes strengthens the country's competitiveness in foreign trade and enhances its global market position. At the same time, the development of the transportation sector contributes to economic growth by expanding foreign trade volume.

Today, the transportation sector encompasses all operational activities necessary for businesses to function efficiently and effectively, including supply chain management, inventory control, warehousing, freight, packaging, distribution, and customer service. These functions aim to enhance customer satisfaction, reduce costs, and improve profitability. Transportation processes are based on key principles such as standardization, cost-efficiency, adequacy, flexibility, simplicity, traceability, transparency, coordination, and cooperation. With its historical roots in military logistics, the transportation sector has evolved rapidly under the influence of globalization and has become a strategically vital economic domain.

In Türkiye, the transportation sector stands out as a key determinant of foreign trade. Effective management of export and import operations relies heavily on transportation services. Türkiye's strategic location positions the country as an international transport hub, substantially contributing to the development of foreign trade. The recent growth in foreign trade volume has closely paralleled advancements in transportation infrastructure. Fast, secure, and cost-efficient transportation services have enhanced Türkiye's export and import capacity. The sector's development has been supported by improvements in road, port, and airport infrastructure, as well as by logistics firms that provide internationally standardized services. This sector has improved the efficiency of foreign trade operations by ensuring timely and effective delivery of key trade components. Moreover, firms operating in this field play a crucial role in the secure transportation, storage, and distribution of goods, as well as in the management and documentation of foreign trade transactions. Foreign trade is shaped by various determinants, including economic, political, geographic, and social factors.

Given its strategic role in the national economy, the transportation sector in Türkiye must be supported through incentives. Tax reductions, credit opportunities, and other forms of governmental support for transportation firms should be designed to accelerate the sector's growth.

6.2. Methodological and Theoretical Contributions

The transportation sector is a fundamental component of modern economies, managing the flow of goods and services and requiring effective planning, organization, and management at every stage of the supply chain. The principles of standardization, cost-effectiveness, and adequacy aim to ensure process order, economic efficiency, and the capacity to meet demand, respectively. Flexibility allows adaptation to changing conditions, while simplicity enhances efficiency by streamlining processes. Traceability and transparency ensure the monitoring of operations and open communication, whereas coordination and collaboration emphasize alignment and effective partnerships within logistics processes.

Foreign trade constitutes the cornerstone of global economic relations. A country's foreign trade policy holds strategic significance in terms of economic growth, competitiveness, and international relations. Imports fulfill the need for goods and services via outside suppliers, whereas exports stimulate economic development by providing domestically produced goods and services to international markets.

The effect of transportation expenses on Türkiye's revenue from foreign trade volume is the main topic of this study. Using modern time series methodologies, the effect of expenditure on various means of transportation on the value of global trade was investigated. Furthermore, the real exchange rate, interest rate, pandemic, and earthquake dummy variables control variables

that could influence the value of global trade were included in the model due to their relevance in the literature. The results demonstrate that the amount of global commerce is positively impacted by transportation spending in all four modes, especially for air and sea transportation. Long-term cointegration among the variables has been verified via the econometric model. The results of the causality test added to the finding that road, sea, and air transportation expenditures were reliable indicators of foreign commerce quantity, without the possible exception of railway transport. In addition, the value of trade was seriously impacted all through the appropriate period by global catastrophes like the COVID-19 pandemic and big earthquakes in Türkiye.

6.3. Limitations and Future Research

The research contains a number of shortcomings in spite of its contributions. Relying solely on yearly statistics might mask short-term variations and quick reactions to emergencies. Furthermore, the lower statistical link seen for this approach may be explained by data limitations, especially with reference to railway expenses. By employing higher-frequency data, sectoral or regional disaggregation, and comparison studies with other strategically placed economies, future research might fill up these gaps and validate and expand the findings.

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