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Article Policy Implications on Transport Infrastructure–Trade **Dynamics:** Case of Turkey

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Abstract: Transportation has a mediating position in international trade formation and in the past few decades, Turkey has invested substantially in transport infrastructure to increase connectivity and integration in global transport networks. Still, limited research has been conducted to understand channels and scope of the transport infrastructure development impacts on foreign trade. The objective of this study is to evaluate short-run and long-run causal linkages between transport infrastructure, exports and imports in Turkey for the period between 1987-2019. An autoregressive distributed lag (ARDL) model is developed considering road and rail transport infrastructure components as well as information and communication technology (ICT) infrastructure as a complement to quality transport networks. Results suggest that a speedy road network serves as a locomotive in trade development whereas rail infrastructure can be beneficial if a holistic connectivity plan is developed in a long-term perspective to improve multimodal transportation under a comprehensive, sustained transport policy. Besides, benefits of transport infrastructure investment can be realized in favor of export promotion rather than import growth if a comprehensive policy is followed. In that way transport infrastructure investment would become a stronger instrument to accomplish export competitiveness.



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1. Introduction

Availability of an advanced transport infrastructure is pivotal in trade competitiveness in international markets, particularly for developing countries. At this point, the causal relationship between trade and transportation infrastructure presents a significant research area. As an emerging economy, Turkey has been among the first 10 countries in the number of projects in terms of infrastructure investments in the past thirty years [1]. In addition, according to Ref [2], Turkey ranked as the 19th biggest economy in terms of GDP in 2018 and transport infrastructure occupies an important place in Turkey's sustainable growth targets. It is also classified as an upper-middle income country based on World Bank classification. Turkey ranked 34th in 2007 with a score of 3.15 and 47th with the same score in 2018 on the Logistics Performance Index (LPI), an indicator taking values between 1 and 5, the former meaning poor performance and the latter high. Turkey aims at doing better on this index as it shows trade and transport related development. For that purpose, Turkey has undergone substantial transport infrastructure investments for more than a decade. In that way, the country seeks to cultivate more from lying at the crossroads of Asia and Europe and having strong commercial connections with western and eastern countries on the transit routes of the Middle Corridor, TRACECA (Transport Corridor Europe Caucasus Asia), VIKING corridor and TEN-T (Trans-European Transport Network) logistics networks. The strategy has found a place in the 11th Development Plan [3] in such a way that Turkey aims to upgrade its ranking on the Logistics Performance Index from 47 in 2018 to 25 in 2023. Moreover, logistics infrastructure development is prioritized in fiscal policy to reach objectives of promoting intermodal and multimodal transportation,

broadening use of maritime and railway modes, and cutting down transport costs in favor of trade to ultimately gain competitive capacity with an enhanced, well-functioning transport system. Turkey plans to increase the inventory of rapid and high-speed train lines along with the percentage of double-track railway lines by many times in the period of the development plan. Besides, other targets include increasing the motorway network by 32% and divided roads by 10%.

Despite heavy infrastructure projects being connected in a continuous manner with the aim of trade competitiveness, the link between transport and international trade growth is an understudied area for Turkey. In Ref [4], the effects of road infrastructure investment and capacity of the road network on the composition of international trade are examined through provincial data for the period of 2003–2012. They support the notion that internal transport infrastructure can be a driver to access international markets depending on transport intensity of prevalent industries, time-sensitivity of trade commodities and the quality level of road inventory. Another study [5] explores causality between highway infrastructure, international trade and economic growth in Turkey between 1970–2005. Although only weak short-run causality between highway infrastructure and exports is detected, no evidence of long-run association between road stock, trade gains and economic growth is found. In Ref [6], coherence of Turkey's investment in road infrastructure is analyzed by estimated demand for the routes through gravity models and scenario analysis with the aim of ex-post investment evaluation rather than an inspection of economic benefits. The demand predictions for passenger and freight transportation for the selected highway projects reveal the superiority of some road investments over others. A recent study by [7] uses quality of the transport infrastructure index as well as the LPI to analyze the effect of transport infrastructure on export value and diversity in Turkey for the time span between 2007–2017 within a gravity model of trade framework. Results suggest that transport infrastructure has a positive impact on the value and to a larger extent on the diversity of exports. Besides, it is concluded that exports are determined mainly by domestic transportation network conditions rather than the infrastructure state of partner countries. In a similar approach regarding other economies, the effect of logistics on trade is explored in [8] by constructing a regional measure of the logistics performance index and land transport infrastructure index for domestic and international trade in Spanish regions between 2003 and 2007. They find that regional export competitiveness is determined by land transport infrastructure in companion with the availability, competence and quality of logistics facilities, which are the main elements of the constructed index for logistics performance. In the same vein, the role of road and maritime infrastructure in trade performance is studied in [9] in the case of Brazil through state-level trade flows. Empirical analysis points to the significant role of port infrastructure endowment for export-led growth and fails to propound robust evidence of any triggering effect of the road network on trade facilitation. The causal impact of highway infrastructure on trade flows between US cities is surveyed in [10] and it is suggested that both intercity network improvements and within city extensions result in reconfiguration of products exported, as an expected outcome of specialization. Specifically, the more improved the highway network of a city is, the higher the production and exports of heavy goods it has. Contrasting results are obtained for Colombian cities in [11] by a tendency of switching to lighter commodities, which are easier to trade with additions to road infrastructure. Based on a panel dataset consisting of bilateral trade flows of countries from all development levels, in [12], trade performance is explained by considering information and communication technology (ICT) along with transport as core infrastructure elements, and additionally institutional quality as a reinforcing intangible factor, as a departure from mainstream selection of explanatory variables. In Ref [13], findings show causality from highway and street inventory to exports as well as reverse causality from economic growth to stock of these inventories in the US. In consideration of tangible and intangible characteristics of transport infrastructure, quality and quantity influences of road, railway, air and maritime infrastructure types in the

expansion of trade flows are decomposed for 20 EU countries by [14]. Interdependencies and interlinkages between individual modes are demonstrated.

As outlined so far, research on trade effects of transport infrastructure identifies road transportation mode as the prominent factor among infrastructure types and shows a tendency to consider short time spans for analysis. This case also holds for the limited strand of studies conducted for Turkey. Besides, papers related to Turkey focus on the regional scale rather than a whole-country perspective. Moreover, there is no consensus about the contribution of transportation modes to trade across research evidence from different countries; a mode can be a primary driver of trade facilitation in one country where no significant effect is found in another one. This study examines the trade development outcome of transport network expansion in Turkey by using two modes of transportationroad and rail—together for a long period of time. Key contributions of this paper to the body of literature on the broader economic benefits of transport infrastructure are threefold. Firstly, as returns from public policies such as infrastructure investment appear over time, this paper attempts to capture the precise nature of long-run effects of infrastructure growth by using an extensive range of time horizon. Moreover, the methodology is chosen in a way to avoid overestimation of short-run phenomena over long-run, which is common in causality analysis. Secondly, trade effects of land transport infrastructure (both road and rail) are analyzed not only for total exports but also for imports, within a broader spectrum of trade. As a third point, we consider ICT infrastructure as complementary to accessibility improvements provided for transport infrastructure.

The analysis comprises five parts. In the first part, the theoretical background is presented, followed by introduction of data and an analytical framework section. Subsequently, a testing procedure for the long-run relationship between transport infrastructure and trade is conducted; then a part concerning short- and long-term analysis succeeds. Finally, concluding remarks, policy insights and practical implications are provided.

2. Theoretical Background

Trade facilitation is a multi-facet process and can be undertaken as two components: tangible and intangible infrastructure [15]. Tangible elements are 'hard' components related to roads, railways, airports, communication; intangibles consist of 'soft' institutional aspects like business practices, customs regulations and transparency. This research concerns tangible dimensions of trade facilitation, focusing specifically on transport infrastructure and its complementary (ICT).

To begin with methodological aspects, three methods are identified in [16] to explore the economic effects of transport infrastructure investments. As the first method, microeconomic analysis inspects the productivity benefits of investment typically through cost-benefit analysis to evaluate investment projects. Secondly, following the early study by [17], the effect of transport infrastructure on economic growth through factors of production is studied on a macroeconomic level, including in [18,19]. The third method is general equilibrium modeling. For instance, a general equilibrium approach is used by [20] and findings suggest that inadequate local investment makes international trade more expensive compared to interprovincial trade. Besides, in [21], the potential magnitude of growth and trade gains from the Belt and Road Initiative (BRI) are quantified considering all modes in aggregate terms through a global computable general equilibrium setting.

Marginal product and rates of return for transport infrastructure investment are calculated with a panel dataset from 96 countries in [22]. The findings suggest that the rate of return is remarkably high for developing countries whereas it is relatively standard to moderate in developed and underdeveloped countries. They also conclude that benefits of infrastructure investment are realized in the long run rather than the short run. In Ref [23], priority has been given to the long-run analysis over the short-run and the following long-term benefits of transportation infrastructure are identified:

- increased GDP;
- higher productivity;

- decreased cost of production;
- rise in income level, employment and wage level;
- favorable rate of return with respect to social cost of capital;
- decreased travel time, better accessibility and higher living standards.

From a policy perspective, in [24] a three-dimensional framework of necessary conditions consisting of economic, investment and policy factors, is developed for the effects of investment in transport infrastructure to be measurable. It is also pointed out that the spatial factors are omitted in the literature, which result in shortfalls in the analysis. Similarly, conflicting evidence on the relationship between transport investment and economic growth is attributed to the lack of spatial considerations, and the necessity to study the network characteristics of the transport infrastructure is stressed by [25]. Additionally, the isolation of public policy implications in the studies about economic growth is criticized by [26]. They underline the scarcity of investigations relying on empirical evidence. However, some studies employ empirical methods in the area. As an example, empirical evidence of causality between transport infrastructure and economic growth is found by [27] both at regional and national levels. In Ref [28], implications of transportation infrastructure investment for private investment, employment level and GDP are investigated for Portugal within a VAR (vector autoregression) framework with annual data between 1976–1998. The results support the idea that investing in transportation is a strategic policy in the long run as it has a remarkable positive impact on economic performance, especially in output growth, along with remedying unemployment and encouraging private investment. Analyzing the cost of shipping a standard container from Baltimore to 64 destinations all over the world in [29], findings reveal that trade is heavily deteriorated by poor infrastructure and being landlocked. Welfare gains from railroads in India are examined by [30] and in the US by [31], employing a multi-region general equilibrium model of trade. Similarly, the welfare effects of increased transportation access are explored in [32] during the rapid economic growth period of China following trade liberalization. They argue that the distribution of benefits from that investment can be realized with the presence of factor mobility.

There exists a cluster of empirical research exploring the role of transport infrastructure on regional-level growth. For instance, a precursor study by [33] evaluates the effect of transport and communication infrastructure on productivity in eight regions in Japan. In Ref [34], the authors examine the impact of transportation investment on state, county and municipality levels and infer the need to regard spillover and lagged effects for unbiased analysis. Significant spatial spillover of road infrastructure expansion on regional growth is identified by a spatial model built upon a dataset of 26 regions in Turkey for the years between 2004 and 2014 in [35]. The critical role of transportation facilities in convergent regional growth is highlighted by [36] after estimating a growth model for 24 provinces in China between 1985 and 1998.

The absence of agreement on the magnitude and direction of a causal mechanism may be the underlying stimulation for studies on the sectoral effects of transport infrastructure, such as [37–40] and more recently [41]. The aggregate level research results on the impact of transport infrastructure (public infrastructure in general) on economic growth are largely divergent [16] and sometimes a direct relationship is not detected, as in the case of [13].

Thus, this condition may come from the fact that the occurrence of transport itself is determined indirectly by different lines of economic activity, namely through trade flows, indicating that its demand grows in parallel to growth of international merchandise trade, as proposed by the notion of 'derived demand' as underlined by [42]. Besides, trade is a specific product of infrastructure development as it is frequently taken as a key driver of development [10]. Transport endowments provide lower transportation costs, efficiency gains and economics of scale in accordance with the implications of comparative advantage and new economic geography, leading to a higher propensity to trade for domestic firms and eventually to trade expansion [29,43,44]. So the direct effects of transport infrastructure growth are realized through exports and imports, ultimately leading to prosperity. With

respect to effects of different modes, scholarly interest in the topic has been concentrated mainly on land transportation, particularly on highways and paved roads (e.g., [45–48]), and to a lesser extent on railways (e.g., [49,50]), occasionally on airports (e.g., [51,52]) and on seaports (e.g., [53,54]).

In line with the brief discussion above, this study aims to analyze the linkage between Turkey's transport infrastructure stock development in land transport components along with ICT as a supplementary infrastructure for trade. Thus, the main concept of analysis includes exports and imports as dependent variables. Concerning logistics networks, both road and railway variables are considered as explanatory factors. Two kinds of road infrastructure are taken into account in modeling procedures to unveil the differential effect of quality of infrastructure. In addition to total roads, we deliberately employ divided road stock as a representative for quality roads. ICT infrastructure is another factor regarded as a determinant by a proxy variable, treated as an enabling instrument for a developed transportation system. In Table 1, the factors selected in model building are listed by category and related references. Descriptive statistics for the variables are also provided in Appendix A Table A1.

Table 1. Variables and sources.

Category	Subcategory	Variables	References
Dependent	Trade Flows	Exports Imports	[4,8,9,15] [9,12]
Independent	Land Transportation	Total Road Divided Road Railway	[9,11,12,15,36,40] [35] [9,15,36,40]
	ICT	Mobile Phone Subscription (as a Proxy)	[12,14]

3. Data and Analytical Methodology

Time series methods are frequently employed tools in the search for causality between investment in infrastructure and economic benefits. We disentangle the connection between transport infrastructure and trade in Turkey by using the ARDL (Autoregressive Distributed Lag) methodology proposed by [55,56] with annual data for the time horizon between 1987 and 2019. ARDL was chosen as it is a convenient and flexible analytical tool with high estimation power for a small sample size. Moreover, the association between dependent and independent factors is examined with concurrent and also lagged values. In [57], other advantages are identified as: (1) long-run relationships are studied under the condition of the same order of integration with stationary variables, however, ARDL allow for order of integration of I(0) and I(1) and their mixture. (2) It provides unbiased estimates and valid test statistics even in the case of complications in statistical properties of variables, e.g., endogeneity. (3) An error correction model (ECM) can be obtained from the ARDL model with a simple transformation, showing integrated dynamics of short-run to long-run adjustment without sacrificing long-run information.

After providing essential information on the variables, preliminary data analysis is conducted with stationarity tests. Then, two different models are constructed as baselines for the ARDL methodology. Existence of cointegration among the factors is tested with bounds testing for the baseline models through the establishment of an unrestricted error correction model (ECM). Having established the long-run association with a bounds test, regression analysis is performed to understand causation from transport infrastructure as well as ICT to trade. This is realized by integrated estimations which combine baseline models and the ECM framework for exports and imports. Finally, robustness of the models is tested to validate statistical power and reliability of findings. All procedures were performed on Eviews 10 software. A detailed explanation on the steps for the data collection procedure and analytical methodology is provided in Figure 1.

Step 1. Data Collection

• All time series data is obtained from secondary data sources. Trade series are taken from World Bank, World Development Indicators database. Transport and ICT infrastructure data is retrieved from Turkish Statistical Institute Transportation and Communication database.

• The data covers annual observations for the years between 1987–2019 for Turkey.

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Step 2. Initial Data Analysis: Stationarity Test

• Stationarity tests are applied on the data to confirm that data generating process of any variables do not have integration of order 2, which means stationarity can be attained by differencing the series twice.

• Due to their power in small sample size, Dickey Fuller-GLS unit root and KPSS tests are applied. Tests prove that all variables are I(1), so we ensure that data is appropriate for ARDL technique.

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Step 3. Baseline Model Specifications

• To analyze the causality between transport infrastructure and trade in Turkey, two generic models-Equations (1) and (2)- are specified with the aim to capture differential impact of divided road network on trade. The same functional form of each model is estimated on exports and imports individually, yielding to a total of 4 models (export model 1, export model 2 as well as import model 1 and import model 2).

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Step 4. Construction of ARDL Models: ECM and Bounds Testing

• Steps in ARDL modeling involves bounds testing for the presence of long-run relationship among variables. This test is separately applied on standard unrestricted Error Correction Model (ECM) formulations as shown in (3) for the generic models (1) and (2). F statistics is used for bounds testing.

• Bounds test results provide evidence of cointegration among variables for each of the 4 models.

Step 5. ARDL Model Estimation: Augmenting Long-Run and Short-Run Dynamics

• Following confirmation of cointegration, lag orders for all variables (dependent and independent) are determined based on Akaike, Schwarz and Hannan-Quinn information criteria. As annual frequency of data dictates, maximum lag order is determined as 2 for all variables, then the lag length is chosen following the aforementioned information criteria.

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• ARDL models for all specifications (4 models) are estimated by augmented components of long-run effects, ECM (short-run effects) and Error Correction Term (ECT (–1)) which shows adjustment from short-run shocks to long-run equilibrium.

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Step 6. Robustness Check: Diagnostic Test

• To confirm the validity and reliability of the estimation parameters, the following tests are applied: serial correlation, heteroscedasticity, stability and normality.

Figure 1. Flowchart for data collection and analytical steps.

Exports of goods and services with constant prices (LNEXPORT) and imports of goods and services with constant prices (LNIMPORT) demonstrate the economic indicators on which the effect of infrastructure prevails. Road and railway comprise the land transport system, so total road length (LNROAD), divided road length (LNDIVIDED), railway length (LNRAIL) and mobile cellular subscription per 100 people (LNICT) are used as indicators for transport infrastructure and ICT respectively, on which details are given in Table 2. Secondary data from the World Bank database (trade variables) and Turkish Statistical Institute (infrastructure variables) are employed. All variables are log-transformed as a common procedure to obtain smoother time series data for better statistical properties.

Variable	Explanation	Supporting References
LNEXPORTS	Exports of Goods and Services (constant 2010 US\$)	[4,8,9,15]
LNIMPORTS	Imports of Goods and Services (constant 2010 US\$)	[9,12]
LNROAD	Total Road Length (km)	[9,11,12,15,36,40]
LNDIVIDED	Divided Road Length (km)	[35]
LNRAIL	Railway Length (km)	[9,15,36,40]
LNICT	Mobile Cellular Subscriptions (per 100 people)	[12,14]

In time series, non-stationarity refers to a stochastic process characterized by a unit root which violates statistical assumptions necessary for estimation. These properties are constant mean, variance and autocorrelation over time, which altogether are composed of essential conditions for statistical inference. In order to prepare time series data for statistical analysis, most methods require a preliminary test for stationarity and application of necessary differencing procedures to obtain stationarized series through I(1)—first differencing and I(2)—second differencing in the case of non-stationarity. Although pretesting and stationarization are not necessary steps in ARDL modeling, we pursued these tests as suggested by [58] to ensure that the I(2) process was not prevalent in any of the variables, which aborts application of the ARDL method.

Dickey–Fuller-GLS and KPSS tests are applied in stationarity analysis pursuant to [59] due to their power in a small sample size. Dickey-Fuller-GLS checks for unit root in time series (non-stationarity) and KPSS is a test for stationarity. The Dickey-Fuller-GLS test is a modification of ordinary Dickey–Fuller test statistics with generalized least squares (GLS) foundation, that stands out as an efficient test robust to sample size and lag length selection. It is applied with a null hypothesis of non-stationarity. The Kwiatkowski–Phillips– Schmidt–Shin (KPSS) test is based on the Lagrange multiplier (LM) test for the rationale of stationarity around a trend. It is executed for the null hypothesis of stationarity, contrary to the null of the first test. In Table 3, stationarity test results are presented. As shown in Table 3, according to the Dickey–Fuller test, null hypothesis is rejected for the first differenced series with 95% confidence level, implying that they are I(1) stationary. Regarding KPSS test results, we failed to reject the null of stationarity for the first differenced data with 95% confidence level, pointing out that variables are I(1) stationary. Overall, the preliminary statistical investigation reveals that series have a homogenous order of integration with the I(1) process, which shows the compatibility of assumptions for the ARDL approach, as it is not possible to implement it in case of higher orders than I(0) and I(1).

Table 3. Stationarity test results.

	DF-GLS Null: Series Has a Unit Root		KPSS Null: Series Is Stationary	
	Level	First Difference	Level	First Difference
LNEXPORT	-1.6865	-5.6323 ***	0.1972 **	0.0604
LNIMPORT	-2.2527	-7.3678 ***	0.1849 **	0.0617
LNROAD	-1.1621	-5.5187 ***	0.4160 **	0.2241
LNDIVIDED	-0.2804	-2.8005 ***	0.6533 **	0.2910
LNRAIL	-1.6491	-4.9582 ***	0.1793 **	0.0859
LNICT	-1.2288	-3.0855 *	0.2000 **	0.0890

Note: ***, ** and * indicate level of significance at the 1%, 5% and 10% levels, respectively.

4. Determination of Long-Run Relationship between Trade and Transport Infrastructure

Our examination begins with construction of an appropriate ARDL framework for the nexus between transport infrastructure and trade. A multivariate study is established on the premise that the main transport infrastructure (land network) would have a promoting impact on international trade flows. For convenience, only a sound set of variables is considered to construct regression functions for the sake of statistical power of the study to counteract constraints by degrees of freedom and complications of time series variables [60]. Upon selected criterion on the variety of factors in each equation, two model specifications are generated differing according to the set of independent variables. Each of the following models are employed for export and import series:

$$TRADE_{t} = \rho 0 + \rho 1 ln DIVIDED_{t} + \rho 2 ln RAIL_{t} + \rho 3 ln ICT_{t} + \pi_{t}$$
(1)

$$TRADE_{t} = \lambda 0 + \lambda 1 lnROAD_{t} + \lambda 3 lnDIVIDED_{t} + \lambda 4 lnRAIL_{t} + \lambda 5 lnICT_{t} + \Psi_{t}$$
(2)

where TRADE_t refers to aggregate value of exports/imports at time t; ρ_0 and λ_0 are constant terms; π_t and Ψ_t are white noise error terms in model 1 and 2, respectively. Divided road network is present in model 1; it is also included along with total road length in model 2. This parametrization attempts to decouple individual effects of different road quality levels. In a nutshell, trade is expressed as a function of divided road, railway and ICT in model 1 and total road, divided road, railway and ICT in model 2.

The ARDL modeling process entails several steps. Firstly, a bounds testing technique is applied to check for cointegration for model 1 and 2. For that purpose, an unrestricted error correction model (ECM) is regressed to test the significance of lagged values of variables at different levels. Upon identification of a cointegration relationship among variables, a second step involves estimation of long-run and short-run parameters of model 1 and 2 for exports and imports by augmenting long-run and ECM (short-run) specifications.

In the formulation of ARDL models, an unrestricted ECM can be generated for model 2 as follows:

$$\Delta \ln TRADE_{t} = \beta 0 + \beta 1 \sum_{i=1}^{p} \Delta \ln TRADE_{(t-i)} + \beta 2 \sum_{j=0}^{q} \Delta \ln ROAD_{(t-j)} + \beta 3 \sum_{k=0}^{r} \Delta \ln DIVIDED_{(t-k)} + \beta 4 \sum_{s=0}^{y} \Delta \ln RAIL_{(t-s)} + \beta 5 \sum_{w=0}^{z} \Delta \ln ICT_{(t-w)} + \alpha_1 \ln TRADE_{(t-1)} + \alpha 2 \ln ROAD_{(t-1)} + \alpha 3 \ln DIVIDED_{(t-1)} + \alpha 4 \ln RAIL_{(t-1)} + \alpha 5 \ln ICT_{(t-1)} + \delta_t$$
(3)

where TRADE_t refers to aggregate value of exports/imports at time t, Δ is the first difference operator, δ_t is white-noise error term, (t - 1) refers to first lag of each variable, and each notation from the group of 'p,q,r,y and z' in summation terms denotes different lag length of each variable chosen based on statistical information criteria. In this framework, Σ terms capture short-run dynamics whereas cointegrating relationships are expressed in lagged parameters at levels with coefficients α_1 to α_5 . In terms of bounds testing, an F-test is exercised to find out whether there is a long-term relationship (cointegration) between exports/imports and transport infrastructure for the following hypothesis:

Hypothesis 1 (H1). $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ (no cointegration).

Hypothesis 2 (H2). $\alpha_1 \neq 0$ or $\alpha_2 \neq 0$ or $\alpha_3 \neq 0$ or $\alpha_4 \neq 0$ or $\alpha_5 \neq 0$ (presence of cointegration).

Table 4 shows the results of the bounds testing process. F statistics show evidence of cointegration with the calculated F scores exceeding critical values at 1% for all models. So an integral long-term link between trade volume and transport infrastructure stock exists in Turkey. This confirms the common verdict put forward by different theories, such as network theory and transport geography, that improvements in transport infrastructure have a reducing effect on transaction and transportation costs, stimulating international

trade interactions. In the next step of analysis, we employ an ARDL model to obtain shortand long-run causation in a single form for exports and imports.

Table 4. Bounds test results.

	F Statistics	Critical Bound Values (10%)	Critical Bound Values (5%)	Critical Bound Values (1%)
Export-Transport Infrastructure Model 1	13.5253 ***	2.67–3.58	3.27-4.30	4.61–5.96
Export-Transport Infrastructure Model 2	5.4622 **	2.52-3.56	3.05-4.22	4.28–5.84
Import-Transport Infrastructure Model 1	7.5996 ***	2.67-3.58	3.27-4.30	4.61–5.96
Import-Transport Infrastructure Model 2	7.1512 ***	2.2-3.09	2.56-3.49	3.29-4.37

Note: *** and ** indicate level of significance at the 1% and 5% levels, respectively.

5. Regression Analysis

5.1. Analysis of Short-Run and Long-Run Dynamics in a Single Framework

After confirming cointegration in the series with a bounds test, short-run and long-run relationships between transport infrastructure and trade are estimated using an ARDL approach. The imposition of maximum lag length is of crucial importance in time series analysis as it determines the power of the test statistics considerably. In Ref [61] (p. 642), it is stated that maximum lag length is primarily mandated by the frequency and sample size of the data, asserting that lag length of 1 or 2 is sufficient for annual frequency. Following this, due to annual frequency of data, maximum lag length is set to 2 for both trade and explanatory variables and optimal lag length is selected based on different modeling measures, namely Akaike, Schwarz and Hannan–Quinn information criteria. Tables 5 and 6 demonstrate the model results for exports and imports.

Firstly, ECT (-1) denotes an error correction term and it corresponds to a feedback effect showing how much of a deviation caused by a positive or negative shock in the previous period is corrected within a year. It is negative as expected, because it incorporates the speed of adjustment to long-run balance. For exports, the models reveal a 44% and 76% convergence to the long-run steady state export level per year in case of a shock. For imports, on the other hand, going back to equilibrium takes less than a year with respective values of -1.09 and -1.25. This is a striking insight as it demonstrates the case that development of transport infrastructure promotes sustainable facilitation of imports rather than exports, considering speed of adjustment. This might be associated with export promotion, requiring other logistics-related reinforcements in support of a better transport system. For example, formation of logistics villages, expansion of the number of industrial zones, enforcement of policy measures to enable doing business more easily and promotion of R&D activities to enhance productivity backed by technological improvements can be integrated into the quality of a logistics system to benefit from agglomeration and network effects.

		Export-Transport Infrastructure Model 1	Export-Transport Infrastructure Model 2
	Variables	Coefficient	Coefficient
Adjustment	ECT (-1)	-0.4424 *** (0.050)	-0.7658 *** (0.120)
Long Run	LNROAD		-0.2764 ** (0.121)
	LNDIVIDED	0.3203 ** (0.129)	0.3593 *** (0.081)
	LNRAIL	2.2492 *** (0.864)	1.1297 (0.744)
	LNICT	0.1035 *** (0.025)	0.1100 *** (0.0150)
Short Run	Δ (LNEXPORT (-1))		0.3784 *** (0.118)
	Δ (LNDIVIDED)		0.5812 *** (0.176)
	Δ (LNDIVIDED (-1))		-0.5702 ***
	Δ (LNRAIL)	-1.4597 **	(0.211) -1.4770 ** (0.622)
	Constant	1.9576 (6.911)	(0.022) 15.2174 ** (7.083)

Table 5. ARDL models for exports.

Notes: *** and ** indicate level of significance at the 1% and 5% levels, respectively. Standard errors are in parenthesis.

Table 6. ARDL models for imports.

		Import-Transport Infrastructure Model 1	Import-Transport Infrastructure Model 2
	Variables	Coefficient	Coefficient
Adjustment	ECT (-1)	-1.0979 *** (0.164)	-1.2515 *** (0.173)
Long Run	LNROAD		-0.2293 * (0.131)
	LNDIVIDED	0.6591 *** (0.105)	0.6445 *** (0.090)
	LNRAIL	0.4393 (0.758)	-0.1899 (0.722)
	LNICT	0.0627 *** (0.018)	0.0699 *** (0.016)
Short Run	Δ (LNDIVIDED)	1.5584 *** (0.255)	1.5126 *** (0.237)
	Δ (LNRAIL)	-3.5874 *** (1.243)	-4.3059 *** (1.214)
	Δ (LNICT)	0.3020 *** (0.061)	0.3149 *** (0.058)
	Constant	15.3161 ^{**} (6.216)	24.1040 *** (7.092)

Notes: ***, ** and * indicate level of significance at the 1%, 5% and 10% levels, respectively. Standard errors are in parenthesis.

The presence of short-run dynamics between trade and infrastructure variables is evident for both imports and exports, despite stemming from different factors. To begin with exports, railway infrastructure is significant at 5% in both models and divided road length, lagged value of exports along with lagged divided road length are highly significant at 1% in model 2. When we consider the sparsely distributed geographic locations of production centers and topographic difficulties of the landscape in Turkey, enhancements in divided roads can boost exports by speed and connectivity advantages. The road transport mode requires less capital investment, making it a more convenient measure in transport policy. Besides, it allows for door-to-door service, access to rural areas and more flexible transport options with economies of scale advantages. The significance of divided road infrastructure rather than total road stock points to a demand for higher speed in the national transport system to compete within global value chains. So, we can say that divided road as a better-quality road transport infrastructure provides transport cost reduction, higher market accessibility and productivity, ultimately upgrading export performance, in support of the conclusions drawn in studies such as [10,62,63]. As for railways, rail networks are expected to connect different provinces with each other in the country and make further connections to the rest of the world, developing both national and international trade environment as shown by [30]. However, the significant negative signs for imports and exports in the short run suggest that it is not the case for Turkey to be realized in a short time window. For the most part, this could be a result of rail network development for freight transport being a recent dimension in transport policy of the country, with an emphasis of intermodality and interconnectivity. However, results show that it will take time to realize the benefits from railway investments under some conditions. Efficiency of railways in trade formation can be realized with an extensive railway connection to gateways and hubs in a cost-advantageous fashion. More policies for rail connectivity and intermodality should be developed to cultivate the contribution of rail connection in welfare generation through trade. The high significance of railway stock in long-run export performance justifies our explanations that rail connection should be handled with a perspective of long-term transport policy and planning. Imports are interrelated with all infrastructure variables with high significance in the short run. The role of divided roads is greater for imports than exports. Similarly, the negative signs on railways with stronger parameters suggest that once trade benefits of railway development are realized, imports will potentially increase to a higher extent than exports in the short run. These two remarkable points create an understanding that land transport systems are especially beneficial for imports growth for Turkey. Significant causation from ICT reveals that information extracted from big data in operations, digital communication tools and development of intelligent transport systems result in increases in imports through transport efficiency and safety benefits in the short term.

Long-run effects show causality from divided roads, railway and ICT to exports as well as from divided roads and ICT infrastructure to imports; any effect is distorted by the significant but negative coefficient of total road infrastructure. In the long run, ICT provides a greater contribution in export development whereas divided road stock favors imports more.

5.2. Reliability and Validity: Model Diagnostic Tests

Finally, we engage in a testing procedure for the reliability and validity of the models to verify inferences we have drawn. After time-series regressions, it is crucial to test for specific properties to validate the model and establish the reliability of the insights deducted from the analysis.

The power and reliability of the models are tested with results presented in Table 7. All models satisfy necessary conditions for valid and unbiased results, leading to reliable estimates. The residuals are serially uncorrelated (LM test) with normal distribution (Jarque–Bera test) and homoscedastic variances (Breusch–Godfrey–Pagan), proving that our models are well-specified. Besides, the Ramsey Reset test confirms stability of models in time, eliminating misspecification or nonlinearity bias.

	Export- Transport Infrastructure Model 1	Export- Transport Infrastructure Model 2	Import- Transport Infrastructure Model 1	Import- Transport Infrastructure Model 2
Serial Correlation	0.11 (0.89)	0.17 (0.84)	0.63 (0.54)	1.20 (0.31)
Heteroscedasticity	1.61 (0.19)	1.58 (0.18)	1.00 (0.45)	1.00 (0.45)
Stability	0.15 (0.85)	0.84 (0.44)	0.85 (0.44)	0.98 (0.39)
Normality	1.09 (0.57)	1.85 (0.39)	0.28 (0.86)	0.26 (0.87)

Table 7. Robustness of models.

Note: *p* values are in parenthesis.

5.3. Practical Implications

This paper explores causality relations among transport infrastructure and trade in the case of a developing country, Turkey, characterized by extensive increase in transportation connectivity to global corridors as well as improvements in the domestic network to enhance integration to world markets. Several practical implications concerning long-run impacts are highlighted to provide guidelines in policy design and investment decisions of the public and private sectors. To begin with a striking insight, railway infrastructure stands out as the most promising investment instrument in the long run to reinforce export-led growth. When resources are allocated to divided roads and railways excluding other road types in transportation infrastructure, a 1% increase in railway inventory leads to a 2.25% rise in exports in the long run. The relatively higher impact might emerge as a result of the crowding-in effect characterized by the situation that government spending acts as a driver for private investment. This emphasizes the importance of public-private partnerships and the potential of private sector for investments in areas with profit potential as well as new business creation in the transport sector. In addition, both models show that a 1% investment in divided roads gives rise to an export increase of around 0.32–0.35%, while an investment of the same proportion in ICT causes exports to go up by around 0.10% in the long run. However, extension of standard roads has a negative impact on exports; a 1% investment decreases exports by 0.27%. So we can draw a conclusion that after a threshold, additional road networks can turn into an obsolete investment and result in crowding-out effects which means the reverse impact of government spending on private investment. Thus increase of road networks can be administered under supervision of government authorities but should be developed in participation with private stakeholders as well to prevent unintended outcomes. Imports growth is also an important part of trade development, especially in the case of imports of raw materials and intermediate goods used as inputs for higher value products to export. For imports, the predominant support comes from divided road networks: a 1% increase in the stock of divided roads results in an imports rise of around 0.65% in the long run. This reveals that private companies prioritize speed and flexible service availability (door-to-door delivery) for imports transportation more. Construction of new railways has no significant impact on imports expansion in the long term. ICT again comes to the forefront for the development of imports as well, with a 1% increase in ICT infrastructure yielding a 0.06–0.07% rise in imports.

In conclusion, each mode has a different effect on exports and imports in the short run and long run to be rigorously evaluated for the development of public policy in the area. The private sector should also be a part of all policy-making stages to obtain full benefits from transport infrastructure investments for trade expansion.

6. Concluding Remarks and Policy Implications

Trade is a spatial interaction and numerical pieces of empirical research recognize that trade is undertaken depending on availability and quality of transport infrastructure as an initial condition, such as [20,29,64]. To the extent of access to domestic and international supply chains, a country achieves trade competitiveness with declining transport costs, increasing productivity and scale economies in combination with external effects.

Regarding this instrumental role of transport infrastructure, Turkey has accelerated transport infrastructure investment especially for road transportation mode beginning from 2003, meanwhile undertaking necessary transport policy measures as a complementary step, with the main concern of setting up a smooth, cheap and safe flow of imports and exports [65]. This paper aims to fill a scholarly gap on the economic effects of transport infrastructure with specific interest in trade enhancement from a developing country perspective, namely in the case of Turkey. To analyze the effects of land transport infrastructure stock (namely total length of roads, divided roads and railways) on exports and imports, a time series technique, ARDL modeling, was employed. ICT infrastructure was also considered as an auxiliary component of the transport system for better and more precise comprehension of the mechanisms and dynamics of causality from land transportation improvements to trade flows. The analysis was conducted with an annual dataset covering the period between 1987 and 2019 for Turkey. Two different model configurations were regressed with explanatory variables for exports and imports separately, with the goal to distinguish the potential effect of higher-quality roads.

This study asserts several insights on the nexus of transport infrastructure and trade development. Firstly, it is found that the infrastructure stock of divided roads is the most significant factor in foreign trade development. This situation may arise from the fact that development of the transportation infrastructure network encourages clustering, provides ease of access to remote areas for companies and increases efficiency. In addition, it can also have a boosting effect on trade with border countries. Secondly, the results suggest that ICT is another significant component of trade development as it provides basic infrastructure for widespread use of digital technologies in communication, optimization of logistics operations with big data, automatization through robotics and artificial intelligence. Another finding is the negative effect of railway stock on trade facilitation in the short run, in contrast to theories of transport geography and new economic geography. This can be explained by the heavy capital requirements of railway construction coupled with the fact that its welfare effects can be realized in a well-developed network for multimodal transportation. Hence, railway development comes forward as a policy issue to be planned carefully with a long-term vision. Finally, this study shows that transport infrastructure development tends to promote imports more, in requirement of policies to foster cluster areas like industrial zones and logistics villages to realize reinforcements in export growth. Overall, transport infrastructure investments should be carried out taking all modes and their connectivity along with agglomeration and network impacts into account as a prolonged public policy. The implementation and feedback of policies and measures should be put into practice by joint participation of public and private sectors in collaboration to accomplish trade competitiveness. A major limitation of this study is that insights are drawn only on the causality between land transport infrastructure and trade excluding other transportation types, due to data availability. As a future research direction, proxy variables to represent other modes can be included to analyze the contribution of infrastructure expansion for each mode in trade development.

From a broader view, long-run effects can be indirectly linked to all dimensions of sustainability. Yet the highest impact can be realized in the economic dimension as transport infrastructure development mainly relates to welfare increase, as the theory of new economic geography asserts an intact association between transport and welfare gains. As transport systems get better in the regions, economic activity is redistributed by declining transport costs, increasing productivity and higher employment opportunities, fostering economic sustainability. Through time, higher income and better connectivity spread across regions and pave the way for social equity through better standards of living, and access to quality education and health services for all citizens, promoting the social dimension of sustainability. In terms of the environmental dimension, progress can be made with efficiency gains in manufacturing and transportation by agglomeration, economies of scale and network effects of transport system developments. **Author Contributions:** Conceptualization, D.Ş. and O.T.; methodology, D.Ş.; formal analysis, D.Ş.; writing—original draft preparation, D.Ş.; writing—review and editing, D.Ş. and O.T.; supervision, O.T. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Table A1. Table below show descriptive statistics for variables used.

	LN EXPORT	LN IMPORT	LNROAD	LN DIVIDED	LNRAIL	LNICT
Median	25.491	25.553	12.816	8.882	9.071	3.742
Std. Dev.	0.730	0.738	0.180	0.920	0.073	3.118
Kurtosis	1.810	1.828	3.102	1.610	2.124	2.224
Mean	25.390	25.461	12.756	8.955	9.105	2.056
Maximum	26.465	26.402	12.968	10.154	9.247	4.578
Minimum	24.104	24.123	12.375	7.413	9.039	-4.607
Observations	33	33	33	33	33	33

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