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Research Article/Araştırma Makalesi

Trade Benefits of Transport Network Expansion Policy in Türkiye[1]

Türkiye'de Ulaştırma Altyapısını Geliştirme Politikasının Ticaret Getirileri

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Abstract

Over the past two decades, Türkiye has undertaken considerable investment in transport infrastructure to build a well-developed transport network and to get integrated into global supply chains. This study aims to evaluate long-term trade expansion benefits of transport network investment in Türkiye to derive recommendations for transport and industrial policy. For this purpose, gravity models of trade are estimated for exports and imports with infrastructure investments in various transport modes as the main explanatory variables; as well as other independent variables involving determinants of bilateral trade flow, Information and Communication Technology (ICT) development. In addition, control variables for Türkiye and for partner countries are involved in the models to obtain robust results. The research covers the period between 2003-2017 for 33 export partners and 28 import partners of Türkiye. A main inference from the analysis entails that transport infrastructure investment acts as a driver for import growth rather than export expansion. As another important conclusion, transport infrastructure investment should be carried out with all transport types considered, based on a long-term transport policy scheme with special attention on road and rail infrastructure. Moreover, transport modes should be integrated to enhance network and connectivity of the overall logistics system. As a final remark, a widespread practice of multimodal and intermodal transportation can be achieved by a holistic integration policy of transport modes.

Jel Codes: *F13, F17, N75*
Keywords: *International Logistics, Transport Infrastructure, Trade Development, Gravity Model, Transport Economics*

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Öz

Son yirmi yılda Türkiye, iyi gelişmiş bir ulaştırma ağı oluşturmak ve küresel tedarik zincirlerine entegre olmak için ulaştırma altyapısına önemli yatırımlar yapmıştır. Bu çalışma, ulaştırma ve sanayi politikası için öneriler elde etmek amacıyla, Türkiye'deki ulaştırma ağı yatırımının ticari genişleme üzerindeki uzun dönemli getirilerini değerlendirmeyi amaçlamaktadır. Bu amaçla, temel açıklayıcı değişkenler çeşitli ulaştırma modlarındaki altyapı yatırımları olmak üzere, ikili ticaret akışını belirleyen faktörler ile bilgi ve iletişim teknolojisi (BİT) değişkeni de bağımsız değişkenlere dahil edilerek, ihracat ve ithalat için çekim modelleri tahmin edilmiştir. Ek olarak, güvenilir sonuçlar elde etmek için Türkiye ve dış ticaret ortağı olan ülkeler için kontrol değişkenleri modellere eklenmiştir. Araştırma 2003-2017 dönemi için Türkiye'nin 33 ihracat ortağı ve 28 ithalat ortağı ülkeyi içeren veri ile gerçekleştirilmiştir. Analizden elde edilen ana sonuç, ulaştırma altyapısı yatırımının ihracat artışından ziyade ithalat artışı için itici bir güç olarak hareket ettiğini göstermektedir. Bir diğer önemli çıkarım olarak, ulaştırma altyapısı yatırımı, karayolu ve demiryolu altyapısına özel önem verilerek, tüm ulaştırma türlerinin dikkate alındığı uzun vadeli bir ulaştırma politikası şemasına dayalı olarak yapılmalıdır. Ayrıca, sistemin bütününde lojistik ağını ve bağlanabilirliğini geliştirmek için taşıma modları birbirine entegre edilmelidir. Son olarak, multimodal ve intermodal taşımacılığın yaygın olarak kullanılması, ulaştırma modlarının bütünsel entegrasyonunu sağlayan bir politika ile sağlanabilir.

Jel Kodları: *F13, F17, N75*
Anahtar Kelimeler: *Uluslararası Lojistik, Ulaştırma Altyapısı, Ticaret Büyümesi, Çekim Modeli, Ulaştırma Ekonomisi*

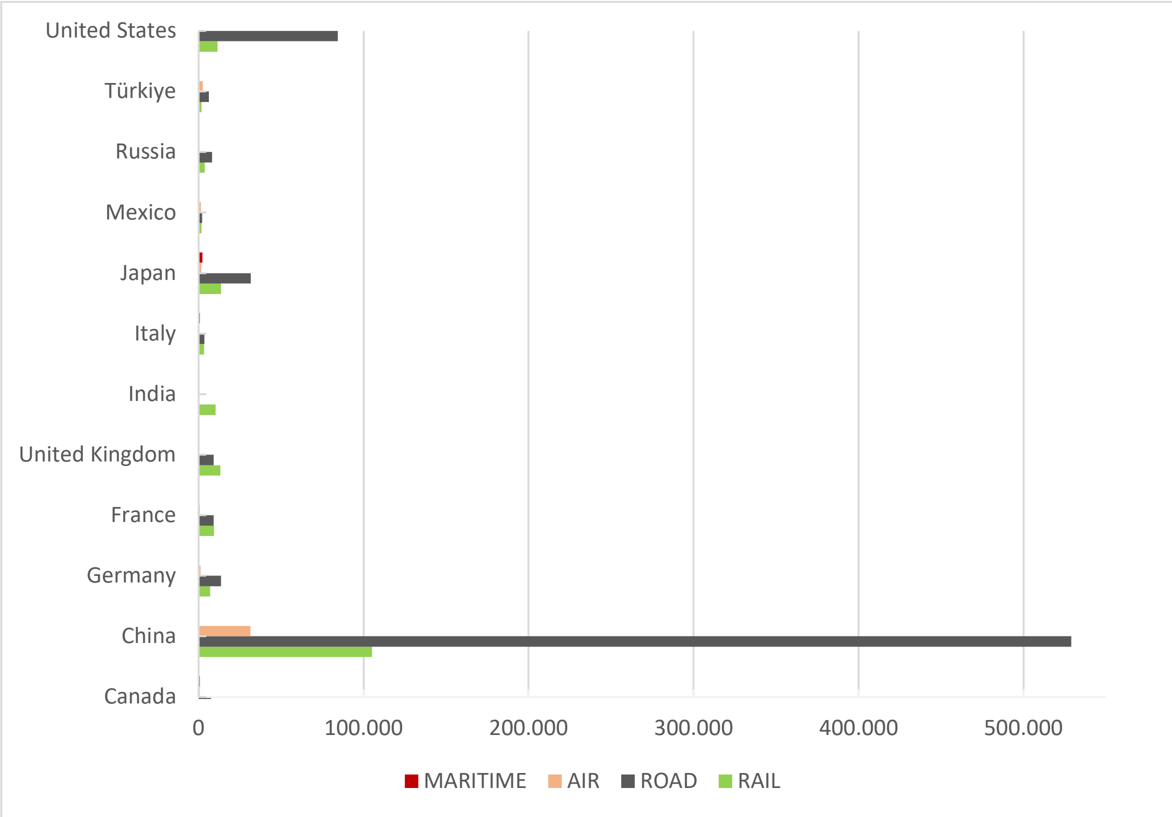
1. Introduction

1.1. Background

An accessible, affordable and reliable transport infrastructure offers important economic benefits (Luo & Xu, 2018). These benefits involve enabling clusters and agglomeration, enhanced productivity, increased market accessibility and implicit rise of supply chain efficiency among others (Chatman & Noland, 2011; Metz, 2008). The economic gains from transportation investments can be classified in two broad categories as short-term gains and long-term gains (Meersman & Nazemzadeh, 2017). Short term gains consist of lower congestion, reduced operational and logistics costs, increasing demand and production, local and regional growth while long-term gains refer to regional/national integration, export growth, higher reliability, rise of industrial and commercial clusters (Meersman & Nazemzadeh, 2017: 318). These benefits make transport infrastructure investment an important instrument in policy formation to stimulate growth in both developed and developing countries. To illustrate, Figure 1 shows investment in rail, road, air and maritime transport types in selected countries in 2017[4]. Several implications can be drawn from Figure 1. Firstly, China is the highest investor in road, rail and air transport types, which can be associated with the country's strategy grounded on trade routes development through One Belt One Road (OBOR) project. In that way, the country aims trade growth by regional and global integration to key markets. Secondly, significant budgets are allocated to road projects particularly in United States, Japan and China as distance to trade partners may be a driver to improve inland transport network. Lastly, rail infrastructure development has been involved in transport infrastructure plans in Germany, France, Japan and United States to enhance connectivity and to establish transport decarbonization in terms of green transformation.

[4] Some values are missing for various transport types. The figure is involved to highlight priority given on specific modes and policy differences among countries.

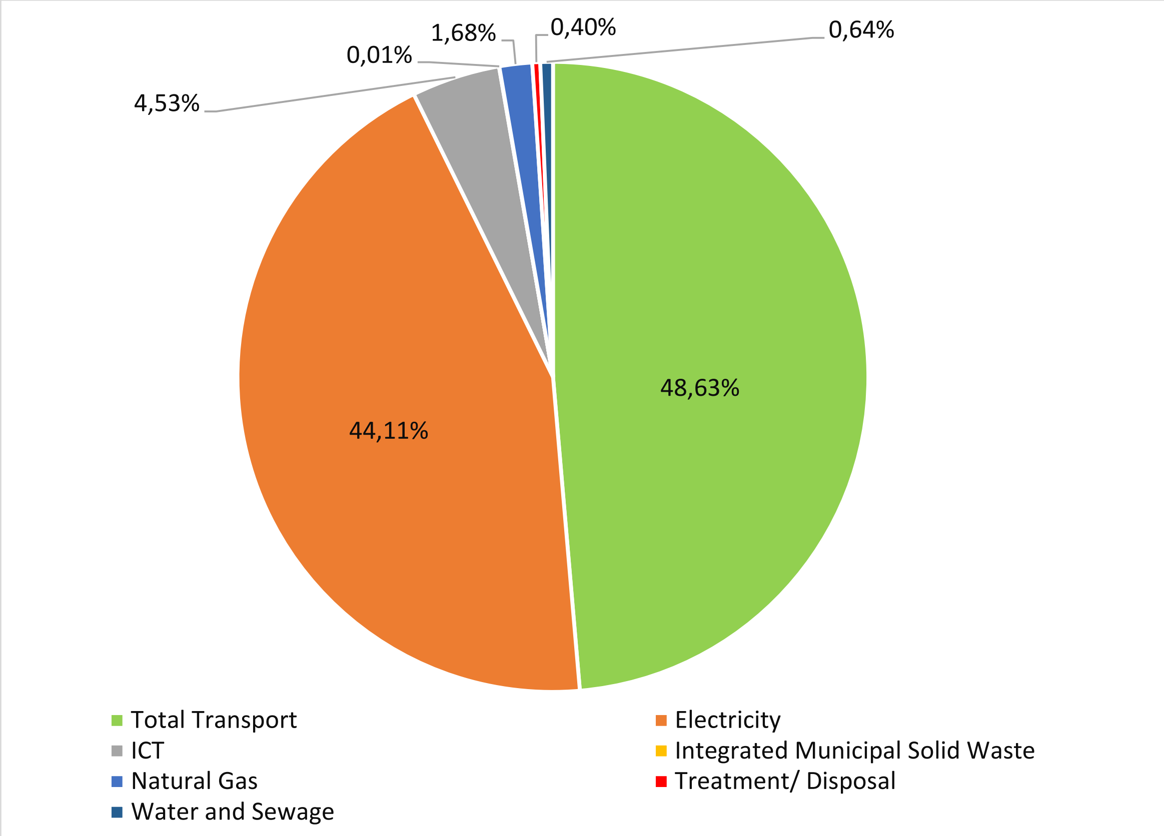
Figure 1: Transport Infrastructure Investment in Selected Countries in 2017 (Million Euro)



Source: OECD (2023).

This study explores trade benefits of transport infrastructure investment in Türkiye that follows a policy approach of investment in various infrastructure types to boost economic growth. In Figure 2, the distribution of private participation in infrastructure investment among sectors is presented for the period between 1990-2020 in Türkiye. As the figure demonstrates, transport infrastructure has a share of almost 50% in infrastructure investment with private participation among all projects in the last thirty years between 1990-2020. Thus, Türkiye has long been pursuing a policy to advance its transport infrastructure.

Figure 2: Private Participation in Infrastructure Investment in Türkiye



Source: World Bank (2019).

1.2. Literature Review and Significance of the Study

The existing body of research on the benefits of transport infrastructure concentrates mainly on project appraisal aspects in the context of micro-level evaluations of mega-projects with respect to cost, time savings and return on investment under Cost-Benefit Analysis (CBA) (e.g., Ansar et al., 2016; Salling & Banister, 2009; Batley et al., 2019), missing broader economic benefits. Evaluation of return on investment for transportation initiatives has focused on direct user benefits and the economic impacts that arise from transportation cost savings in a narrow scope (Laird & Venables, 2017). Moreover, transport infrastructure research mostly investigates the benefits in two extreme country categories, first high-income countries having abundant transport infrastructure capital and second low-income economies which suffer from lack of resources to allocate in transport networks (Duranton et al., 2014). This indicates a research gap on developing countries for which transport infrastructure can function as a growth engine. Banister & Berechman (2001) stress the importance of inclusion of the spatial component in the attempts to quantify the effects of transport infrastructure investment to reach accurate findings. Besides, network attributes of a transport system require spatial considerations in transport infrastructure decisions, as neglecting distance characteristics in ex-ante analysis can lead to inconsistent conclusions on the estimated effects of such investment policies (Deng, 2013).

When the complementarity of transport modes is concerned, transport networks should be established to ensure connectivity among road, rail, air and maritime transport types based on a holistic network structure. However, research on the broader economic benefits of transport infrastructure has focused predominantly on land transportation, especially on highways and roads (e.g., Ozbay et al., 2007; Fan & Chan-Kang, 2005; Crescenzi & Rodriguez-Pose, 2012), then on railways (e.g., Chen & Haynes, 2017; Liang et al., 2020; Diao, 2018) or on land transport system with road and rail transport together (e.g., Wang et al., 2020). Simultaneous inclusion of all types of infrastructure in a comprehensive way lacks in scholarly knowledge, leaving a research gap on the topic (Park et al., 2019). This research tendency also prevails in the limited line of studies for Türkiye as well. In that regard, Coşar & Demir (2016) investigate accessibility benefits of road investments to international markets. Kuştepeli et al. (2012) conduct causality analysis between highway infrastructure and exports. Ülengin et al. (2013) evaluate and rank different road projects in Türkiye. Moreover, these papers examine a narrow time range which might isolate long-run effects as the benefits are realized with time-lags (Canning & Pedroni, 2008; Cigu et al., 2019). Also, the geographical scope of previous studies involves regional analysis for Türkiye which might hinder the true relationship as marginal effect of transport diminishes when scale gets smaller (Berechman et al., 2006; Cantos et al., 2005). Hence, this paper aims to analyze the trade outcome of Türkiye's transport infrastructure investment in all transport types for policy implications involving all modes, with a long-time horizon to consider lagged effects and to capture the overall magnitude.

Upon the general overview introduced on the transport infrastructure and economic benefits nexus so far, the significance of this paper resides in several aspects. First of all, this paper is significant with its focus on Türkiye as an emerging economy. Secondly, all modes are taken into consideration to avoid partial analysis which might lead to misleading results. As outlined above, surveys on the same topic focus on only road transportation for Türkiye, in line with the international studies commonly examining benefits of highways and road investments (e.g., Duranton & Turner, 2012; Fraumeni, 2009; Baum-Snow et al., 2020). Another significance is related to the geographic scale of the analysis, as this paper adopts an overall country exploration contrary to the inquiry on regional effects with a fragmented perspective of the existing studies on Türkiye.

In terms of methodology, this study is based on a spatial interaction analysis by employing a gravity model framework, differentiating from the mainstream line of research in the field using mainly causality examinations such as Saidi et al. (2018), Pradhan & Bagchi (2013), Badalyan et al. (2014), Keho & Echui (2011), Mohmand et al. (2017), Pradhan (2010) and He et al. (2021). In that way, we incorporate spatial dimension of logistics infrastructure in the analysis.

The rest of this study is organized as follows. Section 2 starts with an introduction to gravity model and explains the details of model construction steps and variable selection process. The section proceeds with the description of the extended gravity model built as the main analysis tool of the study. Section 3 provides the results and discusses the findings for the effects of transport infrastructure expansion on trade development. The analysis is provided in different sections for exports and imports, involving subsections that examine the effects of modal interaction. The reliability and validity of the models are also described in this section. Section 4 presents concluding remarks and proposes future research directions.

2. Exploration of Spatial Interactions: Gravity Model of Bilateral Trade Flows

The use of gravity models to explain patterns of international trade flows is proposed by Tinbergen (1962), inspired by Newton's law of gravitation. It is based on the idea that attraction between any two masses occurs with a force in direct proportion to total size of their masses and inverse proportion to squared distance between them. Comparably, bilateral trade flows from country i to country j, Z_{ij}, is positively related to the product of countries' economic sizes, measured by GDP (Y_i and Y_j) and negatively related to the distance ($Dist_{ij}$) between countries. This flow can be represented mathematically as follows:

$$Z_{ij} = \frac{Y_i * Y_j}{Dist_{ij}} \quad (1)$$

As a novel technique, Santos Silva & Tenreyro (2006) propose the use of Poisson pseudo-maximum likelihood (PPML) approach for gravity-type equations as an alternative and more robust estimation method, based on the argument that multiplicative form estimation is the appropriate technique for gravity equation. Although ordinary least squares (OLS) regression is the traditional estimation method with a log-linearized specification, it is shown that PPML technique generates robust estimations to various heteroscedasticity types in contrast to severely biased estimates obtained by OLS. Another issue in gravity modeling is the tackling of zeros in trade flow data, which prevails as an intrinsic property of trade flows. Zero values are all dropped out of the equation with OLS method as logarithm of zero is not defined, therefore PPML comes forward as a convenient alternative to involve zero trade flows and incorporate that information in the analysis as the dependent variable is defined in levels instead of logarithmic form. Egger & Staub (2016) confirm reliability of PPML estimations in both small and large samples as well as in case of various stochastic processes. Furthermore, they emphasize general inconsistency of parameter estimates in OLS setting even if the log-linear equation is the correct model.

PPML approach has been a frequently employed robust instrument for complex spatial interaction analysis for policy research in areas like trade and transport policy (e.g., Coşar & Demir, 2016; Wessel, 2019; Bottasso et al., 2018; Portugal-Perez & Wilson, 2012). Aligning with the general approach, this study follows PPML approach in gravity modeling to explain the effects of logistics infrastructure expansion in different modes on trade development in Türkiye.

2.1. Variable Selection and Construction of the Extended Gravity Model

In structural gravity modeling, it is crucial to determine the correct independent and control variables to obtain a robust analytical framework. Hence, dependent variables (export and import values) and gravity variables (distance, dummies and GDPPC) are selected among typical factors in gravity setup whereas careful consideration is directed to the selection of explanatory and to a larger extent, of control variables. Investment values in transport infrastructure types in Türkiye are taken as the main explanatory variables to understand trade benefits of resource allocation in different transport types, departing from the general inclination for physical capacity measures (i.e., length in km) or less frequently for capital value of transport infrastructure. As another point to investigate, the interactions among transport types are also evaluated to understand the effect of modal competition and substitution on trade development in Türkiye. ICT stands out as a core infrastructure to complement a strong transport network, thus variable for the percentage of internet users to the population in Türkiye is taken as a proxy for ICT infrastructure in Türkiye. Based on the notion that benefits of transport investments can be realized with fine-tuned development policies and supporting regulations (Chatman & Noland, 2011), indicators for government effectiveness and control of corruption for Türkiye are added as representatives of the government's pivotal role in transport decisions and planning (Hasselgren, 2013; Crescenzi et al., 2016). Moreover, these factors function as control variables to get the true mechanism of the impact of transport infrastructure on trade development and to avoid omitted variable bias. In addition, regulatory quality of Türkiye is also considered as a proxy to quality of institutional setting for promoting private sector development (Kyriacou et al., 2019). This factor is added to understand the potential enabler role of favorable institutional environment in receiving returns from transport investment. Besides, it serves as another control variable to ensure robust regressions. Regarding control variables for the partner countries, rigorous attention has been paid to find proxy variables which are not related to transport connectivity of Türkiye to avoid likely statistical problems such as multicollinearity, which distorts estimation procedures. Accordingly, indicators such as logistics performance index (LPI) are not considered due to the possible interaction with transport infrastructure information of Türkiye. With this perspective, access to electricity is taken to account for general infrastructure condition in the partner country while transport value added is included to consider the development of transport sector. Liner shipping connectivity index is also included representing both aspects. Data sources and further explanations on the variables are provided in Appendix 1.

2.2. The Extended Model

As outlined, PPML estimations are carried out with a panel dataset composed of explanatory variables and control variables for the period between 2003-2017. Following Bottasso et al. (2018), analysis is performed by trade flows with the countries which cover 80% of the total value of exports/imports of Türkiye in 2017. The dependent variables are established on trade flows towards 33 partner countries for export models and trade flows from 28 partner countries for import models.

The extended gravity model is defined with the following equation:

$$Tradeflows_{ijt} = exp\,[B_o + B_1 \ln(Distance) + B_2 Common\ Border + B_3\ Common\ Language + B_4\ Colonial\ Relationship + B_5 ln\ (GDPPC_{it} + GDPPC_{jt}) + B_6 ln\ (Road\ Investment_{it}) + B_7 ln\ (Rail\ Investment_{it}) + B_8 ln\ (Airport\ Investment_{it}) + B_9 ln\ (Port\ Investment_{it}) + B_{10}\ ICT_{it} + B_{11}\ Government\ Effectiveness_{it} + B_{12}\ Corruption\ Control_{it} + B_{13}\ Regulatoy\ Quality_{it} + B_{14}\ Electricity\ Access_{jt} + B_{15}\ Transport\ Value\ Added_{jt} + B_{16}\ LSCI_{jt}\,]\varepsilon_{ijt} \quad (2)$$

where $Tradeflows_{ijt}$ represents exports/imports of Türkiye to/from a partner country j in year t; i and j stand for Türkiye and a partner country, respectively; $GDPPC_{it}$ and $GDPPC_{jt}$ stand for GDP per capita of Türkiye ad GDP per capita of partner country j in year t, respectively; ICT_{it} stands for rate of internet users in Türkiye; $LSCI_{jt}$ refers to liner shipping connectivity index for partner country j; ε_{ijt} is error-term.

3. Empirical Analysis and Findings

3.1. Augmented Gravity Model Analysis for Exports

The extended model in Equation 2 is estimated and then its different variations are regressed for in-depth inferences with a panel data for 33 export partners of Türkiye for the period between 2003-2017. The results of gravity regression for exports are presented in Table 1. In the first column, the results of the extended model are shown as a baseline specification, upon which various models are estimated. As the notion of gravitation suggests, the total economic size, namely sum of GDP per capita of Türkiye and partner country, has a significant positive impact on exports of Türkiye in all specifications, the only bilateral trade flow variable which is not dropped out of regressions during the analysis.

A detailed discussion is necessary for divergent impacts of investment in different transport types across models. Firstly, investments for all transport types significantly affect trade according to the baseline estimation of Export Model 1. However, there is a remarkable result that rail investment seems to have a negative effect on trade whereas investments in other transport types seem to contribute to trade development with significant positive coefficients. This can be associated with several unique characteristics of the transportation system in Türkiye. The primary motivation behind railway constructions has traditionally been to establish regional connectivity, which remained as a core policy for a long period. Thus, the railway connectivity is a recent concern in Türkiye, gaining momentum especially after 2003 (MoTI, 2019), which might leave railway transport with inadequate service levels for freight transportation. The share of railway in freight transport keeps at 1% within the last two decades (Turkstat, 2021), implying that railway is not a preferred transport type by actors in the international trade. This is likely to happen because of the failure to provide cost-effectiveness as a natural outcome of inadequate network not only for railway alone but also for intermodality. Overall, railway infrastructure has been neglected for a long time and recent efforts to improve its connectivity can bring results with time lags considering that effects of government infrastructure investment policies are realized with delays. Moreover, railway infrastructure investment variables have consistently negative signs in all models, further pinpointing the need to implement a comprehensive transport planning and policy.

Another noteworthy point is the negative sign of road infrastructure investment when road is the only transport type (in Export Model 2) and only land transportation investment is considered (in Export Model 3) as well as when road and port investment are the factors under investigation (in Export Model 5). This is a surprising result as transportation of Turkish exports depends highly on road transport particularly with border countries. This result can be explained with the dominance of road transport in domestic freight transport rather than international commodity flows. In fact, the share of road transport in exported products falls from around 45% to 28% within the last two decades (Turkstat, 2021). Besides, Türkiye has a well-connected road transport network and additions to the existing stock might be inefficient in trade formation, caused by the nonlinear relationship between road infrastructure and export expansion, which exhibits diminishing rate of returns, as noted by Deng et al. (2014). In particular, as the new infrastructure is added to the total stock, the marginal contribution declines. After a saturation point, there will be no or negative effect on export growth as a result of the nonlinear relationship.

Regarding air and maritime transportation modes, airport and port investments generally come out as drivers for export expansion (with only insignificant exception for port investment in Export Model 5). This reflects the actual state of modal distribution of international freight transportation in Türkiye, shipping being the prominent mode in export transportation with over 60% share and air transport accounting for around 11-14% of export shipments within the last two decades (Turkstat, 2021).

The control variables for Türkiye, namely ICT infrastructure as well as indicators for government effectiveness, control of corruption and regulatory quality, have been included into the regressions in order to ensure robustness as well as to get insights on ICT development and related soft factors (government effectiveness, control of corruption and regulatory quality) which are related to both transport and trade policy. However, changing significance and signs of these variables impede derivation of reliable inferences. As for the control variables of partner countries, electricity access and LSCI are significantly positive in all modes, implying that the infrastructure development along with connectivity level (putting in a different way, openness level) of the partner countries are other determinants of export facilitation for Türkiye.

Table 1: Gravity Regression Results for Exports

Variables	Export Model 1	Export Model 2	Export Model 3	Export Model 4	Export Model 5	Export Model 6	Export Model 7
Ln(GDPPC i + GDPPC j)	1.552***	1.473***	1.483***	1.369***	1.457***	1.435***	1.693***
	(0.337)	(0.252)	(0.257)	(0.275)	(0.265)	(0.269)	(0.310)
Ln(Road Investment i)	0.558***	-0.172***	-0.148***	0.477***	-0.127***		
	(0.164)	(0.0465)	(0.0563)	(0.156)	(0.0248)		
Ln(Rail Investment i)	-0.332***		-0.0414**	-0.289***		-0.111***	-0.0849***
	(0.0757)		(0.0201)	(0.0690)		(0.0150)	(0.0185)
Ln(Airport Investment i)	0.100**						0.0960**
	(0.0443)						(0.0428)
Ln(Port Investment i)	0.247***			0.227***	0.0209	0.0736***	
	(0.0715)			(0.0704)	(0.0266)	(0.0246)	
ICT i	-0.0189**	0.00748**	0.00874***	-0.0122*	0.00486	0.00295	0.00182
	(0.00815)	(0.00307)	(0.00298)	(0.00720)	(0.00408)	(0.00325)	(0.00383)
Government Effectiveness i	0.866**	-0.454**	-0.499**	0.519	-0.336	-0.150	-0.297
	(0.426)	(0.195)	(0.201)	(0.428)	(0.293)	(0.264)	(0.200)
Corruption Control i	-1.581***	-0.160	-0.0626	-1.478***	-0.343	-0.560**	0.0452
	(0.530)	(0.101)	(0.130)	(0.529)	(0.309)	(0.274)	(0.0978)
Regulatory Quality i	-0.0936	0.413**	0.461**	0.0555	0.349*	0.383**	0.231
	(0.234)	(0.184)	(0.186)	(0.240)	(0.208)	(0.195)	(0.183)
Electricity Access j	0.0440**	0.0397*	0.0439**	0.0449**	0.0375*	0.0410*	0.0501**
	(0.0197)	(0.0235)	(0.0223)	(0.0196)	(0.0216)	(0.0214)	(0.0244)
Transport Value Added j	0.0669	0.0542	0.0526	0.0552	0.0553	0.0532	0.0641
	(0.0667)	(0.0715)	(0.0711)	(0.0722)	(0.0726)	(0.0712)	(0.0670)
LSCI j	0.00589*	0.00829**	0.00821**	0.00723**	0.00824**	0.00788**	0.00702*
	(0.00342)	(0.00377)	(0.00373)	(0.00362)	(0.00377)	(0.00371)	(0.00364)
Observations	172	172	172	172	172	172	172
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	6698	2020	2668	5774	2247	2404	3158

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

3.1.2. Modal Interaction Analysis for Exports

Gravity modeling forms a convenient framework to search for interactions among different elements by adding relevant terms to search for whether effects of factors are integrated, as applied by Duranton (2015), Bensassi et al. (2015), Portugal-Perez & Wilson (2012). Considering complementarity and competition concept between transport modes, understanding the nature of interplay among modes can provide valuable insights for promotion of exports. Thus, another line of regressions is performed with interaction terms for investments in different transport types as main infrastructure factors and the results are demonstrated in Table 2. To begin with the interaction between road and rail in Model 1, the negative sign suggests substitutability between these two land transportation investments. This result also reinforces concept of decreasing marginal effect of these transport types on exports. Moreover, the insignificant interaction between road and airport investment in Model 2 as well as railway and airport investment in Model 3 might indicate inadequate land connectivity for air transportation. Besides, there might be a tendency to take investment decisions in air transport infrastructure without considering other modes. As for the interaction between rail and port investment, the insignificant term can be explained by the inefficiency in railway investment and the insufficiency of existing railway networks. The strongly significant interaction between airport and port investment supports scholarly discussions on the complementarity between air and sea transport, the former specializing in high-value freight and the latter for low-value products such as raw materials (Ducruet et al., 2011). Estimates for control variables do not show significant deviations from that of gravity models presented in Table 1. Generally, interaction terms reveal consistent results with gravity estimations in Table 1, strengthening reliability and validity of the analysis.

Table 2: Gravity Regression Results for Modal Interaction in Exports

Variables	Interaction Model 1	Interaction Model 2	Interaction Model 3	Interaction Model 4	Interaction Model 5	Interaction Model 6
Ln(GDPPC i + GDPPC j)	1.502***	1.561***	1.524***	1.453***	1.483***	1.540***
	(0.247)	(0.297)	(0.254)	(0.259)	(0.252)	(0.238)
Ln(Road Investment i)* Ln(Rail Investment i)	-0.0744*** (0.00979)					
Ln(Road Investment i)* Ln(Airport Investment i)		0.0279 (0.0341)				
Ln(Rail Investment i)* Ln(Airport Investment i)			0.0113 (0.0153)			
Ln(Road Investment i)* Ln(Port Investment i)				0.0528* (0.0299)		
Ln(Rail Investment i)* Ln(Port Investment i)					0.0166 (0.0153)	
Ln(Airport Investment i)* Ln(Port Investment i)						0.0549*** (0.0158)
ICT i	0.00825*** (0.00292)	0.000624 (0.00441)	0.00172 (0.00359)	-0.00219 (0.00430)	0.000927 (0.00349)	-0.00369 (0.00391)
Government Effectiveness i	-0.545***	-0.408**	-0.439**	-0.171	-0.365	0.00564
	(0.190)	(0.200)	(0.199)	(0.306)	(0.253)	(0.252)
Corruption Control i	0.0311	-0.112	-0.139	-0.594*	-0.304	-0.647***
	(0.0910)	(0.0970)	(0.109)	(0.334)	(0.240)	(0.219)
Regulatory Quality i	0.425**	0.110	0.146	0.0993	0.146	0.106
	(0.188)	(0.195)	(0.194)	(0.215)	(0.207)	(0.197)
Electricity Access j	0.0496** (0.0245)	0.0475** (0.0234)	0.0460* (0.0249)	0.0390* (0.0204)	0.0427** (0.0208)	0.0343 (0.0236)
Transport Value Added j	0.0521	0.0602	0.0583	0.0585	0.0576	0.0644
	(0.0707)	(0.0697)	(0.0720)	(0.0747)	(0.0745)	(0.0727)
LSCI j	0.00819** (0.00370)	0.00808** (0.00373)	0.00829** (0.00376)	0.00823** (0.00381)	0.00838** (0.00381)	0.00752** (0.00380)
Observations	172	172	172	172	172	172
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	1838	1887	2734	1940	2308	1826

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

3.2. Augmented Gravity Model Analysis for Imports

3.2.1. Gravity Model Results for Imports

The extended model in Equation 2 has also been the baseline model for the investigation of imports with a panel dataset comprising 28 import partners of Türkiye for the period between 2003-2017. Different modifications of the extended model have been estimated to understand the influence of investment in different modes and interaction among transport types on import expansion. The estimation results have been shown in Table 3. The gravity variable for the sum of GDP per capita of Türkiye and partner countries is significant in all model specifications, showing the relevance of economic size for import flows like in the case of exports. To begin with the extended model of Import Model 1 in Table 3, road infrastructure investment appears to have a negative and significant effect on imports. This may occur as a result of geographic distribution of the import partners in remote territories and also constantly declining usage of road transport for imported goods. Moreover, road investment might have become inefficient after a certain stock level with diminishing marginal returns, displaying a nonlinear relationship as proposed by Deng et al. (2014). When modes are considered altogether, airport and port investments seem to have no significant influence on imports. Considering railway investment, the coefficients are strongly significant with the highest values when compared with the other modes. Railway shows up as a consistent contributor for import expansion in all models. This is a plausible insight that railway offers promising benefits for import expansion when its current share of 1% is increased through investments. In reference to the results of the extended model, air and sea transportation components might be interrupted by the potential of railway transport investment.

The effect of road is still negative when its individual effect is explored (in Import Model 2) as well as when air and road is considered (in Import Model 6). This pattern may result from its limited use for transportation of imports, considering its insignificance in some of the models estimated. Regarding airport investment, it is insignificant in most models however it is identified with negative coefficients when combined with road-port and rail-port transport types. The lack of consistent estimates for air transport might imply that this transport type is not an important factor for import growth. As for maritime transport, port infrastructure investment is a determinant factor for import growth in all models with only exception of the extended model in Model 1. The positive relationship between port infrastructure and imports suggests that availability of maritime transport infrastructure is also important for import expansion, following railway infrastructure.

Land transportation types are not among major factors for export growth however railway infrastructure becomes prominent for import expansion. ICT infrastructure stands as a triggering factor with its significance in most models, signaling as a complementary when import flows are concerned. Considering the control variables for Türkiye, government effectiveness drives import development as a soft variable, apparently influential through policies supporting trade openness and free markets. Control variables for partner countries do not affect imports unlike the case for exports, still they are involved in the models to mitigate the possible disturbance by unobserved effects.

Table 3: Gravity Regression Results for Imports

Variables	Import Model 1	Import Model 2	Import Model 3	Import Model 4	Import Model 5	Import Model 6	Import Model 7	Import Model 8	Import Model 9	Import Model 10	Import Model 11
Ln(GDPPC i + GDPPC j)	0.697***	0.812***	0.904***	0.913***	0.568***	0.831***	0.568***	0.911***	0.621***	0.595***	0.633***
	(0.199)	(0.170)	(0.144)	(0.164)	(0.162)	(0.179)	(0.161)	(0.149)	(0.158)	(0.171)	(0.171)
Ln(Road Investment i)	-0.239**	-0.141***				-0.142***	0.0168			0.0746	
	(0.112)	(0.0426)				(0.0420)	(0.0405)			(0.0576)	
Ln(Rail Investment i)	0.196***		0.137***					0.137***	0.0950***		0.0739***
	(0.0577)		(0.0202)					(0.0202)	(0.0243)		(0.0267)
Ln(Airport Investment i)	-0.0508			-0.0143		-0.0210		-0.00727		-0.162***	-0.128***
	(0.0532)			(0.0266)		(0.0265)		(0.0259)		(0.0355)	(0.0311)
Ln(Port Investment i)	0.0288				0.0824***		0.0852***		0.0704***	0.125***	0.0975***
	(0.0452)				(0.0160)		(0.0171)		(0.0176)	(0.0252)	(0.0205)
ICT i	0.00356	0.00675***	0.0141***	0.0101***	0.0116***	0.00490*	0.0121***	0.0135***	0.0135***	0.000374	0.00232
	(0.00264)	(0.00224)	(0.00218)	(0.00308)	(0.00196)	(0.00293)	(0.00246)	(0.00294)	(0.00208)	(0.00258)	(0.00261)
Government Effectiveness i	0.867**	0.754**	0.177	0.390	0.800***	0.763**	0.770**	0.179	0.596*	0.854**	0.790**
	(0.369)	(0.359)	(0.351)	(0.314)	(0.291)	(0.363)	(0.353)	(0.353)	(0.341)	(0.371)	(0.363)
Corruption Control i	0.0314	0.349***	0.0500	0.259***	-0.0366	0.357***	-0.0578	0.0526	-0.138	-0.190*	-0.164*
	(0.123)	(0.0904)	(0.0818)	(0.0904)	(0.101)	(0.0910)	(0.101)	(0.0830)	(0.0861)	(0.103)	(0.0836)
Regulatory Quality i	-0.676**	-0.226	0.0796	0.00732	-0.266	-0.304	-0.244	0.0541	-0.204	-0.856***	-0.763**
	(0.342)	(0.321)	(0.284)	(0.312)	(0.262)	(0.344)	(0.308)	(0.302)	(0.276)	(0.322)	(0.338)
Electricity Access j	-0.0130	-0.0286***	-0.00180	-0.0199**	-0.0164**	-0.0300***	-0.0151	-0.00228	-0.00483	-0.0200*	-0.0146
	(0.00830)	(0.00887)	(0.00869)	(0.00862)	(0.00830)	(0.00886)	(0.00973)	(0.00862)	(0.00920)	(0.0103)	(0.00925)
Transport Value Added j	-0.0309	-0.0446	-0.0239	-0.0347	-0.0649	-0.0409	-0.0650	-0.0226	-0.0514	-0.0458	-0.0392
	(0.0455)	(0.0419)	(0.0433)	(0.0438)	(0.0496)	(0.0432)	(0.0498)	(0.0454)	(0.0496)	(0.0537)	(0.0524)
LSCI j	0.110	0.412	0.543	0.572	0.254	0.400	0.263	0.540	0.279	0.0967	0.116
	(0.718)	(0.688)	(0.698)	(0.672)	(0.748)	(0.673)	(0.754)	(0.697)	(0.740)	(0.727)	(0.736)
Observations	157	157	157	157	157	157	157	157	157	157	157
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	2528	1515	2270	1787	2219	1564	2295	2548	3111	2685	2801

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations. Regressions for some combination of modes have not converged (failing to provide estimations), so they are not considered.

3.2.2. Modal Interaction Analysis for Imports

To account for modal complementarity and rivalry, gravity regressions are re-run with interaction terms of infrastructure investments in different transport types. According to the regression results in Table 4, interaction among all involved combinations of modes indicate complementarity except for road and airport infrastructure pair which shows a substitution relationship. New requirements in global supply chains transform interrelationships between transport types, e.g., leading to substitution between road and air modes. As another noteworthy interaction, the substitution relationship between road and rail for exports turned to be a complement relation in imports. Considering the distance of major importing countries, companies can be indifferent between these two land transport options for the domestic short haulage transportation service where road transport is inevitable for the final leg of delivery. The complementarity of land components for air and maritime transport is evident by the strongly significant interaction terms in Table 4, except for the substitution between road and air. This result is expected by the predominance of two transport types for imports, e.g., maritime and air transport with a share of 63% and 14% in 2019, respectively (Turkstat, 2021). Moreover, the positive interaction reveal complementarity between these modes as in exports. Ducruet et al. (2011) explains this relationship with differentiated service levels of air and maritime transport for distinct product groups. Overall, there is strong evidence to infer that modal complementarity is an important catalyst in fostering imports. Another noteworthy result involves the higher value of ICT variable when transport types are in interaction, implying the power of ICT infrastructure for the facilitation of intermodality by digital transformation of logistics systems, improved tracking and tracing services, faster and reliable information flow among supply chain actors.

Table 4: Gravity Regression Results for Modal Interaction in Imports

Variables	Interaction Model 1	Interaction Model 2	Interaction Model 3	Interaction Model 4	Interaction Model 5	Interaction Model 6	Interaction Model 7	Interaction Model 8	Interaction Model 9
Ln(GDPPC i + GDPPC j)	0.924***	0.920***	0.830***	0.586***	0.597***	0.637***	0.674***	0.892***	0.655***
	(0.157)	(0.163)	(0.139)	(0.152)	(0.144)	(0.159)	(0.137)	(0.150)	(0.135)
Ln(Road Investment i)* Ln(Rail Investment i)	0.0383*** (0.0140)								
Ln(Road Investment i)* Ln(Airport Investment i)		-0.0632*** (0.0191)							
Ln(Rail Investment i)* Ln(Airport Investment i)			0.0763*** (0.0137)						
Ln(Road Investment i)* Ln(Port Investment i)				0.0919*** (0.0181)					
Ln(Rail Investment i)* Ln(Port Investment i)					0.0761*** (0.0126)				
Ln(Airport Investment i)* Ln(Port Investment i)						0.0527*** (0.0123)			
Ln(Road Investment i)* Ln(Rail Investment i)* Ln(Airport Investment i)*Ln(Port Investment i)							0.0521*** (0.00930)		
Ln(Road Investment i)* Ln(Rail Investment i)* Ln(Airport Investment i)								0.0255** (0.0111)	
Ln(Road Investment i)* Ln(Rail Investment i)* Ln(Port Investment i)									0.0726*** (0.0124)
ICT i	0.0133***	0.00389	0.0193***	0.0145***	0.0131***	0.0159***	0.0186***	0.0148***	0.0153***
	(0.00216)	(0.00277)	(0.00259)	(0.00226)	(0.00210)	(0.00252)	(0.00269)	(0.00249)	(0.00231)
Government Effectiveness i	0.228	0.564	0.255	0.608**	0.653**	0.640**	0.423	0.276	0.452
	(0.364)	(0.347)	(0.329)	(0.284)	(0.285)	(0.292)	(0.299)	(0.354)	(0.300)
Corruption Control i	0.172**	0.316***	0.117	-0.132	-0.130	0.0528	-0.0587	0.191**	-0.160*
	(0.0862)	(0.0900)	(0.0921)	(0.106)	(0.0933)	(0.101)	(0.0951)	(0.0895)	(0.0890)
Regulatory Quality i	0.141	-0.292	0.339	-0.121	-0.229	0.0358	0.148	0.203	-0.0722
	(0.312)	(0.350)	(0.316)	(0.258)	(0.251)	(0.267)	(0.277)	(0.339)	(0.258)
Electricity Access j	-0.0116	-0.0273***	-0.00470	-0.00978	-0.00701	-0.0140*	-0.00399	-0.0125	-0.00261
	(0.00860)	(0.00892)	(0.00799)	(0.00835)	(0.00838)	(0.00826)	(0.00835)	(0.00841)	(0.00869)
Transport Value Added j	-0.0317	-0.0290	-0.0439	-0.0632	-0.0552	-0.0646	-0.0564	-0.0383	-0.0506
	(0.0425)	(0.0423)	(0.0437)	(0.0499)	(0.0486)	(0.0483)	(0.0474)	(0.0428)	(0.0481)
LSCI j	0.615	0.472	0.599	0.327	0.261	0.398	0.450	0.617	0.363
	(0.701)	(0.661)	(0.702)	(0.738)	(0.728)	(0.745)	(0.721)	(0.700)	(0.716)
Observations	157	157	157	157	157	157	157	157	157
Cluster FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wald Test	1445	1239	2490	2422	2597	2030	2442	1812	2696

Notes: Robust standard errors are in parentheses. Star signs refer to as *** significance at 1%, ** significance at 5%, * significance at 10%. Dummies for bilateral trade flows and distance are dropped out of regressions by Stata program for convergence because of the presence of fixed effects in the equations.

3.3. Reliability and Validity

Although this study has examined the reliability and validity of the analysis all along the research process, some issues are further monitored. To begin with, as a main issue, endogeneity, i.e., reverse causality, refers to the case where there is a bi-directional feedback relationship in which export growth is driven by transport infrastructure and in turn transport infrastructure stimulates export growth. In terms of methodological robustness, partner country fixed effects are added to alleviate possible complications by endogeneity which poses a major issue in gravity models although the stimulation is expected to proceed from transport infrastructure to import development with one-directional causation (Portugal-Perez & Wilson, 2012; Francois & Manchin, 2013). Furthermore, RESET test is applied to control for the accuracy of model specification in PPML framework which assumes a multiplicative functional form. RESET test has given evidence for accurate model specification as the null hypothesis of 'correct functional form' is failed to be rejected at all confidence levels for the extended model under the PPML method, reassuring robustness of the baseline model specification both for exports and imports.

4. Conclusion

Türkiye has been implementing substantial investments in transport infrastructure for nearly two decades, to increase accessibility and connectivity to get potential trade benefits from its geographic position. Specifically, transport investment receives a share of 30-35% in the government budget (Bodur Gümüş, 2018). This study examines the relationship between transport infrastructure improvements and trade development in Türkiye for policy recommendations.

As a main result, transport infrastructure investment has a triggering effect on imports rather than exports of Türkiye. If Türkiye aims to benefit from the considerable investments in transport infrastructure for export promotion to achieve export-led growth, issues about land transport should be addressed carefully. To be more specific, instead of extensions to already well-founded road infrastructure, new investments can be allocated to areas with an insufficient road network, which offer high trade potential. Investment plans can be ranked based on their prospective benefits and a systematic investment plan can be implemented starting from the projects with the highest potential in trade generation per investment. Moreover, railway connectivity should be prioritized and this process should be accelerated beginning from key ports. Road and rail transport require special attention particularly for export promotion. The system characteristics of transport networks shows that, investment and transport network decisions should be made by considering all modes together instead of separate treatment for each. Such a policy approach would enhance exports and imports further when coupled with supporting industrial policies that enable accessibility, network effects and agglomeration economies. Moreover, necessary institutional setting should be created, which supports persistence of policy implementation along with inclusive decision making including various stakeholders and cooperation with private sector.

ICT stands as an essential instrument in offering differentiated transport services such as traceability and visibility. It also increases efficiency by automated solutions in transport processes and cuts off total transport costs with improved productivity. Thus, ICT infrastructure should be integrated into transportation sector for particularly import promotion.

For import transportation, high level of complementarity among modes shows that multimodal and intermodal transportation is applied. However, application of such business practices lacks for exports as indicated by the limited modal interaction. Thus, infrastructure planning should be handled in a way that multimodal and intermodal transportation become a common business practice with long-term targets.

This study involves several limitations which also offer new directions for future research. A major limitation of this study lies in the potential endogeneity problem which might be inherent in the structure of gravity model equation built to analyze transport infrastructure and trade relationship within a spatial setting. There is no formal and straightforward way to detect endogeneity in a regression analysis, so measures are taken to capture unobserved effects on exports and imports, namely incorporation of partner country fixed effects and control variables for Türkiye as well as for partner countries to minimize possibility of endogeneity. As another limitation which is related to methodological aspects, although the panel dataset of gravity models is strongly balanced, missing data is dropped out of regression analysis in PPML approach, leading to a loss in number of observations. For future research, the resilience of logistics networks can be studied. This will enable to analyze recent shocks such as pandemic, lockdowns, container shortages as well as driver shortages for policy recommendations to remedy such issues in the future.

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Çıkar Beyanı: Yazarlar arasında çıkar çatışması yoktur.
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Appendix 1: Gravity Model Data Explanation and Sources

Variable	Explanation	Data Sources
Exports	Export value of goods, in thousand US dollars.	TSI
Imports	Import value of goods, in thousand US dollars.	TSI
Distance	Bilateral distance between capitals of Türkiye and a partner country, measured in km.	CEPII
Common Border	Dummy variable for contiguity between Türkiye and a partner country.	CEPII
Common Language	Dummy variable for a common language between Türkiye and a partner country (spoken by a minimum of 9% of the population).	CEPII
Colonial Relationship	Dummy variable for a colonial relationship between Türkiye and a partner country.	CEPII
GDPPC	GDP per Capita, in current US dollars.	World Bank
Road Investment	Road infrastructure investment, in current Euros.	OECD
Rail Investment	Rail infrastructure investment, in current Euros.	OECD
Airport Investment	Airport infrastructure investment, in current Euros.	OECD
Port Investment	Port infrastructure investment, in current Euros.	OECD
Road Quality	Indicator for road infrastructure quality, ranging between 1 and 7.	GCI (WEF)
Rail Quality	Indicator for rail infrastructure quality, ranging between 1 and 7.	GCI (WEF)
Airport Quality	Indicator for airport infrastructure quality, ranging between 1 and 7.	GCI (WEF)
Port Quality	Indicator for port infrastructure quality, ranging between 1 and 7.	GCI (WEF)
ICT	Percentage of population using the internet.	ITU-D
Government Effectiveness	Indicator of government's ability for quality policy formulation and implementation, ranging between -2.5 and 2.5 from lowest to highest score.	WGI
Corruption Control	Indicator on the degree of abuse of public power to gain private interest, ranging between -2.5 and 2.5 from lowest to highest score.	WGI
Regulatory Quality	Indicator of government's ability for an effective regulatory environment formulation and implementation to reinforce private sector development, ranging between -2.5 and 2.5 from lowest to highest score.	WGI
Liner Shipping Connectivity Index (LSCI)	Index of a country's integration into global markets, measured by benchmarking according to the value of 100 for the highest connected country in the first quarter of 2006.	UNCTAD
Electricity Access	Variable indicating the percentage of population with access to electricity, %.	World Bank
Transport Value Added	Value added by transport sector as a share of GDP.	OECD