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CONFERENCE PAPER

# A Panel Data Analysis of Turkish Export Market: a Gravity Model Approach

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***Abstract:*** *For nearly half a century, changing economic conditions have also changed the determinants of foreign trade, and different factors have begun to be evaluated. Economic globalization, more widely discussed today, defines a framework in which controls on goods are reduced, capital is in free circulation, labor mobility is present, international entrepreneurship is spread, and various integration unions such as Free Trade Zones, Special Economic Zones, and economic and monetary unions are increasing. Factors such as growth, product differentiation, distance, exchange rates, and supply chain elements have become important, apart from supply and demand differences between countries. In such a context, understanding the mechanisms and limitations of international trade and the factors affecting the volume and direction of trade flows is an important agenda item for conducting economic policy. One of the most popular econometric models that aims to determine these factors and can be derived from many trade theories is known as the gravity model of international trade. The aim of this article is to perform an econometric analysis of the effects of the main driving forces on Turkey's export performance with its trading partners using the gravity model. In this context, the study was conducted with panel data of the top 21 countries in Turkey's exports in seven periods determined between 2007-2023. The periods evaluated were determined as the years in which the Logistics Performance Index, one of the important measures published by the World Bank and used to determine the challenges and opportunities faced by countries in their international trade and logistics activities, was published. Some countries that are at the forefront and have high trade with Turkey but whose periodic variable data could not be accessed were excluded from the analysis. Therefore, although 25 countries were examined, 21 of them were used in the analysis. Nowadays, researchers consider expanding the scope of the model by including logistics performance data in the analysis to make it more qualified to measure cross-border trade performances of countries using the gravity model with statistical methods. Total export*

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*performance with the specified countries is considered as the dependent variable in our gravity model. Independent variables include economic growth, national income differences, exchange rates, logistics performance index of partner countries and distances of countries' capitals to Ankara, the capital of Turkey. The econometric findings obtained as a result of this research confirm that the model will produce results consistent with the theoretical expectations of the Gravity model. While the increase in distance between countries negatively affects export income, the increase in total income of countries positively affects trade. Additionally, it was seen that logistics performance was also a determining factor in exports. The conclusion section provides a general evaluation of the findings and various policy recommendations to increase Turkey's trade volume.*

***Keywords:*** Turkey's Exports; Logistics Performance Index; Gravity Model; PPML Method

***JEL classification:*** F1, F4, F6, B4

## Introduction

The World Bank, IMF, and World Trade Organization, known as "Bretton Woods" organizations established under the dominating role and planning of the United States after World War II, have determined the standards of the global economy. In the following periods, with the collapse of the Socialist bloc and China's integration into these institutions of capitalism, the process of globalization encompassed strongly almost the entire world. Economic globalization occurs through the reduction of controls on goods, the free movement of capital, labor mobility, the spread of international entrepreneurship and the creation of various integration unions, such as Free Trade Zones, Special Economic Zones, and economic and monetary unions.

Economic integrations, in particular, caused a boom in world trade in the second half of the 20th century, surpassing the growth rate of global GDP many times over. Integration unions strive to facilitate the free movement of goods and services among member countries by reducing trade costs to the lower levels.

Since the 1970s, there has been a focus on studies regarding the economic determinants of foreign trade. This period, characterized by significant growth in world trade and increased competition because of the participation of developing countries in the international division of labor, has been modeled with an emphasis on cost reduction. Because of such models, differences in supply and demand among countries have become less significant, and growth, product differentiation, distances, exchange rates, and supply chains have emerged as key factors determining trade between countries.

In such a context, understanding the dynamics of international trade and the factors affecting its barriers, trade trends, and volumetric changes is an essential agenda for conducting economic policy. One of the most popular econometric models that

aims to identify these factors and can be derived from many trade theories is known as the gravity model of international trade. In recent decades, econometric tools for gravity modeling have been significantly enriched by the emergence of theoretically grounded modifications of the gravity equation.

Turkey's integration into global trade began in the 1980s and has continued at an increasing pace, and this process of trade liberalization has continued with the support of the liberalization of financial transactions implemented in 1989. The factors that shaped Turkey's foreign trade policies in the 1990s were its participation in the Uruguay Round Final Act, which established the World Trade Organization (WTO) in 1995, and the Customs Union (CU) Agreement, which was concluded and entered into force in 1996 and now registered Turkey's trade partnership with Europe. In the 2000s, foreign trade was shaped by growth strategies aimed at the competitive structure of the free market economy, implemented exchange rate policies, and developments in the world economy. Therefore, a detailed econometric analysis of the factors affecting Turkey's foreign trade, emphasizing growth, distance, logistics performance, exchange rates and income inequalities in the context of the gravity model, will be useful to understand whether the process from 1989 to the present has increased the foreign trade potential (Mangır, 2006).

The motivation of our study was the desire to make a specific evaluation, especially including the logistics performance index, using the gravity model, which allows measuring the factors affecting Turkey's foreign trade, whether economic or not, in the historical development. This study, which aims to measure the effect of the factors to be included in the gravity model by analyzing the data of the countries that stand out in Turkey's exports, was conducted with panel data on the relevant factors of 21 countries that are at the forefront of exports in seven periods determined between 2007-2023.

The 7 periods evaluated in our study consist of the years 2007, 2010, 2012, 2014, 2016, 2018, and 2023, when the Logistics Performance Index measure published by the World Bank and used to determine the difficulties and opportunities countries face in international trade and logistics activities was published. Some of the countries that have high trade with Turkey and are among the top 25 were excluded from the analysis due to the inability to access the factor variable data to be used in the model, and only 21 of them were included in the analysis.

In our study, to evaluate the effect of logistics performance on trade performance, the logistics index was added to the Gravity Model, and the study was made specific. Our analysis has proven that the Gravity model created to measure the factors affecting Turkey's exports is valid and robust. Empirical findings confirm that the model aligns with theoretical expectations, reinforcing the negative impact of distance on export performance and the positive effects of economic growth and logistics efficiency. These results highlight the increasing importance of logistics capabilities in sustaining and expanding Turkey's global trade competitiveness. The final section of this study

presents a summary of findings along with policy recommendations aimed at bolstering Turkey's trade volume and strengthening its economic position in global markets.

The structure of our study is as follows; the introduction section is followed by the second section, which includes the literature on the gravity model, the third section, which covers the data, methods and analysis results, and the final section, which presents the conclusions and recommendations.

## Literature review

The gravity model, a popular trade model in international economics, provides a theoretical foundation for estimating trade flow predictions. It primarily focuses on two key dependent variables: national income and the distance between countries. Over time, this model has been expanded to incorporate additional indicators, enhancing its functionality. It is now frequently used in empirical studies of trade policies employing methods such as Ordinary Least Squares (OLS), Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), Poisson Quasi Maximum Likelihood (PQML), Poisson Pseudo-Maximum Likelihood (PPML), Feasible Generalized Least Squares (FGLS), and Heckman two-step models, as summarized below.

Okubo (2004) utilized the gravity model to analyze the border effect in the Japanese market. The study employed data on goods traded within Japan from 1960 to 1990, analyzed using OLS. The model included GDP, distances, and trade volumes as explanatory variables. Export and import data from eight Japanese regions to 40 countries were incorporated. The results revealed that interregional trade significantly exceeded international trade in the earlier years of the analysis, but the border effect diminished over time. Interestingly, the study found the border effect in Japan to be lower than that observed in the United States and Canada.

Fidrmuc (2009) examined the challenges posed by non-stationary variables in gravity models used in trade analysis. He argued that traditional model specifications, which explain bilateral trade flows through the combined outputs of countries, introduce cross-sectional correlation. Referring to Pesaran (2007), Fidrmuc highlighted that standard panel unit root tests are biased and recommended the use of cross-sectionally augmented panel unit root tests for gravity models with small time-series dimensions and large cross-sections. He concluded that the variables used in these models are typically integrated of the first degree. This property supports the use of panel cointegration techniques, such as FMOLS and DOLS, which provide consistent results. Fidrmuc also found that FMOLS and DOLS estimates closely align with those of fixed-effects models, thereby minimizing potential biases.

Siliverstovs and Schumacher (2009) compared the traditional OLS estimator applied to the log-linear form of the gravity model with the PQML estimation technique

proposed by Santos Silva and Tenreyro (2006) for the nonlinear multiplicative specification. Their study analyzed annual trade flows of level-3 manufacturing goods in OECD countries from 1988 to 1990. GDP values served as explanatory variables, alongside factors like educational attainment, secondary school enrollment, and GDP per capita. Additional variables included distances, economic center proximity, preferential trade agreements, shared borders, common language, and historical ties. The findings revealed no significant differences in exporter and importer income elasticities, distance elasticity, or the impact of preferential trade agreements and shared languages between OLS and PQML. However, PQML better captured the trade-promoting effects of shared borders and historical ties. Regression misspecification tests provided further support for PQML over OLS.

Dorakh (2020) conducted a scientific analysis using the gravity model with data from 6 host and 33 source countries representing more than 70% of the world investment during the period 1991-2017 to examine the patterns of foreign direct investment (FDI) across the EU, identify the investment determinants and estimate whether EU membership encourages FDI to accession countries. In the study, a series of OLS and PPML models were empirically constructed to account for all country-time-specific and country-pair factors. The FDI gravity model was estimated with the traditional estimator OLS. Panel data analysis, which has the advantage of reducing heterogeneity across countries, was used. According to the results, FDI was found to be positively correlated with GDP and negatively correlated with distance and investment disputes. It was also understood that richer countries are more attractive for FDI but require greater expenditure and logistics costs.

Sy et al. (2020) applied an augmented gravity model to evaluate the impact of logistics performance on trade in the ASEAN region, focusing on priority commodity sectors such as agriculture, fisheries, textiles, and electronics. Using data from the World Bank's Logistics Performance Index (LPI), bilateral trade statistics, and various economic indicators from 2007 to 2016, the study employed methods including OLS, fixed effects (FE), random effects (RE), robust RE, FGLS, PPML, and Heckman two-step models. The results demonstrated that logistics performance positively affects total trade and sector-specific trade, highlighting its critical role in enhancing regional and sectoral trade flows.

## Research methodology

In this section, first, brief literature about the gravity model used in the analysis within the scope of our study, the data set information used in the analysis, and the gravity equation are given in an explanatory manner. Then, the findings are given with a discussion of the methods used as estimators in the model.

*Gravity Model*

The gravity trade model, initially developed by Tinbergen (1962) and Pöyhönen (1963), remains one of the most widely used econometric tools for providing empirical evidence on the fundamental determinants of trade flows between countries. Later, Bergstrand (1985, 1989) introduced a general equilibrium framework to establish theoretical foundations for bilateral trade based on the gravity model. Furthermore, Helpman and Krugman (1985) enhanced the model by incorporating product heterogeneity and increasing returns to scale. Otsuki et al. (2000) applied the gravity model to explore the effects of standards and barriers on international trade. Anderson and Wincoop (2003), as well as Martínez-Zarzoso and Suárez-Burguet (2000), developed theoretical extensions of the gravity equation to account for supply-side factors and the direction of trade flows between countries.

*Data and Equation*

The basic gravity model posits that a country's GDP positively impacts its exports, while the distance between trading partners exerts a negative influence. In our study, we utilize official data to examine macroeconomic determinants, including total trade, Türkiye's GDP, GDP differences with trading partner countries, geographical distance, currency exchange rates, and logistics performance. The dataset comprises 21 countries, accounting for approximately 60% of Türkiye's export market, spanning seven distinct periods between 2007 and 2023. Table 1 provides a detailed description of the variables and their sources.

Table 1: Description of variables used in the gravity equation

| Variables | Definition | Data Source |
|---|---|---|
| **Export (EX)** | Total exports from Türkiye to trading partner country i in million US$ at time t | TFTS (2024). Türkiye Statistics of Foreign Trade Values, https://data.tuik.gov.tr/Bulten/Index?p=Dis-Ticaret-Istatistikleri-Nisan-2024-53528 |
| **GDP (Y)** | The GDP-Gross Domestic Product of trading partner country i in million US$ at time | World Bank-WB (2024). Country Data, and OECD Data Files, https://data.worldbank.org/indicator/ NY.GDP.MKTP.CD |
| ***Linder* Effect (LE)** | The difference between GDP of Türkiye and country I | World Bank-WB (2024). Country Data, and OECD Data Files, https://data.worldbank.org/indicator/ NY.GDP.MKTP.CD |
| **Distance (lD)** | Geographical distance from from Türkiye's capital city Ankara and importing country *j* capital city. | Distance of Countries. www.mapcrow.info |
| **Currency (C)** | The nominal exchange rate | The Central Bank of the Republic of Türkiye (2024). Indicative Exchange Rates, https://www.tcmb.gov.tr/wps/wcm/connect / TR/TCMB+TR/Main+Menu/Istatistikler /Doviz+Kurlari/ Gosterge+Niteligindeki+ Merkez+Bankasi+Kurlarii/ |
| **Logistic Performance Index(LPI)** | The LPI score | World Bank (2024). Full LPI Dataset: 2007, 2010, 2012, 2014, 2016, 2018, 2023, https://lpi.worldbank.org/report |

Source: Authors

The gravity model equation, as defined in Morland et al. (2020:3), provides the following framework for estimating structural relationships:

$$EX_{ijt} = \frac{GDP_{it}\, GDP_{jt}}{Distance_{ijt}} (Costs_{ijt})\, \varepsilon_{ijt} \quad (1)$$

Factors in equation;
$EX_{ijt}$ = *The exports flows from country* i *to country* j *in year* t,
$GDP_{it}$ = *nominal GDP for exporting county i in year t,*
$GDP_{jt}$ = *nominal GDP for importing country j in year t,*
$Distance_{ijt}$ = *geodesic distance between representative cities of countries i and j, and*
$Costs_{ijt}$ = *cost to trade from country i to country j in year t.*
$\varepsilon_{ijt}$ = *idiosyncratic error term specific to trade from country i to country j in time year*
*In the gravity model equation used for Türkiye's export variable,* i *represents Türkiye,* j *represents the counterpart country with which trade is made, and* t *represents time.*

To provide econometric evidence on determinants of exports based on the Poisson Pseudo Maximum Likelihood (PPML) method, we estimate the following model to assess the effects of the logistic performance index on trade flows.

We perform a PPML estimator to estimate the following gravity equation:

$$ln(EX_{ijt}) = ln(GDP_{it}) + ln(GDP_{jt}) + ln(Lin_{ijt}) + ln(Distance_{ijt}) + ln(C_{ijt}) + ln(LP_{ijt}) + ln(\varepsilon_{ijt}) \quad (2)$$

*Criticisms of OLS and Advantages of PPML*

OLS estimation, commonly used in previous gravity model studies, has been criticized for several limitations, including logarithmic transformation issues, failure to satisfy the homoscedasticity assumption, and biases caused by zero trade flows (Shepherd, 2013:28; Burger et al., 2009:6).

For these reason, this paper considers the Poisson type of the estimation model developed by Santos Silva and Tenreyro (2006) to provide an alternative view of the OLS specification of the gravity model of trade.

One of the important benefits of applying the PPML estimator to the gravity model is that it addresses and resolves the problem of non-flow trade due to not all countries trading with every country and also deals with heteroskedasticity in the series (Mulabdic and Yasar, 2021:4). This feature of the PPML estimator makes it a reliable method that helps avoid the potential bias and inconsistency of OLS estimators.

*Findings*

In our paper, we present the descriptive statistics of the panel data estimations (mean, standard deviation, min and max. statistics). Panel A of Table 2 presents the summary statistics (mean value and standard deviation) of exports, gross domestic product (GDP current US$), GDP difference, LPI, distance, and currency.

Panel B presents the Pearson correlation coefficients in pairs between the variables used in the main regressions. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Among the controlled variables in the model, GDP (0.577), LPI (0.5346), GDP difference (0.4297), Distance (0.059330), and Currency (0.352117) is positively and significantly ($p < 0.01$) correlated with the explained variable (export) respectively. The finding confirms the premise that larger countries tend to trade more. Conversely, there is a moderately negative correlation between trade and distance, meaning that the larger the country, the less trade is done with larger pairs. Nevertheless, the finding is consistent with the basic intuition of the surrogate model.

Table 2: The Summary and Correlation statistics of the panel data estimations

| **Panel A. Summary Statistics** | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Obs** | **Mean** | **Std. Dev** | **Min** | **Max** |
| **Exports** | 147 | 9.564381 | 0.295166 | 8.955545 | 10.32383 |
| **GDP** | 147 | 11.86135 | 0.628345 | 10.659747 | 13.33798 |
| **GDP differences** | 147 | 13.28160 | 0. 0.085502 | 13.19651 | 13.62574 |
| **Distance** | 147 | 3149.061 | 1779.446 | 925 | 8162 |
| **Currency** | 147 | 6.019435 | 8.037845 | 1.307790 | 30.04629 |
| **Overall LPI** | 147 | 3.600000 | 0.525365 | 2.06338 | 4.225967 |
| **Panel B. Pearson Correlation Coefficients** | | | | | |
| **Correlation Probability** | | | **Exports** | | |
| **Exports** | | | 1.000000 | | |
| **GDP** | | | 0.577162*** | | |
| **GDP differences** | | | 0.429769*** | | |
| **Distance** | | | 0.059330* | | |
| **Currency** | | | 0.352117*** | | |
| **OverallLP** | | | 0.534641*** | | |

Source: Authors

Table 3 presents the results of the PPML estimated gravity model. The p-values of the heteroscedasticity-robust Ramsey (1969) RESET test reveal that the data set shape of the regression is appropriate.

Table 3: PPML Test Results

| Dependent Variable: Exports / Independent Variables | PPML | P-value |
|---|---|---|
| **GDP** | 1.277019 | 0.0000 |
| **GDP Differences** | -4.721051 | 0.0000 |
| **Currency** | 0.040183 | 0.0000 |
| **Distance** | -0.000110 | 0.0000 |
| **Overall LPI Score** | 0.124572 | 0.0000 |
| **Reset Test** | | 0.05 |
| **Observation Numbers** | 147 | |

Source: Authors

According to PPML estimation results, factors that significantly affect Turkey's exports include the GDPs, currencies, and general LPI scores of partner countries. When importers' income increases, they tend to purchase more export goods. The statistic reached here is: "If there is a 1% increase in the GDP of the importing country, Turkey's exports increase by approximately 1.2%."

In addition, the results were determined to support the Linder effect (similarity in preferences argument) in Turkey's bilateral trade with 21 major trading partners. In addition, the importance of foreign demand in Turkey's manufacturing exports is seen. Therefore, from a policy perspective, exporters are advised to develop Turkish-origin products by examining consumer behavior in European Union countries and adapting them according to tastes and preferences.

The coefficient on currency and logistic performance is also statistically significant and affects exports of Türkiye positively. 0.124572% estimation provides evidence that inefficiencies within the transportation infrastructure can have adverse effects on exports.

A depreciation of the foreign exchange rate makes Türkiye's exports more competitive but raises the cost of importing goods into Türkiye. This economic theory expectation is proven by our empirical results that a 1% currency depreciation increases the exports of Türkiye by 0.040183%.

On the other hand, the distance coefficient is negative and significant at the 1% level. Therefore, a 1% increase in the distance between Turkey and the country it trades with reduces exports by approximately 0.000110%. In addition, the distance between the sampled partner countries, which is an indicator of transportation costs, negatively affects Turkey's exports.

According to these results, it is found that the export volume of Türkiye is positively associated with the country's economic size, as expected from assumptions of the Gravity model. Additionally, the distance between Türkiye and other countries shows a negative association, as expected. Furthermore, the coefficients found are statistically significant.

## Conclusion and policy implications

To provide evidence about the general economic determinants of the export trade, it is necessary to check the validity of trade theories that allow for designing macroeconomic policies. For this reason, this paper employs the Gravity Model, initiated by Tinbergen (1962) and Pöyhönen (1963), and then extended by Krugman's new trade theories, many studies have focused on the determining power of income size and distance of trade partners on export performance.

In our study, the Gravity Model is specifically applied with the addition of a logistics index to assess the impact of countries' logistics performance on their trade. The analysis focuses on the top 21 countries with which Turkiye conducted the most trade between 2007 and 2023. Our aim was to determine and model the factors affecting Turkey's foreign trade. Variables such as exports, nominal GDP, the Linder effect, distance, exchange rates, and logistics performance are analyzed to understand their influence on trade.

The results of the panel regression analysis show a coefficient value of 0.70 and an F-statistic significance at 0.05% level, indicating high statistical consistency and significance. The Gravity model constructed to determine the impact of variables on Turkey's foreign trade is proven to be valid and robust.

Based on the empirical findings of the Gravity Model study, the following policy recommendations can be summarized:

1. Results support the importance of income size and Linder effect, meaning that Türkiye trading partners' income growth has boosted their demand for Türkiye products. Türkiye should focus on expanding trade relations beyond traditional partners by targeting high-growth markets in Africa, Southeast Asia, and Latin America. This would reduce dependency on a limited number of economies and enhance resilience against economic shocks.
2. A 1% increase in the exchange rate increases exports by 0.040183, which means that as long as the Turkish Lira remains strong, imports will start, production capacity will decrease and the economy will shrink. Maintaining a stable exchange rate is crucial for sustaining export competitiveness while mitigating inflationary pressures. Policymakers should implement measures that prevent excessive currency fluctuations to ensure a conducive trade environment.
3. According to the research results, logistics performance positively affects export performance and being at the top of the LPI index can be seen as one of the basic success factors in increasing trade volume. While other studies in the literature also support this information, it is understood that logistics performance criterion components contribute to a positive concentration in international trade. In this direction, improving logistics performance components, namely logistics services, is of great importance. The effect of improving logistics elements will lead to a direct decrease in costs, the removal of obstacles, the provision of speed and

flexibility, and, as a result, an increase in bilateral trade. Investments in logistics, including transportation networks, supply chain efficiency, and digitalization, are essential to improving trade competitiveness. Strengthening Turkey's position in the Logistics Performance Index can significantly lower trade costs and increase export volumes.

4. As expected, the empirical results support the gravity model assumptions that the distance between Turkey and other countries has a negative relationship. This is partly due to transportation costs: sending a package from Turkey to Germany is half as expensive as sending a package to India. Therefore, Turkey's trade will outpace that of both because its own economy will expand faster and because its neighbors will grow faster than those in their own backyards.
5. Finally, Streamlining customs procedures and reducing bureaucratic obstacles will enhance Turkey's integration into global trade networks. Facilitating smoother cross-border trade will enable businesses to operate more efficiently and expand their international reach.

In conclusion, by implementing these strategic policies, Türkiye can strengthen its trade performance, sustain economic growth, and remain a competitive player in the global marketplace. Further research should explore the role of digital trade facilitation and emerging markets in shaping Türkiye's future trade trajectory.

## Declarations

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*Conflicts of interest/Competing interests*

There is no conflict of interest/Competing interests

*Availability of data and material*

The data that support the findings of this study are openly available in the website of World Bank (www.worldbank.org).

*Code Availability*

The computer program results are shared through the tables in the manuscript.

*Authors' Contributions*

**Metehan Ortakarpuz:** Investigation, Conceptualization, Data Collection Writing, Review and Editing.
**Fatih Mangır:** Investigation, Methodology, Conceptualization, Writing, Review.

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