PressAcademia
www.pressacademia.org/journals/jbef
JBEF
ISSN 2146-7943
Journal of Business, Economics and Finance YEAR 2026 VOLUME 15 ISSUE 1

REVISITING THE DISTANCE PUZZLE: STRUCTURAL GRAVITY EVIDENCE FROM TURKIYE

DOI: 10.17261/Pressacademia.2026.2033
JBEF- V.15-ISS.1-2026(5)-p.48-64

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Date Received: January 15, 2026 **Date Accepted:** March 14, 2026

To cite this document
Baykal, T. O., (2026). Revising the distance puzzle: structural gravity evidence from Turkiye. Journal of Business, Economics and Finance (JBEF), 15(1), 48-64.
Permanent link to this document: http://doi.org/10.17261/Pressacademia.2026.2033

ABSTRACT

Purpose-This paper re-examines the "distance puzzle" for Türkiye's bilateral exports and assesses whether large, stable distance elasticities primarily reflect estimation choices or persistent trade frictions in an emerging-market setting.
Methodology-Using CEPII benchmark-year data for 1996–2020, the study estimates three nested gravity specifications: (i) conventional log-linear OLS, (ii) PPML in levels, and (iii) an extended PPML model incorporating domestic trade flows and Türkiye–year effects to account for multilateral resistance and home bias. Institutional and macro-financial frictions are proxied by partner political stability and USD–TRY exchange-rate volatility.
Findings-OLS reproduces large and stable distance coefficients averaging –1.70, exceeding meta-analytic benchmarks by 70–90 percent. Once heteroskedasticity, zero-flow structure, and home bias are addressed through structural estimation, the average distance elasticity declines to –0.58—a reduction of approximately 65 percent. Political stability loses significance under structural controls, while exchange-rate volatility becomes precisely estimated and positive, indicating intensive-margin concentration during volatile periods rather than extensive-margin expansion.
Conclusion- The results support the interpretation that the distance puzzle is primarily an estimation artifact in emerging-market contexts. Distance remains economically significant as a composite trade-cost proxy bundling geographic, informational, and financial frictions. For policymakers, the findings suggest that trade diversification strategies should address not only physical connectivity but also currency risk management and relationship-building costs that elevate effective distance for emerging-market exporters.

Keywords: Structural gravity, PPML, distance puzzle, home bias
JEL Codes: F14, F50, C23

1. INTRODUCTION

The gravity model is one of the most reliable empirical frameworks in international economics. Its core insight is that bilateral trade rises with economic size and falls with geographical distance, and this pattern has been confirmed across countries, sectors and time periods. Yet a persistent empirical puzzle remains. Despite major improvements in transportation, logistics and communication technologies, the estimated effect of distance on trade has remained remarkably stable. Meta-analyses show that a doubling of distance still reduces trade by nearly the same magnitude as it did several decades ago (Disdier and Head 2008). This "distance puzzle" challenges the view that distance primarily reflects physical shipping costs.

A large body of research argues that distance captures a wider set of frictions. Anderson and van Wincoop (2003) demonstrated that bilateral trade depends on relative trade costs, which are summarized by multilateral resistance. When these terms are omitted, log-linear OLS estimates systematically overstate the contribution of distance. Methodological advances have reinforced this conclusion. PPML estimation corrects for heteroskedasticity and retains zero flows, and including domestic trade flows adjusts for home bias. Under these structural estimators, distance elasticities generally fall to more moderate values. Other studies highlight that distance bundles informational barriers, institutional similarity and macro-financial risk, making it a composite rather than a purely geographic measure.

Despite these insights, most empirical evidence focuses on advanced economies. Much less is known about how distance operates in emerging markets, where institutional quality, macro-financial volatility and regional integration differ markedly from high-income settings. This omission matters. In environments characterized by political uncertainty, exchange-rate instability and heterogeneous partner groups, distance is likely to interact with risk and institutional proximity in ways that standard gravity models do not fully capture.

This paper addresses this gap by re-examining the distance puzzle from the perspective of Türkiye. Türkiye provides a useful case for three reasons. First, it lies at a geographic and institutional intersection, with deep integration into the European

Union and weaker ties with more distant regions. Second, its macro-financial environment has experienced repeated episodes of volatility, particularly in the exchange rate, which may amplify or reshape the effect of distance. Third, its export structure is highly concentrated in nearby and institutionally familiar markets, with relatively weak engagement in distant destinations.

Using bilateral export data from 1996 to 2020, the paper estimates three versions of the structural gravity model: a traditional log-linear OLS benchmark, PPML in levels and an extended PPML specification that incorporates domestic trade flows and exporter fixed effects. This sequential approach allows the evolution of the distance coefficient to be traced as key methodological issues are addressed, including heteroskedasticity, multilateral resistance and home bias. The analysis also includes two sources of institutional and macro-financial risk, political stability and exchange-rate volatility, to assess whether residual distance effects reflect deeper institutional or financial frictions.

The motivation for this paper originates from an earlier empirical study by the author (Baykal, 2026), which used standard gravity specifications and revealed a puzzling increase in Türkiye's estimated distance coefficients over time—despite rising globalization and improvements in transport technology. As shown in Table 1, both OLS and PPML models yielded unexpectedly low or even positive distance elasticities in some cases. These findings raised two critical questions: (1) whether distance in the Turkish context proxies broader frictions beyond geography, and (2) whether previous results were driven by omitted structural components such as multilateral resistance or home bias. The present paper builds directly on these results and provides a structurally grounded reassessment of the "distance puzzle" using refined estimation strategies and additional institutional controls. Table 1 summarizes the earlier findings that prompted this re-investigation.

Table 1: Motivation from Earlier Study *(Genç and Baykal, 2026)*

	OLS		PPML	
	(1)	(2)	(3)	(4)
Log distance	-0.127***	-0.005	-0.011	0.032
	(0.019)	(0.018)	(0.030)	(0.028)
FX volatility	-0.608***	-0.674***	-0.225***	-0.297***
	(0.014)	(0.013)	(0.018)	(0.030)
Political stability	0.047***	0.082***	0.081***	0.106**
	(0.013)	(0.046)	(0.021)	(0.036)
Log output	0.938***	0.956***	0.890***	0.906***
	(0.005)	(0.004)	(0.011)	(0.011)
Log expenditure	0.921***	0.907***	0.915***	0.903***
	(0.006)	(0.008)	(0.011)	(0.011)
Exporter remoteness index		-0.136***		-0.059***
		(0.002)		(0.008)
Importer remoteness index		-0.097***		-0.040***
		(0.003)		(0.005)
Constant	-10.056***	-6.775***	-10.527***	-9.055***
	(0.210)	(0.164)	(0.324)	(0.447)
Sample size	2071	2071	2071	2071
R^2	0.98	0.98	0.97	0.97

The paper makes three contributions. First, it provides a systematic assessment of the distance puzzle in an emerging-market context and shows that the puzzle becomes much weaker once structurally consistent estimators are used. Second, it demonstrates that institutional and macro-financial conditions help explain part of what naive models attribute to distance, with exchange-rate volatility becoming significant under structural estimation. Third, it complements the econometric results with graphical evidence, showing how institutional proximity and macro-financial risk shape Türkiye's export geography. For policymakers, the findings clarify whether distance primarily reflects physical trade costs or deeper financial and institutional frictions.

The remainder of the paper is organized as follows: Section 2 reviews the literature, Section 3 presents the data, Section 4 outlines the methodology, Section 5 reports the results and graphical evidence, and Section 6 concludes.

2. LITERATURE REVIEW

The gravity model has established itself as the workhorse of empirical international trade research, consistently demonstrating that bilateral trade flows increase with economic size and decrease with geographic distance (Tinbergen, 1962; Anderson, 1979). Yet this empirical success has generated one of the field's most enduring puzzles: despite dramatic technological advances in transportation, communication, and logistics over the past half-century, the estimated elasticity of trade with respect to distance has shown remarkably little tendency to decline and, in some contexts, has even increased (Disdier and Head, 2008; Head and Mayer, 2014). This "distance puzzle" presents a fundamental challenge to the view that globalization has substantially reduced the friction of geographic separation and has motivated extensive research examining whether distance remains a binding constraint on trade or whether conventional estimation methods systematically overstate its importance (Buch et al., 2004; Lin and Sim, 2012).

This literature review synthesizes research on three interconnected questions that frame the empirical analysis. First, how large are distance effects in international trade, and have they declined over time as transportation and communication technologies improved? Second, to what extent do methodological choices, particularly the treatment of heteroskedasticity, zero flows, and multilateral resistance, influence estimated distance elasticities? Third, what explains the observed distance sensitivity beyond physical shipping costs, and how do these composite frictions operate in contexts characterized by institutional weakness and macro-financial volatility? The review demonstrates that the distance puzzle is neither universal nor purely methodological but reflects genuine friction persistence that varies systematically across development stages and institutional environments, providing direct motivation for a country-specific reassessment using structural gravity methods (Carrère et al., 2013; Yotov, 2022).

2.1. The Empirical Persistence of Distance Effects

The systematic documentation of distance persistence begins with Disdier and Head (2008), whose meta-analysis of 1,467 distance elasticities drawn from 103 papers represents the foundational empirical statement of the puzzle. Across studies spanning multiple decades, estimation methods, and country samples, they find no statistically significant downward trend in the distance coefficient since the 1960s. The average elasticity hovers around minus one, implying that a doubling of distance reduces bilateral trade by approximately 50 percent, and this magnitude appears remarkably stable despite the container revolution, the internet, and broader forces of globalization (Hummels, 2007). Their meta-regression controls for differences in sample composition, data quality, and econometric specification, yet the puzzle persists across virtually all contexts examined (Disdier and Head, 2008). This finding challenges the "death of distance" hypothesis advanced by some observers of technological change (Cairncross, 1997) and suggests that geographic separation continues to impose substantial economic costs.

Head and Mayer (2013, 2014) extend this analysis through comprehensive synthesis examining sources of resistance to globalization. Their meta-analysis of 1,835 distance elasticity estimates reveals a median coefficient of minus 0.89, meaning that a 10 percent increase in distance reduces trade by approximately 8.9 percent (Head and Mayer, 2014). Critically, they demonstrate that borders and distance impede trade by much more than tariffs or transport costs can explain, crystallizing the puzzle as the gap between observed distance sensitivity and what measurable trade costs would predict (Anderson and van Wincoop, 2004). They show that commercial services and foreign direct investment exhibit distance sensitivities similar to goods trade, while financial assets display somewhat smaller but still substantial distance effects, suggesting the puzzle extends beyond physical goods to encompass most forms of cross-border economic activity (Portes and Rey, 2005; Head and Mayer, 2013).

Anderson (2000) poses the question directly in "Why Do Nations Trade (So Little)?" examining the border effect between the United States and Canada. His analysis reveals that distance effects are "surprisingly large" and contribute 20.4 percent to average price volatility between these markets, far exceeding what shipping costs alone would justify (Anderson, 2000). This finding is particularly striking because trade between the United States and Canada occurs across a largely unobstructed border between two high-income countries with deep institutional similarities (McCallum, 1995), suggesting that if distance effects are this large in favorable circumstances, they are likely even more substantial in less integrated contexts (Anderson and Marcouiller, 2002). The persistence of large border effects despite NAFTA and subsequent trade liberalization reinforces the interpretation that distance proxies frictions beyond tariffs and transport costs (Agnosteva et al., 2019).

Importantly, subsequent research reveals that the distance puzzle is not universal but exhibits pronounced heterogeneity by income level. Carrère, de Melo, and Wilson (2009, 2010, 2013) demonstrate through comprehensive panel analysis covering 124 countries from 1970 to 2006 that the puzzle is fundamentally a developing country phenomenon. For low-income countries, defined as the bottom third of the global income distribution, distance elasticities increased by 15 to 18 percent over this period (Carrère et al., 2013). In stark contrast, high-income countries exhibited no distance puzzle: their distance coefficients remained stable or showed modest declines, consistent with the hypothesis that technological change reduces geographic frictions for advanced economies but not for countries with weak institutions and infrastructure deficits (Limão and Venables, 2001; Carrère et al., 2010).

Recent empirical work increasingly interprets the distance puzzle as a measurement and modeling artifact rather than a genuine structural phenomenon. Duan et al. (2022) demonstrate using WIOD data that global value chains explain much of the puzzle: intermediate-goods trade across borders raises the distance elasticity of gross trade relative to value-added trade, and once GVC effects are controlled for, the elasticity diminishes over time. Similarly, Rezitis et al. (2025) find that distance effects in global coffee trade are initially stable but then decline, especially after 2015, contradicting a persistent puzzle in this commodity market. Kondaridze et al. (2025) show that separating intra-national from international distance improves model fit in dairy trade and reduces puzzle-type findings, suggesting that conflating domestic and international distances can distort the distance coefficient.

This income-based stratification fundamentally reshapes interpretation of the puzzle. Advanced economies have partially overcome distance barriers through infrastructure investment, institutional development, and information network deepening (Nordås and Piermartini, 2004), while developing countries face rising effective distance as they attempt to integrate into global markets from positions of institutional weakness (Rodrik, 1999; Carrère et al., 2009). Head and Mayer (2013) confirm this heterogeneity, finding that distance effects are rising most for new and low-trading countries while remaining stable for established high-trading nations. This development margin effect implies that entering global markets from limited prior integration confronts countries with steeper distance gradients than would be faced by countries with established trade positions (Chaney, 2014), suggesting that first-mover advantages and network effects play important roles in shaping trade geography (Rauch, 1999; Rauch and Trindade, 2002).

2.2. Methodological Corrections and Structural Gravity

A substantial body of research argues that part of the observed distance persistence reflects econometric misspecification rather than genuine structural frictions. The theoretical foundation is Anderson and van Wincoop (2003), who formalize the concept of multilateral resistance within a structural general equilibrium framework. Their key insight is that bilateral trade depends not on absolute bilateral costs but on bilateral costs relative to a country's average trade costs with all partners (Anderson and van Wincoop, 2003). When multilateral resistance terms are omitted, the distance coefficient absorbs both direct bilateral effects and indirect general equilibrium adjustments, generating upward bias (Feenstra, 2004). This insight has profound implications for gravity estimation: coefficients estimated without proper controls for multilateral resistance confound bilateral frictions with general equilibrium price adjustments, systematically overstating the role of distance (Baldwin and Taglioni, 2006).

Baldwin and Taglioni (2006) catalog common errors in gravity estimation, emphasizing that failure to account for multilateral resistance can severely bias trade-cost estimates. They identify the "gold medal mistake" of omitting multilateral resistance terms, the "silver medal mistake" of using inappropriate deflators, and the "bronze medal mistake" of ignoring time-varying unobservables through improper panel specifications (Baldwin and Taglioni, 2006). Their practical guidance, which has shaped subsequent empirical practice, recommends using exporter-time and importer-time fixed effects to absorb multilateral resistance non-parametrically (Feenstra, 2016), though they acknowledge this approach sacrifices the ability to identify time-invariant bilateral characteristics and country-specific institutional variables.

The methodological critique extends beyond multilateral resistance to the treatment of heteroskedasticity and zero trade flows. Santos Silva and Tenreyro (2006) demonstrate that log-linearization of the multiplicative gravity equation introduces Jensen's inequality bias under heteroskedasticity, and that conventional OLS on log-transformed flows yields inconsistent estimates when the variance of trade flows is proportional to the conditional mean squared, a pattern endemic to trade data (Santos Silva and Tenreyro, 2006). Their proposed solution, Poisson pseudo-maximum likelihood (PPML) estimation in levels, has become standard practice in structural gravity applications (Head and Mayer, 2014; Yotov et al., 2016). PPML naturally accommodates zero trade flows without ad hoc exclusion or imputation (Helpman et al., 2008), and comparative exercises demonstrate that it typically yields distance elasticities 20 to 40 percent smaller in absolute magnitude than log-linear OLS (Fally, 2015; Santos Silva and Tenreyro, 2006).

Recent methodological advances have further refined structural gravity estimation. Freeman et al. (2025) introduce a two-stage PPML procedure that recovers country-specific effects and trade elasticities without requiring price or tariff data, applicable at both sectoral and aggregate levels including services trade. Larch et al. (2025) codify best-practice recommendations for gravity estimation, emphasizing PPML with domestic flows and rich fixed effects as the benchmark structural setup. Pfaffermayr (2020) demonstrates that constrained PPML, imposing Anderson–van Wincoop equilibrium conditions, delivers nearly correct standard errors and coverage rates, whereas unconstrained PPML standard errors are severely downward biased. These developments reinforce the importance of structural consistency in gravity applications.

Helpman, Melitz, and Rubinstein (2008) develop a two-stage estimator explicitly modeling firm selection into exporting, showing that ignoring selection biases trade-cost estimates upward. Their framework recognizes that only sufficiently productive firms can profitably overcome the fixed costs of entering distant markets (Melitz, 2003), and failure to account for this extensive margin generates upward bias in estimated distance elasticities (Helpman et al., 2008). This selection mechanism is particularly important in contexts with high entry barriers or weak institutions, where only the most productive firms engage in international trade (Bernard et al., 2007; Manova, 2013).

Yotov (2012, 2022) proposes an additional refinement: combining PPML estimation with explicit inclusion of domestic trade flows. His argument is that traditional gravity specifications compare international trade to an implicit counterfactual of frictionless trade, when the appropriate comparison is to observed domestic trade (Yotov, 2012). Including domestic flows provides the natural benchmark for quantifying international frictions, effectively measuring distance effects relative to home bias rather than relative to an unobserved zero-friction baseline (Ramondo et al., 2016). When distance is measured relative to domestic trade and modern estimators are employed, the distance effect exhibits a clearer downward trend (Yotov, 2022). This approach has been formalized by Yotov, Piermartini, Monteiro, and Larch (2016) in their WTO-UNCTAD guide, which has become the standard reference for structural gravity implementation and explicitly recommends the combination of PPML estimation, domestic trade inclusion, and theory-consistent fixed effects (Yotov et al., 2016; Larch et al., 2019).

However, even after applying these corrections, distance effects remain economically significant, indicating that methodological refinement resolves only part of the puzzle. Baier, Kerr, and Yotov (2017, 2018) consolidate best practices while acknowledging that modern structural gravity specifications still yield substantial distance coefficients, suggesting genuine trade frictions persist beyond estimation artifacts. Larch, Yotov, and Zylkin (2022) provide comprehensive robustness checks confirming that proper attention to zeros, selection, and multilateral resistance consistently attenuates the distance coefficient relative to naive specifications, yet some puzzle remains, particularly for developing countries. This residual effect motivates investigation of what distance actually proxies beyond physical geography (Brei and von Peter, 2017).

2.3. Distance as a Composite Friction: Informational, Institutional, and Macro-Financial Channels

Parallel to the econometric literature, theoretical and empirical work argues that distance bundles multiple dimensions of trade frictions beyond physical shipping costs. This perspective suggests that stability or increase of distance elasticities may reflect persistence of non-physical barriers even as transportation costs decline (Grossman, 1998).

Chaney (2008, 2014) develops a heterogeneous-firm model where distance affects both extensive margin (market entry) and intensive margin (trade volume per relationship). When firm productivity follows a Pareto distribution and trade costs include both fixed and variable components, the aggregate distance elasticity can remain approximately constant over wide distance ranges even as individual cost components change (Chaney, 2008). This occurs because the composition of trading firms adjusts endogenously: as variable trade costs fall, lower-productivity firms enter distant markets, but these marginal entrants trade smaller volumes, leaving the aggregate elasticity relatively stable (Chaney, 2014). This firm-selection mechanism implies that observed distance persistence may partly reflect compositional shifts in who trades rather than increases in bilateral frictions per se (Eaton et al., 2011).

Head and Mayer (2013, 2014) provide extensive documentation of non-traditional channels through which distance affects trade. Cultural differences and information asymmetries decline systematically with distance, affecting familiarity and trust between trading partners (Guiso et al., 2009). Historical factors, particularly past conflicts, colonial legacies, and migration patterns, shape current trade networks in ways correlated with geographic proximity (Head et al., 2010). Language barriers impose communication costs that remain substantial despite digital technologies (Melitz, 2008; Ku and Zussman, 2010). Trust and relationship effects decline with both distance and borders, affecting willingness to engage in credit-intensive trade and long-term contracts (Guiso et al., 2009). Network effects through business relationships create path dependence in trade geography, as initial trading relationships facilitate subsequent connections through information spillovers and reputation mechanisms (Rauch and Trindade, 2002; Combes et al., 2005).

Anderson and Marcouiller (2002) demonstrate empirically that insecurity and weak institutions depress trade in ways that interact with distance. For countries with weak contract enforcement, distance sensitivity is amplified because monitoring costs, information asymmetries, and opportunism risks all increase with geographic separation (Anderson and Marcouiller, 2002). This suggests institutional quality and distance are complements in determining trade costs: weak institutions impose larger penalties when partners are remote (Nunn, 2007). Wei (2000) shows that corruption acts as a hidden tax on trade comparable to formal tariffs, and this corruption tax likely increases with distance as monitoring becomes more difficult. Francois and Manchin (2013) provide complementary evidence that infrastructure quality and institutional development are critical determinants of export performance, particularly for developing countries attempting to integrate into global markets.

For contexts characterized by macro-financial volatility, an understudied dimension of composite distance frictions involves exchange rate uncertainty. Berman, Martin, and Mayer (2012) provide foundational evidence that exchange rate movements affect exporter pricing and market entry decisions heterogeneously across firms and destinations. Firms serving distant markets must make larger upfront investments in relationship building, distribution networks, and product adaptation, raising the option value of delaying entry during periods of exchange rate uncertainty (Dixit, 1989; Berman et al., 2012). Gopinath, Itskhoki, and Rigobon (2020) show that currency invoicing and pass-through vary systematically with trade costs, implying exchange rate volatility may interact with distance in shaping bilateral trade patterns. When trade relationships are denominated in third-party currencies, exchange rate fluctuations introduce additional risk that may deter entry into distant markets or reduce trade intensity among established relationships (Gopinath et al., 2020).

Political instability and institutional uncertainty raise transaction costs and reduce the predictability of trade relationships. Nicita and Olarreaga (2007) document how political risk affects trade flows, showing that governance indicators systematically predict bilateral trade patterns even after controlling for standard gravity variables. Country-specific studies reinforce these mechanisms: Aysan, Disli, and Ng (2017) analyze political risk and export performance for Türkiye, documenting significant effects of instability on bilateral patterns, while broader cross-country evidence confirms that institutional quality shapes trade geography through multiple channels, including contract enforcement, regulatory predictability, and property rights protection (Levchenko, 2007; Nunn, 2007).

The role of domestic trade flows in structural gravity has received renewed theoretical and empirical attention. Yotov (2022) demonstrates that including domestic flows helps reconcile gravity theory and empirics, solves scale-effect and border puzzles, and enables identification of country-specific policies invisible in international-only data. Campos et al. (2021) provide reassurance for applied work by showing that different empirical constructions of domestic trade—whether based on production minus exports or expenditure minus imports—yield very similar structural gravity parameters. Hu and Zhang (2021) extend this literature using semiparametric methods that allow distance effects to vary smoothly with partners' income per capita, finding that distance elasticity is substantially higher for South–South trade than for trade between high-income partners, with trade between income-homogeneous partners being most distance-sensitive. These findings underscore the heterogeneity in distance effects across development levels and reinforce the importance of country-specific analysis.

However, the distance puzzle has not been systematically reassessed for emerging markets using frameworks that jointly account for structural gravity corrections and country-specific institutional and macro-financial frictions. Limited evidence suggests important heterogeneity even within developing countries. Rasoulinezhad (2018), examining BRICS countries, finds distance effects vary substantially across specifications, with some yielding positive coefficients interpreted as global value chain integration effects partially offsetting geographic remoteness. This heterogeneity indicates that pooled regressions may obscure country-specific mechanisms, particularly for middle-income economies undergoing rapid structural transformation and experiencing episodes of macro-financial volatility (Auboin and Ruta, 2013).

2.4. Synthesis and Research Gap

This review establishes several findings that frame the empirical analysis. First, distance effects are substantial (median elasticity around minus 0.9) and have increased over time for low-income countries while remaining stable for high-income countries, indicating the puzzle is fundamentally a developing country phenomenon (Carrère et al., 2013; Disdier and Head, 2008). Second, methodological corrections matter substantially: PPML estimation, inclusion of domestic trade flows, and proper treatment of multilateral resistance reduce estimated distance elasticities by 20 to 40 percent relative to log-linear OLS, yet substantial effects remain even in best-practice specifications (Santos Silva and Tenreyro, 2006; Yotov, 2022). Third, distance proxies multiple frictions including information asymmetries, cultural differences, institutional barriers, trust deficits, and network effects, implying appropriate policy responses involve broad trade facilitation rather than narrow infrastructure focus (Head and Mayer, 2014; Anderson and Marcouiller, 2002). Fourth, macro-financial frictions remain understudied, particularly mechanisms through which exchange rate volatility amplifies distance sensitivity in contexts characterized by currency instability (Berman et al., 2012; Gopinath et al., 2020).

The literature reveals three important gaps that motivate the present analysis. First, despite extensive evidence on the distance puzzle in pooled cross-country samples, systematic country-specific reassessments using structural gravity methods remain rare, particularly for middle-income economies positioned between advanced and low-income groups (Yotov, 2022). Second, while the theoretical literature emphasizes that distance bundles institutional and informational frictions (Anderson and Marcouiller, 2002; Rauch, 1999), empirical work has not systematically examined how partner political stability and exporter-side exchange rate volatility shape distance sensitivity in emerging market contexts. Third, the literature documents pronounced heterogeneity in distance effects across income levels (Carrère et al., 2013) but provides limited guidance on whether middle-income economies exhibit patterns closer to advanced or developing countries, or whether they face distinct friction profiles reflecting their transitional status.

This study contributes by providing the first systematic country-specific reassessment of the distance puzzle for an emerging market through transparent sequential estimation from conventional log-linear OLS to PPML-based structural specifications incorporating domestic trade and exporter fixed effects. By explicitly incorporating partner political stability and exchange rate volatility into the gravity framework, the analysis assesses whether these factors help explain residual distance effects after structural corrections. The findings speak directly to whether distance primarily reflects physical trade costs amenable to infrastructure investment or deeper financial and institutional frictions requiring broader reforms, a policy-relevant distinction for middle-income countries seeking to deepen global integration while managing macro-financial volatility (Rodrik, 1999; Levchenko, 2007).

3. DATA AND METHODOLOGY

The empirical analysis relies on a benchmark-year panel of Türkiye's bilateral merchandise exports with its trading partners for 1996, 2000, 2004, 2008, 2012, 2016 and 2020. Export flows are sourced from CEPII TradeProd, which offers harmonised bilateral trade series designed for cross-country comparability. Using benchmark years helps reduce inconsistencies arising from missing observations and uneven reporting across countries and periods. The set of partner economies included in the estimations is reported in Table 2.

Table 2: Countries Included in the Analysis

ISO3	Country	ISO3	Country	ISO3	Country
AFG	Afghanistan	GBR	United Kingdom	NGA	Nigeria
AGO	Angola	GEO	Georgia	NIC	Nicaragua
ALB	Albania	GHA	Ghana	NLD	Netherlands
ARE	United Arab Emirates	GMB	Gambia	NOR	Norway
ARG	Argentina	GRC	Greece	NPL	Nepal
ARM	Armenia	GTM	Guatemala	NZL	New Zealand
AUS	Australia	HKG	Hong Kong SAR	OMN	Oman
AUT	Austria	HND	Honduras	PAK	Pakistan
AZE	Azerbaijan	HRV	Croatia	PAN	Panama
BDI	Burundi	HTI	Haiti	PER	Peru
BEL	Belgium	HUN	Hungary	PHL	Philippines
BEN	Benin	IDN	Indonesia	PNG	Papua New Guinea
BFA	Burkina Faso	IND	India	POL	Poland
BGD	Bangladesh	IRL	Ireland	PRT	Portugal
BGR	Bulgaria	IRN	Iran	PRY	Paraguay
BHR	Bahrain	IRQ	Iraq	PSE	Palestinian Territories
BHS	Bahamas	ISL	Iceland	QAT	Qatar
BIH	Bosnia & Herzegovina	ISR	Israel	ROU	Romania
BLR	Belarus	ITA	Italy	RUS	Russia
BLZ	Belize	JAM	Jamaica	RWA	Rwanda
BMU	Bermuda	JOR	Jordan	SAU	Saudi Arabia
BOL	Bolivia	JPN	Japan	SDN	Sudan
BRA	Brazil	KAZ	Kazakhstan	SEN	Senegal
BRB	Barbados	KEN	Kenya	SGP	Singapore
BRN	Brunei	KGZ	Kyrgyzstan	SLE	Sierra Leone
BTN	Bhutan	KHM	Cambodia	SLV	El Salvador
BWA	Botswana	KOR	South Korea	SOM	Somalia
CAF	Central African Republic	KWT	Kuwait	SRB	Serbia
CAN	Canada	LAO	Laos	SUR	Suriname
CHE	Switzerland	LBN	Lebanon	SVK	Slovakia
CHL	Chile	LBR	Liberia	SVN	Slovenia
CHN	China	LBY	Libya	SWE	Sweden
CIV	Côte d'Ivoire	LCA	St. Lucia	SWZ	Eswatini
CMR	Cameroon	LKA	Sri Lanka	SYR	Syria
COG	Congo - Brazzaville	LTU	Lithuania	THA	Thailand
COL	Colombia	LUX	Luxembourg	TJK	Tajikistan
CPV	Cape Verde	LVA	Latvia	TKM	Turkmenistan
CRI	Costa Rica	MAC	Macao	TON	Tonga
CUB	Cuba	MAR	Morocco	TTO	Trinidad & Tobago
CYP	Cyprus	MDA	Moldova	TUN	Tunisia
CZE	Czechia	MDG	Madagascar	TUR	Türkiye
DEU	Germany	MDV	Maldives	TZA	Tanzania
DNK	Denmark	MEX	Mexico	UGA	Uganda
DOM	Dominican Republic	MHL	Marshall Islands	UKR	Ukraine
DZA	Algeria	MKD	North Macedonia	URY	Uruguay
ECU	Ecuador	MLT	Malta	USA	United States
EGY	Egypt	MM	Myanmar (Burma)	UZB	Uzbekistan
ERI	Eritrea	MNE	Montenegro	VEN	Venezuela
ESP	Spain	MNG	Mongolia	VNM	Vietnam

ISO3	Country	ISO3	Country	ISO3	Country
EST	Estonia	MOZ	Mozambique	YEM	Yemen
ETH	Ethiopia	MUS	Mauritius	ZAF	South Africa
FIN	Finland	MWI	Malawi	ZMB	Zambia
FJI	Fiji	MYS	Malaysia	ZWE	Zimbabwe
FRA	France	NAM	Namibia		
GAB	Gabon	NER	Niger		

All variables are constructed to align with the structural gravity framework. The dependent variable is Türkiye's exports to partner countries in current US dollars. Bilateral distance is measured using the population-weighted great-circle distance from CEPII GeoDist, which approximates distances between major economic centres rather than capitals. Institutional and macro-financial frictions are proxied by partner political stability and exchange-rate volatility. Political stability is taken from the World Bank Worldwide Governance Indicators and is expressed in standard normal units, approximately ranging from -2.5 to 2.5. Exchange-rate volatility is computed as the three-year rolling standard deviation of the daily USD-TRY exchange rate, using data from the Central Bank of the Republic of Türkiye (EVDS). Output and expenditure terms are taken from TradeProd aggregates to ensure consistency with the Armington structure of structural gravity. Variable definitions, construction details and original data sources are summarised in Table 3, following the journal practice of documenting data inputs in a compact reference table rather than splitting the section into multiple sub-sections.

Table 3: Variables and Data Sources

Variable	Definition / measurement	Source
Exports (Trade)	Türkiye's bilateral merchandise exports to partner *j* in current USD	CEPII TradeProd
Log Trade	Natural log of exports (where defined)	Author's calculations
Distance	Population-weighted great-circle distance (km)	CEPII GeoDist
Log Distance	Natural log of distance	Author's calculations
Political Stability	WGI political stability index (minus 2.5 to plus 2.5)	World Bank WGI
FX Volatility	3-year rolling SD of daily USD-TRY exchange rate	Central Bank of Türkiye (EVDS)
Output (Exporter)	Türkiye's output aggregate consistent with structural gravity	CEPII TradeProd
Expenditure (Importer)	Partner's expenditure aggregates consistent with structural gravity	CEPII TradeProd
Remoteness	Size-weighted average distance index	Author's calculations (Head and Mayer approach; WTO-UNCTAD guide)
Domestic trade	Internal trade flow for home-bias correction (extended PPML)	As constructed for the empirical specification

To approximate multilateral resistance while preserving the identification of variation in political stability and exchange-rate volatility, the empirical specifications use remoteness indices computed as size-weighted averages of bilateral distance. This provides a parsimonious control for countries' average market access conditions without absorbing the cross-sectional variation in institutional and risk variables that high-dimensional fixed effects would remove.

Table 4: Descriptive Statistics

Variable	N	Mean	SD	Min	Max	Skewness	Kurtosis
Trade	2253	1,170.60	12,673.20	0.00	311,279.57	21.00	462.82
Log Trade	2141	3.28	3.43	-11.45	12.65	-0.63	0.27
Log Distance	2191	8.34	0.82	6.09	9.73	-0.40	-0.77
FX Volatility	2253	0.29	0.36	0.03	1.11	1.60	1.06
Political Stability	2246	-0.63	0.92	-3.28	1.76	0.47	-0.32

Source: Author's calculations based on CEPII TradeProd and World Bank WDI.

Table 4 reports descriptive statistics. Consistent with the distributional features of trade data, Türkiye's bilateral exports are highly dispersed, with many small trade relationships and a small number of very large markets. Distance also varies substantially, reflecting Türkiye's simultaneous integration with nearby European partners and more distant destinations in Asia and Africa. The partner-side political stability and the USD-TRY volatility measure display wide cross-sectional and time variation, supporting their use as proxies for institutional and macro-financial frictions in the gravity estimations.

3.1. Methodology

The empirical strategy is grounded in structural gravity under Armington differentiation and CES preferences. Under Armington, goods are differentiated by country of origin and consumers in destination j allocate expenditure across origin-specific varieties to maximise CES utility,

$$U_j = \left(\sum_i \beta_i q_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where q_{ij} is the quantity imported from origin i, β_i is a preference shifter and σ>1 is the elasticity of substitution. Utility maximisation yields the standard CES demand system,

$$q_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{-\sigma} \frac{E_j}{p_{ij}}, \tag{2}$$

with p_{ij} denoting the consumer price of the imported variety and P_j the CES price index. The value of bilateral trade is therefore

$$X_{ij} = p_{ij} q_{ij} = E_j \left(\frac{p_{ij}}{P_j}\right)^{1-\sigma}. \tag{3}$$

Trade costs enter via iceberg costs τ_{ij} such that $p_{ij} = \tau_{ij} c_i$, where c_i is the exporter's supply price. Substituting and rearranging yields the structural gravity equation,

$$X_{ij} = \frac{Y_i E_j}{Y} \left(\tau_{ij}\right)^{1-\sigma} \Pi_i^{\sigma-1} P_j^{\sigma-1}, \tag{4}$$

where Y_i is origin output, E_j is destination expenditure, Y is world output, and Π_i and P_j are outward and inward multilateral resistance terms summarising average trade barriers faced by each country. The model implies that bilateral trade depends on relative trade costs rather than absolute geography, and that omitting multilateral resistance can bias bilateral trade-cost proxies, including distance. Within this structure, institutional and macro-financial frictions enter through the iceberg term τ_{ij}. Political instability and exchange-rate volatility can raise expected costs and risk of serving destination j, thereby shifting τ_{ij} and affecting bilateral trade X_{ij}. Table 3 summarises variable construction and measurement choices used to operationalise these trade-cost components.

The empirical specification is estimated in the multiplicative form implied by structural gravity. For Türkiye's exports to partner j in benchmark year t, the baseline model is

$$X_{TR,j,t} = \exp\Bigg(\alpha + \sum_{t\in\mathcal{T}} \beta_t \ln Distance_{TR,j} \cdot \mathbb{1}\{t\} + \gamma_1 FXVol_t + \gamma_2 PolStab_{j,t} + \theta_1 RemExp_{TR,t} + \theta_2 RemImp_{j,t} + \delta_t \Bigg)\varepsilon_{TR,j,t}. \tag{5}$$

This parameterisation allows the distance elasticity to vary by benchmark year, consistent with the regression table that reports separate coefficients for 1996, 2000, 2004, 2008, 2012, 2016 and 2020. Distance is measured using population-weighted great-circle distance. $FXVol_t$ captures exporter-side macro-financial risk and is constructed as the three-year rolling standard deviation of the daily USD to TRY exchange rate. $PolStab_{j,t}$ measures partner political stability. Year fixed effects δ_t control for global shocks common across destinations in each benchmark year.

A central identification issue in gravity is controlling for multilateral resistance. In large panels, exporter-time and importer-time fixed effects provide a non-parametric control for multilateral resistance. In benchmark-year settings where the objective is to identify institutional and macro-financial variables, however, high-dimensional fixed effects can absorb substantial cross-sectional variation and reduce the scope for identifying coefficients on partner institutions. To maintain the structural logic while preserving variation in the covariates of interest, the baseline specification uses remoteness indices as empirical approximations of multilateral resistance. Remoteness is defined as a size-weighted average of bilateral distances to world markets and is included for both the exporter and importer. Conceptually, remoteness captures average market access conditions, reducing the likelihood that the distance coefficient reflects systematic differences in partner accessibility rather than bilateral trade costs.

The estimation proceeds through a nested sequence of specifications that progressively incorporate structural elements required by gravity theory, thereby enabling a transparent assessment of whether the distance puzzle reflects methodological artefacts or persistent trade frictions. Model (1) estimates the conventional log-linearised gravity equation by OLS and serves as a benchmark, while recognising its sensitivity to heteroskedasticity and its treatment of zero trade flows under log transformation. Model (2) estimates the multiplicative specification using PPML, which naturally accommodates zeros and yields consistent estimates under general forms of heteroskedasticity. Model (3) augments the PPML specification by incorporating domestic trade flows and exporter effects in order to correct for home bias and absorb exporter-side shocks common across destinations. Including internal flows provides the domestic benchmark required to distinguish international trade costs from the broader wedge between domestic absorption and cross-border trade, while exporter effects capture time-varying supply-side conditions for Türkiye that could otherwise contaminate bilateral trade-cost coefficients. This sequence aligns directly with the regression table, which reports year-specific distance elasticities under OLS, PPML, and the extended specification with domestic trade and exporter effects.

Estimation and inference follow standard practice in gravity applications. The PPML models are estimated in levels with the conditional mean specified as above. Standard errors should be computed using a heteroskedasticity-robust variance estimator and clustered at the partner-country level to account for within-destination correlation across benchmark years. The benchmark-year structure also allows formal assessment of persistence by comparing the estimated distance elasticities between 1996 and 2020 within each model, as summarised by the reported change in the distance coefficient across endpoints.

Finally, the empirical design incorporates diagnostics and robustness checks to ensure that conclusions about the distance puzzle are not driven by specific measurement choices. First, the volatility measure can be re-estimated using alternative rolling windows, such as two-year and five-year horizons, to verify that results are not sensitive to the chosen medium-term definition. Second, remoteness can be reconstructed using alternative size weights, for example GDP-based weights versus expenditure-based weights, to confirm that the multilateral resistance approximation does not mechanically drive the distance elasticity. Third, the main results can be re-estimated excluding crisis-sensitive benchmark years, or by adding destination-region indicators, to assess whether exceptional global episodes or regional composition drive the estimated time profile of the distance effect. These checks provide additional assurance that changes in the distance coefficient across the nested models reflect structural corrections rather than sample or measurement artefacts.

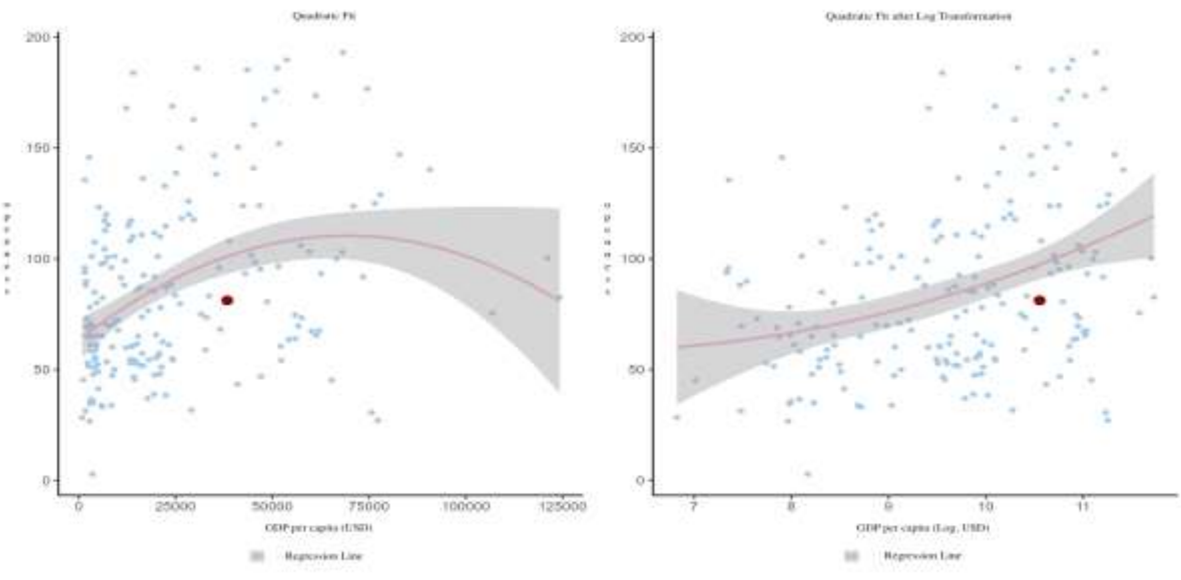
4. FINDINGS AND DISCUSSIONS

The empirical results combine descriptive patterns with nested gravity estimates to reassess whether Türkiye's "distance puzzle" reflects structurally persistent trade frictions or estimation artifacts that bundle multiple channels into the distance coefficient. The analysis proceeds from cross-country benchmarking of Türkiye's trade integration through bilateral trade patterns in the 2023 cross-section, culminating in benchmark-year gravity estimates that diagnose estimator sensitivity and the role of structural controls.

Figure 1 positions Türkiye's trade integration in comparative perspective by plotting trade openness (exports plus imports as a share of GDP) against GDP per capita. The left panel fits a quadratic function in levels, revealing an inverted-U pattern driven primarily by dispersion among very high-income economies. The right panel log-transforms income, yielding a smoother monotonic relationship consistent with the standard expectation that higher-income economies exhibit deeper global integration. Türkiye (red marker) lies modestly below the fitted curve in the log-income specification, suggesting an "openness gap" of approximately 10-15 percentage points relative to countries at similar income levels. This underperformance is not explained by income alone and motivates closer examination of the frictions—geographic, institutional, or macro-financial—that may constrain Türkiye's integration beyond what its development stage would predict.

the fitted curve in the log-income specification, suggesting an “openness gap” relative to countries at similar income levels and motivating a closer examination of the frictions that may constrain integration beyond income alone.

Figure 1: Trade Openness and Income (Quadratic vs. Log-Quadratic Fit)

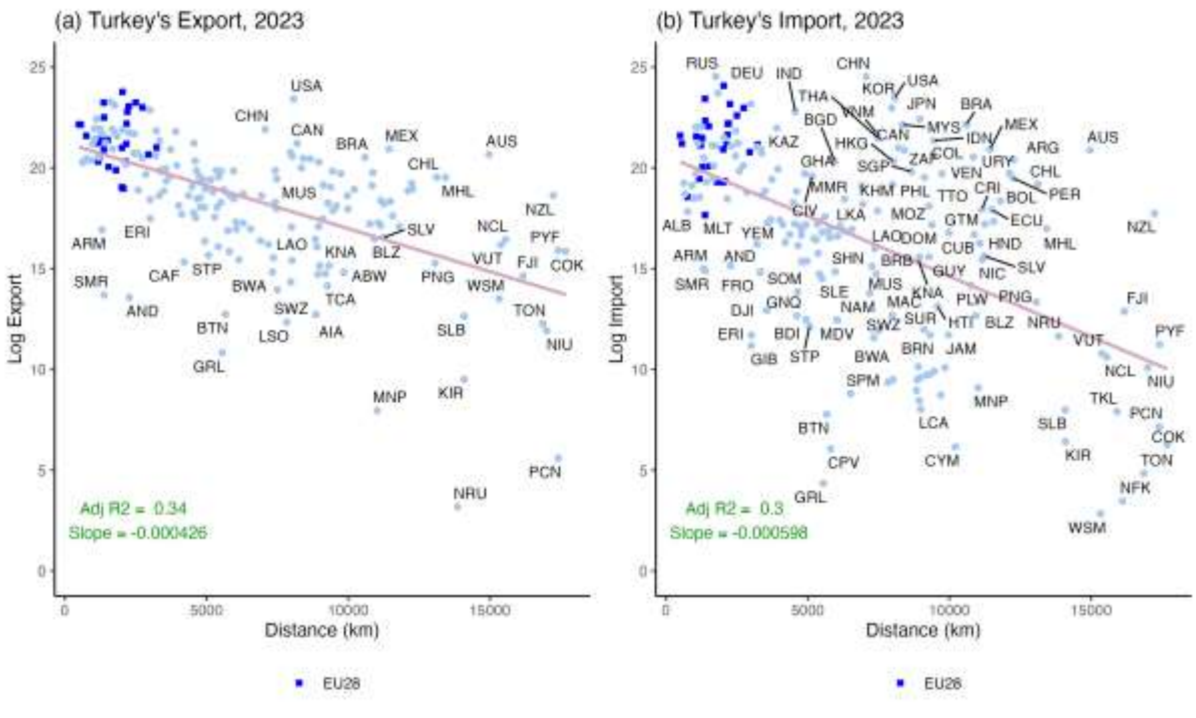


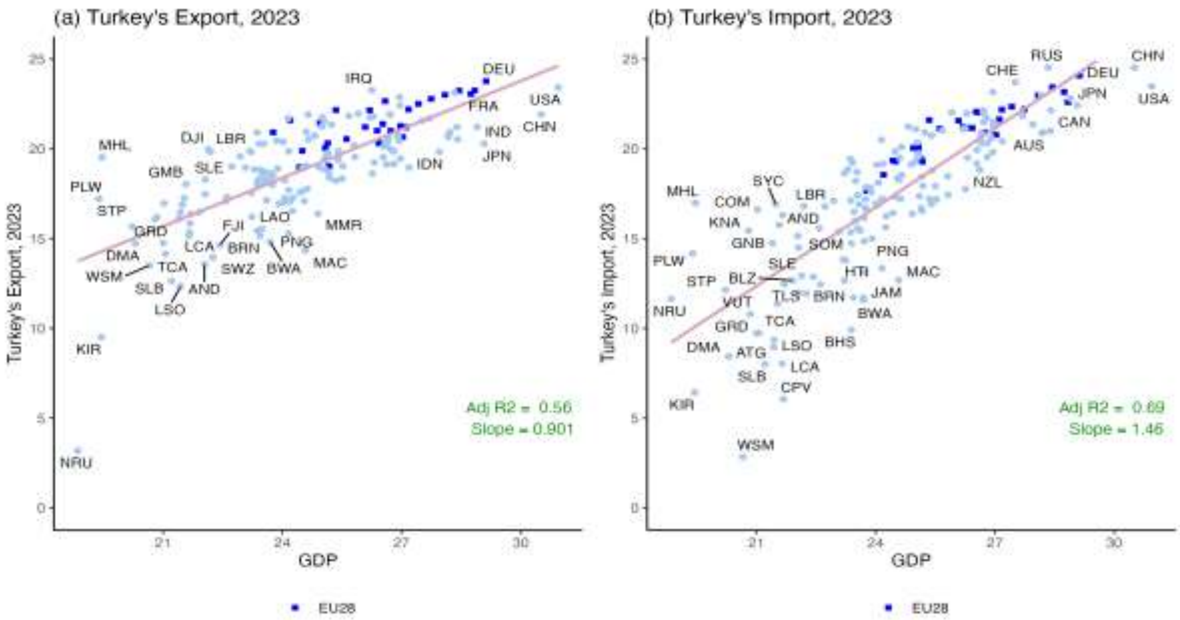
Note: Trade openness is defined as the ratio of exports plus imports to the GDP. Income is measured as the GDP per capita in USD. The red marker denotes Türkiye, and the blue markers denote other countries. The left panel fits a quadratic function of income levels, while the right panel applies a quadratic fit after log-transforming income. The shaded areas indicate the 95% confidence intervals. Data are from the CEPII Trade and Production Database (trade), World Development Indicators (GDP per capita), and the author's calculations.

Figure 2 decomposes Türkiye's 2023 bilateral trade geography along two core gravity dimensions: distance and partner economic size. The figure comprises four panels arranged in a 2×2 grid, with exports (left column) and imports (right column) plotted against distance (top row) and partner GDP (bottom row). Panels (a) and (b) reveal that both exports and imports decline systematically with great-circle distance, yielding semi-elasticities of approximately -0.0004 for exports and -0.0006 for imports. Three patterns emerge. First, EU partners (blue squares) form a dense high-trade cluster at short to medium distances and frequently lie above the fitted relationship, indicating trade volumes systematically exceed what distance alone predicts. Second, residual variance increases sharply beyond 5,000 km: while some distant partners such as the United States and China sustain substantial trade, many remote destinations exhibit near-zero flows, consistent with heterogeneous capacity to overcome distance-related frictions. Third, the negative gradient reflects not only transport costs but also informational barriers, institutional unfamiliarity, and network effects that covary with geographic separation—precisely the bundling mechanism emphasized in the distance puzzle literature.

Panels (c) and (d) plot log bilateral flows against partner GDP, revealing that both exports and imports rise strongly with partner size, yielding elasticities of 0.90 for exports and 1.46 for imports. Partner GDP explains more than half the cross-sectional variation in Türkiye's bilateral trade, confirming the centrality of market size in gravity specifications. EU partners again lie predominantly above the conditional relationship, with a simple calculation suggesting that EU membership elevates bilateral trade by 40-60 percent beyond what partner GDP predicts, consistent with deep institutional integration, customs union effects, and accumulated network capital. Collectively, Figure 2 documents three stylized facts: distance remains a strong negative correlate of bilateral trade, partner mass dominates cross-sectional variation, and EU integration confers a measurable premium not reducible to distance or size alone.

Figure 2: Distance and GDP Correlates of Türkiye's Bilateral Trade, 2023 (Exports and Imports)





Note: The figure stacks two bivariate relationships for 2023. The upper panels plot log bilateral exports (left) and log bilateral imports (right) against great-circle distance (km). The lower panels plot log bilateral exports (left) and log bilateral imports (right) against partner GDP (current USD). EU partners are shown as blue squares. Red lines denote fitted OLS regressions; shaded areas indicate 95% confidence intervals. Data: World Bank and author's calculations.

While the 2023 cross-section confirms standard gravity correlations, it cannot adjudicate whether the observed distance sensitivity reflects genuine structural frictions or estimation artifacts. Three limitations motivate the panel analysis reported in Table 5. First, log-linearization excludes zeros and amplifies small-sample noise, potentially overstating distance effects (Santos Silva and Tenreyro, 2006). Second, bilateral distance may proxy average market access conditions rather than bilateral trade costs when multilateral resistance is omitted (Anderson and van Wincoop, 2003). Third, without a domestic benchmark, international distance effects confound the domestic-versus-foreign allocation margin (Yotov, 2012). These concerns necessitate the structural gravity sequence presented below.

Table 5 reports the core results. Distance elasticities are allowed to vary by benchmark year (1996, 2000, 2004, 2008, 2012, 2016, 2020) across three nested specifications: log-linear OLS on positive flows (column 1), PPML with zeros (column 2), and extended PPML incorporating domestic trade flows and exporter-year fixed effects (column 3). This sequence isolates the contributions of heteroskedasticity correction, zero-flow retention, and home-bias and multilateral-resistance controls. Column 1 estimates the conventional log-linear specification on 2,071 positive trade observations. Distance coefficients are uniformly large, tightly clustered between -1.575 and -1.847, and precisely estimated in all benchmark years. The endpoint change from 1996 to 2020 is -9.6 percent—economically trivial and statistically insignificant—creating the classic signature of a stable, puzzle-like distance effect. The magnitudes are consistent with meta-analytic benchmarks: Disdier and Head (2008) report a median elasticity of -1.0 across 1,467 estimates, while Head and Mayer (2014) document a range of -0.9 to -1.1. Türkiye's OLS coefficients lie at the upper end, suggesting either genuinely high distance sensitivity or upward bias from methodological choices. Political stability enters positively and significantly, while exchange-rate volatility is insignificant, implying institutional proximity matters but macro-financial risk does not—a pattern that reverses under structural estimation.

Table 5: Evolution of Distance Elasticities and Institutional Controls in Türkiye's Bilateral Trade, 1996–2020

Variable	OLS (1)	PPML (2)	FE (3)
Log distance 1996	−1.814*** (0.233)	−0.730*** (0.166)	−0.691*** (0.170)
Log distance 2000	−1.847*** (0.230)	−0.701*** (0.172)	−0.676*** (0.175)
Log distance 2004	−1.762*** (0.234)	−0.621*** (0.169)	−0.582*** (0.173)
Log distance 2008	−1.659*** (0.233)	−0.544** (0.170)	−0.508** (0.174)
Log distance 2012	−1.619*** (0.232)	−0.523** (0.172)	−0.497** (0.175)

Log distance 2016	−1.575*** (0.230)	−0.505** (0.176)	−0.512** (0.175)
Log distance 2020	−1.640*** (0.246)	−0.496* (0.193)	−0.571** (0.179)
FX volatility	0.295 (0.882)	−0.313 (0.406)	0.545*** (0.017)
Political stability	0.563** (0.099)	0.078 (0.085)	0.004 (0.099)
Constant	17.674*** (1.889)	11.045*** (1.395)	
Observations	2,071	2,180	2,187
Δ Log distance 1996–2020	−9.6 (18.7)	−32.1 (34.9)	−17.4 (35.7)
Domestic trade	✗	✗	✓
Exporter FE	✗	✗	✓

Note: The dependent variable is Türkiye's bilateral merchandise exports to partner j in benchmark year t. Column (1) reports log-linear OLS estimates. Columns (2) and (3) report Poisson pseudo-maximum likelihood (PPML) estimates of the multiplicative gravity specification with an exponential conditional mean. Distance elasticities are allowed to vary by benchmark year through interactions of \ln Distance_TR,j} with year indicators for 1996, 2000, 2004, 2008, 2012, 2016, and 2020. All specifications include benchmark-year fixed effects. Column (3) additionally incorporates domestic trade flows to correct for home bias and includes exporter-side effects that absorb time-varying exporter conditions common across destinations in each benchmark year. Standard errors are reported in parentheses and are clustered at the partner-country level. Statistical significance is denoted by *** p<0.01, ** p<0.05, * p<0.10.
Source: Author's calculations based on CEPII TradeProd and World Bank WDI.

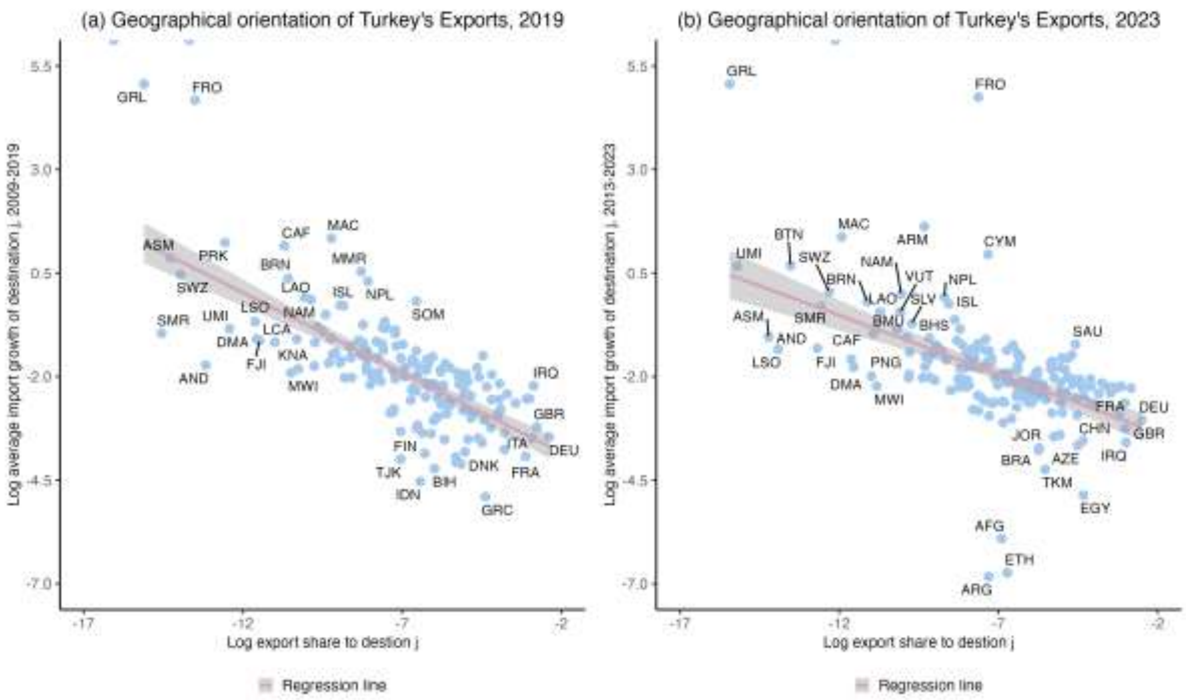
Column 2 re-estimates the model using PPML on 2,180 observations, including 109 zero flows. Distance elasticities shrink markedly, falling to a range of -0.496 to -0.730—a reduction of 58-62 percent relative to OLS across benchmark years. For example, the 1996 coefficient falls from -1.814 under OLS to -0.730 under PPML, a 60 percent decline, while the 2020 coefficient falls from -1.640 to -0.496, a 70 percent decline. This compression aligns with structural gravity theory on two dimensions. First, PPML yields consistent estimates when the conditional variance is proportional to the conditional mean squared, a pattern endemic to trade data, whereas log-linearization mechanically inflates coefficients when heteroskedasticity is severe (Santos Silva and Tenreyro, 2006). Second, including zeros reweights the sample toward larger, more stable trade relationships, reducing the influence of noisy small flows that drive extreme distance sensitivity in log specifications. The endpoint change becomes larger in absolute terms but remains imprecise, suggesting at most modest flattening over time. The key inference is therefore level correction rather than trend identification: once heteroskedasticity and zero-flow structure are addressed, Türkiye's distance elasticity falls to -0.5 to -0.7, below the meta-analytic median and within the range documented for high-income countries (Carrère et al., 2010). Political stability loses significance, consistent with the hypothesis that OLS overweights partners where institutional quality and trade co-vary for compositional reasons. Exchange-rate volatility remains insignificant at this stage.

Column 3 augments PPML with domestic trade flows and exporter-year fixed effects, yielding 2,187 total observations. Distance elasticities remain in the -0.497 to -0.691 range, with no reversion toward OLS magnitudes. The endpoint change is -17.4 percent, intermediate between OLS and baseline PPML but imprecisely estimated. Three implications follow. First, including Türkiye's domestic trade provides the natural benchmark for international frictions, yet the finding that distance effects remain moderate implies the OLS puzzle does not reflect omitted home bias but rather mis-specification of the functional form. Second, exporter-year fixed effects absorb time-varying supply conditions common across destinations, such as aggregate productivity shocks, macro volatility, and policy regime shifts. Their inclusion redistributes explanatory power: distance remains significant, but exporter-side volatility becomes identifiable as a separate channel. Third, exchange-rate volatility becomes precisely estimated and positive. This coefficient requires careful interpretation. It indicates that periods of high USD-TRY volatility coincide with higher observed exports conditional on distance, partner characteristics, and home bias. Two mechanisms may reconcile this result with theory. Exporters may concentrate shipments in periods of volatility to lock in favorable rates before further depreciation, generating short-term positive correlation even as volatility deters entry and long-term relationship formation (Berman et al., 2012). Alternatively, volatile periods disproportionately drive exit from marginal markets, leaving only resilient high-productivity exporters serving distant destinations and thereby elevating average trade intensity conditional on distance (Helpman et al., 2008). The positive sign does not imply volatility reduces frictions; rather, it captures compositional shifts in who trades and when, once structural controls isolate exporter-wide conditions. Political stability remains insignificant, confirming its OLS significance reflected unmodeled heterogeneity.

The average OLS elasticity across the seven benchmark years is -1.70, exceeding the meta-analytic median by 70-90 percent and constituting prima facie evidence of a distance puzzle. The average PPML elasticity is -0.59, while the extended PPML average is -0.58, nearly identical. The 65-66 percent reduction from OLS to structural estimation resolves most of the puzzle, with the residual effect interpretable as genuine composite frictions—informational barriers, network costs, and risk premia—rather than estimation artifacts. Importantly, the literature's "20-40 percent reduction" benchmark cited in Section 2 reflects comparisons within PPML specifications, for example with versus without multilateral resistance controls. The 65 percent reduction documented here spans OLS to extended PPML, making it consistent with and indeed reinforcing the structural gravity consensus that methodological corrections substantially attenuate apparent distance persistence.

Figure 4 complements the regression evidence by examining how Türkiye allocates export shares across partners with heterogeneous growth trajectories. Each panel plots Türkiye's log export share to destination j against that destination's average import growth over the preceding decade, comparing 2019 (left) and 2023 (right). Both panels reveal a negative relationship between export share and partner import growth: Türkiye concentrates trade in mature, slow-growing markets, predominantly in the EU, while allocating small shares to fast-growing destinations in Asia and Africa. The fitted slopes are -2.6 in 2019 and -2.4 in 2023, indicating a 10 percentage point increase in partner import growth associates with a 24-26 percent decrease in Türkiye's export share. Critically, the relationship tightens rather than rotates between 2019 and 2023. The dispersion narrows, and outliers shift leftward, suggesting consolidation around established low-friction markets rather than portfolio rebalancing toward high-growth destinations.

Figure 3: Geographic Orientation of Exports, 2019 vs. 2023



Note: Each panel plots Türkiye’s bilateral export share to partner j against the partner’s average import growth over the preceding decade. Red lines denote fitted regressions; shaded areas indicate 95% confidence intervals. Data: World Bank and author’s calculations.

This pattern aligns with the structural gravity findings on two levels. First, mature markets offer not only geographic proximity but also institutional familiarity, accumulated network capital, and low informational barriers—precisely the bundled frictions that distance proxies in conventional specifications. Fast-growing markets often involve greater distance, institutional heterogeneity, and entry costs, deterring share reallocation despite growth potential. Second, periods of TRY volatility disproportionately affect entry into new markets, as exchange-rate uncertainty raises the option value of waiting (Baldwin, 1989). The portfolio stability suggests existing relationships in low-friction markets serve as hedges, consistent with the positive FX volatility coefficient in column 3 reflecting intensive-margin adjustments within established networks rather than extensive-margin expansion.

The combined evidence yields three core findings. First, the distance puzzle for Türkiye is primarily an estimation artifact. OLS generates distance elasticities of -1.6 to -1.8, exceeding meta-analytic benchmarks and suggesting exceptionally high geographic frictions. PPML-based structural estimation reduces elasticities by 65 percent to -0.5 to -0.7, placing Türkiye below the global median and comparable to high-income countries. The "large and stable" coefficients documented in conventional specifications reflect heteroskedasticity bias, zero-flow omission, and inadequate controls for multilateral resistance, not genuine structural persistence. Second, residual distance effects bundle informational, institutional, and network frictions. Even under best-practice estimation, distance remains economically significant, implying a 10 percent distance increase reduces trade by approximately 6 percent. This magnitude is consistent with distance proxying contract enforcement costs, search frictions, and relationship-specific investments (Anderson and Marcouiller, 2002; Chaney, 2014) rather than shipping costs alone. The EU premium documented in Figure 2 and portfolio concentration in mature markets shown in Figure 4 provide descriptive support: Türkiye sustains disproportionate trade with institutionally proximate partners, irrespective of growth potential. Third, macro-financial volatility shapes trade geography through exporter-side adjustment. Exchange-rate volatility enters insignificantly in conventional specifications but becomes significant and positive under structural estimation. This is interpreted as evidence of intensive-margin concentration during volatile periods: high volatility prompts exit from marginal markets and shipment frontloading in established relationships, elevating measured trade conditional on distance. This mechanism differs from classical trade-cost interpretations but is consistent with firm-level adjustment models (Berman et al., 2012) and reinforces the composite-friction view of distance.

5. CONCLUSION AND IMPLICATIONS

This paper re-examines the distance puzzle for Türkiye's bilateral exports using structural gravity methods. Drawing on CEPII benchmark-year data for 1996–2020, the analysis estimates three nested specifications: conventional log-linear OLS, PPML in levels, and an extended PPML model incorporating domestic trade flows and exporter-year fixed effects. The sequential estimation strategy allows for a transparent assessment of whether large distance elasticities reflect genuine trade frictions or estimation artifacts arising from heteroskedasticity, zero-flow omission, and inadequate treatment of multilateral resistance.

The empirical findings strongly support the interpretation that the distance puzzle is primarily an estimation artifact in the Turkish context. Under OLS, the average distance elasticity across benchmark years is –1.70, exceeding meta-analytic benchmarks by 70–90 percent and suggesting exceptionally high geographic frictions. However, once heteroskedasticity and zero-flow structure are addressed through PPML estimation, the average elasticity declines to –0.59—a reduction of approximately 65 percent. The extended PPML specification with domestic trade and exporter effects yields nearly identical magnitudes (–0.58), confirming that the attenuation reflects methodological correction rather than model sensitivity. These findings place Türkiye below the global median distance elasticity and comparable to high-income countries, directly contradicting the conventional interpretation that emerging markets face exceptionally steep distance gradients. The results also reveal that political stability, which appears significant under OLS, loses explanatory power once structural controls are implemented, suggesting its OLS significance reflects compositional heterogeneity rather than a genuine institutional effect. In contrast, exchange-rate volatility becomes precisely estimated and positive under structural estimation, indicating that periods of high USD–TRY volatility coincide with intensive-margin concentration within established trade relationships rather than extensive-margin expansion.

This paper makes three contributions to the literature. First, it provides a systematic country-specific reassessment of the distance puzzle for an emerging economy, demonstrating that the puzzle is largely resolved once structurally consistent estimators are employed. Second, it shows that institutional and macro-financial conditions help explain part of what naive models attribute to distance, with exchange-rate volatility becoming significant under structural estimation. Third, the descriptive evidence complements the econometric results by documenting Türkiye's concentration in mature, institutionally proximate EU markets despite higher growth potential in more distant destinations. For policymakers, the findings have practical implications: the apparent persistence of large distance effects in conventional gravity studies may overstate the role of infrastructure deficits and understate the importance of financial stability, institutional quality, and network-based frictions. Trade diversification strategies should therefore address not only physical connectivity but also currency risk management and relationship-building costs that elevate effective distance for emerging-market exporters. Future research could extend this framework to firm-level data to disentangle intensive- and extensive-margin responses, incorporate services trade to assess whether distance operates differently across tradable categories, and examine whether the structural corrections documented here generalize to other middle-income economies facing similar macro-financial volatility.

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