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Do double taxation treaties enhance bilateral trade? Evidence from India using an augmented gravity model

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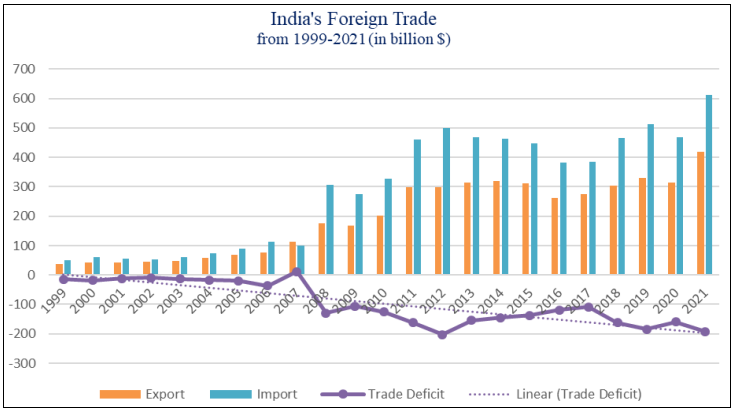
Abstract
The study attempts to analyses how Double Taxation Avoidance Agreements affect bilateral trade between India and its top 18 partner countries from 2000 to 2020 using the augmented gravity model of trade. The study employs Poisson Pseudo Maximum Likelihood (PPML) as a base line estimation technique to handle zero trade flows and address issues of heteroskedasticity and autocorrelation. The results of the study reveal that double taxation treaties considerably boosts India's bilateral trade even after controlling for factors like economic size, distance, legal origin, and historical ties. Further to ensure the robustness of the results the study has employed Feasible Generalized Least Squares (FGLS) model reaffirming the results of the PPML model The results of the study reinforce the conceptualization of tax treaties not only as investment-boosting tools but also as catalyst of India's international trade through the reduction of legal uncertainty, elimination of double taxation, and help in building stronger commercial relationships.

Keywords: Double taxation treaties, bilateral trade, gravity model, PPML, FGLS

1. Introduction
The Indian economy experienced a major reform shift through economic liberalization in 1991 which created significant changes in India's trade policy framework. Government reforms introduced a fundamental shift by repositioning India from import substitution practices to foreign trade expansion philosophy. The strategy of government interference and import substitution was abandoned, and industrial licencing was liberalised. The accessibility of foreign capital permitted Indian international trade to grow significantly. Foreign trade regulations have also been eased. As a result, industries could diversify their production; increase their capacity without excessive impediments. Fascinatingly, the latest wave of global economic integration has elevated bilateral trade flows to a position of paramount importance, particularly in terms of their impact on globalisation, the magnitude of trade flows, and the movement of capital between countries (Anaman and Atta-Quayson, 2009) [1]. According to the Ministry of Commerce and Industry, India's total trade (exports plus imports) increased from approximately USD 42 billion in 1990-91 to over USD 1.43 trillion in 2021-22, reflecting an extensive integration into the global economy. Figure 1 provides the overview of composition of India's foreign trade from 1999 to 2021.

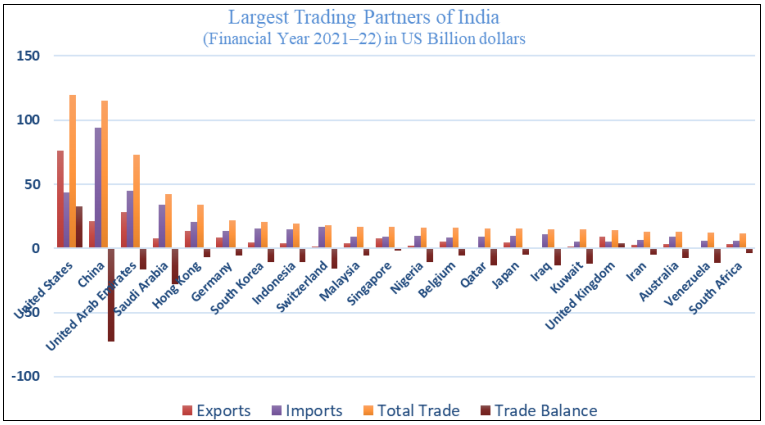


Source: Author's own calculation by accessing DOTS database

Fig 1: Composition of India's Foreign Trad

The significance of trade in India's economic growth after liberalization cannot be overstated. Trade has been a significant driver of GDP growth, contributing to the expansion of the industrial sector, generating employment, and improving foreign exchange reserves. Export-oriented sectors have embraced cutting-edge technologies and production processes, which contributed to industrialization and modernization of the economy. Increased imports have also facilitated access to essential inputs, capital goods, and technologies that have improved domestic manufacturing and boosted productivity levels. India's current account deficits have also been greatly reduced by trade, as proceeds from exports helped to stabilize the macroeconomic environment and balance import payments.

The Indian export market experienced major transformation by shifting away from traditional primary commodities to value-added manufactured goods and services. While petroleum and gold maintain their position as leading imported products yet the import of capital goods and high-tech components still show a growing trend over time. Moreover, India has experienced a dramatic modification in its trading relationships across different geographic areas. The United States and United Arab Emirates along with China maintain their positions as top trading partners for India yet the country has developed new strategic markets including ASEAN countries and Africa and Latin America to integrate its economic growth with the rest of the world. According to the Ministry of Commerce and Industry, the fifteen largest trading partners of India represent 59.37% of total trade by India in the financial year 2019-2020. India exported approximately $422 billion worth of goods in the fiscal year 2021-2022, and approximately $250 billion worth of goods during the same period. Figure 2 provides the graphical presentation of India's top 22 trading partners, as measured by the sum of their imports and exports, in billions of US dollars for the fiscal year 2021-2022.



Source: Author's own calculation by accessing DOTS database.

Fig 2: Largest Trading Partners of India

Despite these gains India continues to experience challenges regarding trade promotion, institutional effectiveness, and the investment climate. One important but often overlooked institutional tool that plays a pivotal role in shaping international economic relations is the Double Taxation Avoidance Agreement (DTAA). Double taxation can increase the cost of doing business, reduce profit margins, and make goods and services less competitive in the global market. DTTs address this issue by allocating taxing rights between the contracting states. This ensures that businesses are not subject to double taxation on their international trade activities, thereby lowering the effective tax rate and enhancing their competitiveness. Traditionally seen as mechanisms to prevent the to the same income being taxed twice in different jurisdictions, DTTs simultaneously build fiscal transparency and environment of legal certainty that decrease trade costs and improve economic collaboration between nations. By reducing tax barriers and aligning fiscal regimes between two countries, DTAAs may incentivize firms to engage in more trade, especially in sectors where tax treatment significantly affects pricing, cost competitiveness, or investment in supply chains. Yet, the empirical evidence, particularly in the context of India, remains scarce and inconclusive.

Given India's extensive DTAA network which comprises 96 treaty countries and its aim to become a global manufacturing and trade hub through initiatives like "Make in India", "Aatmanirbhar Bharat", and on-going trade negotiations with blocs like the EU and GCC, it becomes imperative to empirically investigate the trade-related effectiveness of these treaties. This study contributes to the literature on international trade and public finance in several ways. First, it extends the use of the gravity model to include tax treaties as a key explanatory variable. Second, the study employs robust estimation techniques (PPML and FGLS) to improve the reliability of results. Third, it fills a vital gap in Indian empirical literature by focusing on trade rather than investment effects of tax treaties. The findings offer both theoretical implications for modelling trade flows and practical relevance for policymakers involved in trade negotiations and treaty formation. This study aims to fill these gaps by studying the impact of these tax treaties on bilateral trade of India with its top 18 trading partners for the sample period from 2000 to 2020.

2. Literature Review

The theoretical framework for analysing the impact of tax treaties on trade is built in the concepts of international trade theory and the gravity model of trade. The gravity model, initially developed by Tinbergen (1962) [30] and Poyhonen, states that bilateral trade flows between two countries are positively related to their economic sizes (GDPs) and negatively related to the distance between them. Over time, the model has been augmented and refined to include a wide range of economic, institutional, and cultural factors influencing trade.

2.1 Theoretical and Empirical Foundations of the Gravity Model

The gravity model was micro-founded by Anderson and van Wincoop (2003) [2], who added multilateral resistance terms to account for the omitted variable bias regarding trade environment. Their contributions led to more reliable applications in policy analysis that helped resolve some of the model's earlier shortcomings. Baldwin and Taglioni (2006) [4] also underlined the significance of appropriate estimation methods, arguing that neglecting heteroskedasticity and zero trade flows can produce biased results. Santos Silva and Tenreyro (2006) [29] later addressed this problem by putting forth the Poisson Pseudo Maximum Likelihood (PPML) estimator.

Empirical application of gravity model typically shows that larger economies trade more with each other and geographical distance negatively affects the trade. Additional variables such as common border, common language, colonial ties, trade agreements, and institutional quality have been found to significantly influence bilateral trade flows between two countries (Frankel *et al*., 1995; Head & Mayer, 2014) [13, 18].

2.2 Gravity Model Applications in Indian Trade Studies

The gravity model has been used in a number of studies that analyse bilateral trade flows due to its success at the forefront of international trade research. Tinbergen (1962) [30] and Poyhonen used the gravity model for the first time in international trade studies to examine the patterns of bilateral trade flows among European countries. The model is based on Newton's law of gravity, which states that bilateral trade flows between two nations are directly proportional to their GDP as a proxy for size and indirectly proportional to the distance between them, keeping other things constant (Krugman & Obstfeld, 2009) [23]. Frankel *et al*. (1995) [13] augmented the gravity model to include dummy variables like common boundary and language and found that these variables are positively correlated with bilateral trade flows. Filippini and Molini (2003) [12]. employed the gravity model technique for examining the geographical factors that impact bilateral trade. The author finds that factors such as the respective GDP of the trading nations, the distance between the two, the colonial linkages (if any) and the economic policies considerably impact the bilateral trade volume. Using a panel dataset on Fiji's trade with Asian economies, Gani (2008) [14] reported that infrastructure and trade openness have mixed effects on trade flows, while GDP and distance play significant positive role. Similarly, Eita (2008) [10] investigated the determinants of Namibian exports from 1998 to 2006 using a gravity model and panel data from 29 countries. He found that Namibian exports increased in lockstep with GDP, whereas importers' GDP per capita had a negative impact on export. According to theoretical expectations, distance was also found to have significant negative relationship with exports. Akpoilih and Farayibi (2015) [11] used the gravity model to examine the determinants of Nigeria-China bilateral trade relations in manufacturing products from 1995 to 2012. They found that economic size, as measured by GDP and income has a significant positive relationship with total exports, whereas distance has a significant negative relationship.

In the context of India Haq and Kaur's (2019) [17] analyses India's trade potential with the BRICS nations and concluded that higher GDP, openness, and political stability tend to improve trade. Another study conducted by Tripathi and Leitão (2013) [31] examined India's bilateral trade with OECD countries using fixed and random effects models. Their findings showed that political globalisation and cultural proximity have a favourable impact on bilateral trade of India. The study included economic size and a common border and confirmed the favourable impact on bilateral trade. Mishra *et al*. (2015) [25] also employed the gravity framework to investigate trade dynamics between India and BRICS countries for the time period of 1990-2010 and the results of the study concluded that openness and per capita income as significant trade determinants of trade. Moreover, import GDP ratio and inflation rate insignificantly related to trade.

2.3 Double Taxation Treaties and Trade: Emerging Empirical Insights

While a plethora of studies have analysed the impact of tax treaties on foreign direct investment (Egger *et al*., 2006; Barthel *et al*., 2010; Hong, S. 2018; Kaur *et al*., 2024) [9, 6, 20, 21], recent literature has turned attention toward their implications for trade. V. Vicard (2011) [32] examined the role regional trade agreements and found that tax treaties as a reginal trade agreement can enhance trade when supported by strong institutions. Pham *et al* (2019) [27] is the first study which directly analysed the impact of tax treaties on bilateral trade of Vietnam with ASEAN member countries and compared it with its European Union member countries. The study used an extensive dataset of 67 largest trading partners of Vietnam over the period of 2001 to 2016. Using the panel gravity-based approach and Generalised Least Square (GLS) analysis techniques, the study confirms the significant positive impact of the double taxation treaties on Vietnam's bilateral trade not only with ASEAN member countries but also with European Union member countries. Using gravity model estimation, Camarero *et al*. (2020) [7] and Nguyen *et al*. (2020) [26] studied the impact of DTTs on trade flows in emerging economies and came to the conclusion that tax agreements greatly reduce trade frictions and improve bilateral trade. Kim (2010) [22] and Wei & Wang (2010) [33] extended the gravity framework to incorporate tax treaties as institutional variables. The results of the study revealed consistent positive impact of tax treaties on bilateral trade, especially when treaty partners are institutionally aligned. However, there is still a dearth of empirical research on India in this area, with the majority of studies focusing on the effects of foreign direct investment rather than trade outcomes. The role of DTTs as trade facilitators in the Indian context thus remains an open empirical question.

3. Data Description and Methodology

3.1 Theoretical Framework: The Gravity Model of Trade

The empirical analysis of this study is based on the widely accepted gravity model of international trade, which draws its conceptual foundations from Newton's law of gravitation. In trade economics, the model states that bilateral trade flows between two countries are directly proportional to their economic sizes and inversely proportional to the geographic distance between them.

The standard form of the gravity equation is given by:

$$\mathbf{Trade_{ijt}} = G.\frac{GDPi.GDPj}{Dij}$$

Where:

- $Trade_{ijt}$ represents the trade flow between reporter and partner country in time t
- GDP_{it} and GDP_{jt} are the economic sizes of reporter and partner countries respectively in time t
- D_{ij} is the distance between the two countries.
- G is a constant of proportionality

Taking natural logarithms of both sides transforms it into a linear form, commonly used in empirical analysis:

$$\mathbf{\ln(Trad_{eijt})=\alpha+\beta_1\ln(GDP_{it})+\beta_2\ln(GDP_{jt})+\beta_3\ln(DIST_{ij})+\varepsilon_{ijt}}$$

To make the model more comprehensive and relevant for policy analysis, the basic gravity model is augmented by incorporating additional economic, institutional, and historical variables that influence bilateral trade.

3.2 Model Specification

The augmented gravity model used in this study takes the following form:

$$\mathbf{\ln(Trade_{ijt}) = \alpha_0 + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(GDP_{jt}) + \beta_3 \ln(TradeOpen_{it}) + \beta_4 \ln(TradeOpen_{jt}) + \beta_5 \ln(Dist_{ij}) + \beta_6 (DTT_{ijt}) + \beta_7 (ComB_{ij}) + \beta_8 (ComOL_{ij}) + \beta_9 (ColRel_{ij}) + \beta_{10} (ComCol_{ij}) + \varepsilon_{ijt}}$$

Where:

- $\ln(Trade_{ijt})$ is the log of bilateral trade between India (i) and partner country (j) at time t (in USD).
- $\ln(GDP_{it})$ and $\ln(GDP_{jt})$ are the log of gross domestic product of India and the partner country respectively (constant 2015 USD).
- $\ln(DTT_{ijt})$ is the log of distance between India and country j (in kilometers).
- $\ln(TradeOpen_{it})$ and $\ln(TradeOpen_{jt})$ represent log of trade openness of India and partner countries respectively (exports + imports as % of GDP).
- (DTT_{ijt}) is dummy variable indicating the existence of a Double Taxation Treaty between India and partner j.
- $(ComB_{ij})$ represents dummy for shared borders.
- $(ComOL_{ij})$ is the dummy for common official language.
- $(ColRel_{ij})$ is the dummy for colonial relationship.
- ε_{ijt} is the Error term.

This augmented gravity model enables the study to isolate the impact of DTTs while controlling for traditional and institutional trade determinants.

3.3 Estimation Strategy

3.3.1 Choice of the Poisson Pseudo Maximum Likelihood (PPML) Estimator

The PPML estimator, as proposed by Santos Silva and Tenreyro (2006) [29], is used as the baseline model in this study for various reasons. First PPML handles the issues of heteroscedasticity and zero values in trade flows which are common in trade data (Silva and Tenreyro 2006) [29]. Second Silva and Tenreyro (2006) [29] highlighted that when PPML coefficients are computed they are typically smaller and more accurate compared to the Ordinary Least Square (OLS) coefficients. Finally Head and Mayer (2014) [18] further supported the use of PPML model due to its advantages in handling dummy variables over other models. Another significant challenge is the potential endogeneity of trade policy variables. Baier and Bergstrand (2007) [3] recommend using country-pair fixed effects to address endogeneity concerns. Additionally, year-fixed effects are also included to control for macroeconomic shocks, which ensures that the model accounts for time-specific influences. To check the robustness of our results we have applied FGLS model to ensure consistency and validity of the findings. FGLS method accounts for the autocorrelation and heteroscedasticity structure in the error term and adjusts the estimation accordingly, providing efficient and unbiased coefficients under feasible conditions. FGLS model is suitable where time period (T) is greater than the number of cross sections (N).

3.4 Data Description

For the completion of this study, secondary data of top 18 investing countries with which India has double taxation agreements for the period of 2000 to 2020 has been used. These countries account for over 70% of India's total trade volume. These countries include United States, United Arab Emirates, United Kingdom, China, Saudi Arabia, Switzerland, Singapore, Indonesia, Republic of Korea, Germany, Japan, Belgium, Malaysia, Bangladesh, Russian Federation, Nigeria, Qatar and Canada

3.4.1 Data Sources

The data on bilateral trade has been collected from the IMF Direction of Trade Statistics (DOTS). Data on India's tax treaties have been collected from OECD database. Data on GDP and Trade Openness has been collected from World Bank World Development Indicators (WDI). Data pertaining to distance, common border, common official language and colonial relationships have been collected from CEPII database which is a French data base-providing data on gravity model of trade. The description of variables is presented in Table 1.

Table 1: Description of Variables and Data Sources

Variable	Description	Data Source
DTT	Double Taxation Treaty (Dummy variable) = 1 if India has signed a DTT with the partner countries; 0 otherwise	OECD
BT	Total bilateral trade between India and its treaty partners	UN Comtrade
GDPind	Gross Domestic Product of India	WDI
GDPptr	Gross Domestic Product of partner countries	WDI
TOPind	Trade openness of India	WDI
TOPptr	Trade openness of partner countries	WDI
Dist	Distance from the capital cities of India and its partner countries	CEPII
ComB	Common Border (Dummy variable) = 1 if India and its partner country share a common border; 0 otherwise	CEPII
ComOL	Common Official Language (Dummy variable) = 1 if India and its partner country have a common official language; 0 otherwise	CEPII
ColRel	Colonial Relationship (Dummy variable) = 1 if India and its partner country were in a colonial relationship in the past; 0 otherwise	CEPII

Source: *Author's computation*

4. Results and Discussion

This section presents and discusses the empirical findings of the study. The study starts with descriptive statistics and correlation analysis then conducts panel data diagnostic tests for verifying underlying assumptions. This section analyses findings from the Poisson Pseudo Maximum Likelihood model while moving on to robustness evaluations based on the Feasible Generalized Least Squares model. The interpretation focuses not only on statistical significance but also on the economic and policy implications of the results.

4.1 Descriptive Statistics

The initial evaluation of data is essential to understand the distribution patterns and variability of the variables. Table 2 presents the summary statistics for the key variables.

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lnBT	378	23.058	1.093	19.211	25.286
ln GDPind	378	28.038	0.388	27.409	28.619
lnGDPPtr	378	27.472	1.399	24.24	30.623
ln TOPind	378	3.725	0.222	3.258	4.022
lnTOPPtr	378	4.269	0.68	2.973	6.081
lnDist	378	8.465	0.522	7.26	9.398
DTT	378	0.81	0.393	0	1
ComB	378	0.111	0.315	0	1
ComOL	378	0.278	0.448	0	1
ColRel	378	0.056	0.229	0	1

Source: *Author's computation From Stata 17.*

The dependent variable, bilateral trade shows moderate variability across sample countries, indicating heterogeneity in trade volumes. Variables such as GDP of India and GDP of partner countries exhibit relatively stable distributions, consistent with the gravity model's assumptions regarding economic size. The mean value of tax treaties indicates that approximately 81% of sample countries have concluded tax treaty with India which reflects India's extensive treaty network.

4.2 Correlation Matrix and Multicollinearity Check

The estimated outcomes of correlation analysis are depicted in table 3. Correlation analysis reveals the expected positive associations between trade and economic size (GDP of India and GDP of Partner countries), and a negative association with distance which aligns with the predictions of the gravity model of trade. Double taxation treaty which is the main explanatory variable of the study exhibits a positive relationship with bilateral trade of India. The other variables like trade openness of India, trade openness of partner countries, common official langue and colonial relationship show a positive linkage with trade whereas common border shows a negative relationship with trade. Importantly, none of the variables exhibit strong pairwise correlations ($r > 0.8$), which mitigates the risk of multicollinearity. To validate this, Variance Inflation Factor (VIF) values were calculated which are presented in table 4. The results of the VIF analysis reveal that all VIFs were below the critical threshold of 5, with the highest being 4.88 for distance, confirming that multicollinearity does not distort the estimated results.

Table 3: Correlation Matrix

Variables	lnBT	lnGDPi	lnGdpP	lnTOPi	lnTOPp	lnDist	DTT	ComB	ComOL	ColRel
lnBT	1.00									
lnGDPi	0.60	1.00								
lnGdpP	0.48	0.17	1.00							
lnTOPi	0.55	0.51	0.10	1.00						
lnTOPp	0.02	0.01	-0.52	0.08	1.00					
lnDist	-0.10	0.00	0.60	0.00	-0.20	1.00				
DTT	0.09	0.20	0.22	0.05	0.04	-0.07	1.00			
ComB	-0.02	0.00	0.04	0.00	-0.30	-0.49	0.17	1.00		
ComOL	0.08	0.00	0.21	0.00	-0.06	0.59	-0.02	-0.22	1.00	
ColRel	0.02	0.00	0.20	0.00	-0.09	0.16	0.12	-0.09	0.39	1.00

Source: *Author's computation From Stata 17.*

Table 4: Variance Inflation Factor

Variables	VIF	1/VIF
lnDist	4.883	0.205
lnGDPptr	3.405	0.294
ComOL	2.186	0.457
ComB	2.082	0.48
lnTOPptr	1.677	0.596
lnGDPind	1.455	0.687
lnTOPind	1.39	0.72
ColRel	1.334	0.75
DTT	1.245	0.803
Mean VIF	2.184	

Source: *Author's computation From Stata 17.*

4.3 Diagnostic Tests

Before going to the regression results, we have performed some important panel diagnostic tests to ensure the reliability, validity, and robustness of the estimated models. These tests help identify and address various econometric issues such as autocorrelation, heteroscedasticity, cross-sectional dependence, and unit root problems, which can otherwise lead to biased, inconsistent, or inefficient estimators. The results of these tests are presented in table 5. For the purpose of autocorrelation, we have used Woodridge test and the results of the test indicate that there is a strong evidence of first-order autocorrelation in the data. For the purpose of testing Heteroscedasticity, we employed Breusch Pagan test and the results of the test indicate strong evidence of heteroscedasticity in our regression model. To address the issues of autocorrelation and heteroscedasticity, we have used PPML with robust stand standard error and FGLS model in our regression model. These models provide efficient estimates under autocorrelation and heteroscedasticity conditions by transforming the data to stabilize variance (Silva and Tenreyro (2006) [29], Baltagi, 2008, Greene, 2012,) [5, 15]. The study also performed Cross-Sectional dependence test using Breusch-Pagan LM test of

independence. The results of the test imply that the error terms across the cross-sectional units (countries) are independent, indicating no significant cross-sectional dependence in the dataset.

The study also tests the data for stationarity. Given that no cross-sectional dependence in the data, the study employed first-generation panel unit root tests. Specifically, the Levin-Lin-Chu (LLC) test is utilized. The results of the test are presented in table 6. The outcomes of the test indicate that all variables in our panel data are stationary at level, ensuring that their statistical properties are constant over time. The absence of unit roots aligns with the assumptions necessary for applying models like the PPML and feasible generalized least squares FGLS as employed in our study (Gujarati, 2009) [16]. This strengthens the robustness of our analysis in the study.

Table 5: Basic Diagnostic Tests

Test	Test Statistic	p-value	Conclusion
Wooldridge Test for Autocorrelation	F(1,17) = 549.93	0.0000	Serial correlation present
Breusch-Pagan Test (Heteroskedasticity)	$\chi^2(1) = 13.57$	0.0002	Heteroskedasticity present
LM Test for Cross-Sectional Dependence	$\chi^2(231) = 743.21$	0.2573	No cross-sectional dependence

Source: *Author's computation From Stata 17.*

Table 6: Panel Unit Root Test

Variable	Adjusted t-stat	p-value	Stationarity Decision
L_BT	-4.4673	0.0000	Stationary (Reject H₀)
L_GDPind	-2.7868	0.0027	Stationary (Reject H₀)
L_GDPptr	-5.9560	0.0000	Stationary (Reject H₀)
L_TOPind	-4.9179	0.0000	Stationary (Reject H₀)
L_TOPptr	-2.9724	0.0015	Stationary (Reject H₀)
DTT	-2.2848	0.0085	Stationary (Reject H₀)

Source: *Author's computation From Stata 17.*

4.4 Regression Results: Poisson Pseudo Maximum Likelihood (PPML) model

The Poisson Pseudo Maximum Likelihood (PPML) estimation results in Table 7 offer critical insights into the determinants of India's bilateral trade flows and the role of Double Taxation Avoidance Agreements (DTAAs). The model is specified in three variants to increase robustness and address unobserved heterogeneity: Model 1 (baseline PPML), Model 2 (with time fixed effects), and Model 3 (with both time and country fixed effects). The estimation strategy is consistent with Silva and Tenreyro (2006) [29], who advocate PPML as the preferred approach in gravity models due to its robustness to heteroskedasticity and its capacity to handle zero trade flows without transformation bias.

The empirical results of PPML model indicate that the coefficients of GDP of India and GDP of partner countries remain positive and statistically significant across all three models. In model 1 the coefficient of GDP of India states that 1% increase in GDP of India is associated with the 0.0521% of India's bilateral trade. Similarly, the coefficient of GDP of partner countries suggests that 1% increase in GDP of partner countries leads to 0.0478% increase in India's bilateral trade. These results are in line with the classical gravity model (Tinbergen, 1962; Anderson & van Wincoop, 2003) [30, 2], which posits that larger economies trade more due to their greater production capacity and demand potential. The variables trade openness of India and trade openness of partner countries have positive and statistically significant coefficients across all specifications. This suggests that liberal trade policies, fewer non-tariff barriers, and integration into global value chains lead to increased trade. As expected, the coefficient of distance is negative and highly significant across all models, confirming its role as a trade deterrent. In Model 3, the coefficient increases in magnitude to -0.290, highlighting the friction that physical separation imposes on trade. Despite advances in transportation and digital connectivity, distance still poses a substantial barrier (Disdier, A. C., & Head, K. 2008) [8]. Policymakers should continue to invest in trade facilitation infrastructure (e.g., port efficiency, logistics corridors like Sagarmala and Bharatmala) to reduce effective trade costs.

Double taxation treaty which is the key explanatory variable of interest and other variables used in our study, such as common borders, common official languages, and colonial relationships, are dummy variables indicating the presence or absence of each factor to predict their impact on India's bilateral trade. Following Silva and Tenreyro (2006) [29], the effect of change in variable x on variable y is calculated by $\{(e^{\alpha} - 1) \times 100\}$where α is the coefficient of a dummy variable. Interpreting the coefficients of dummy variables in an exponential form is essential in log-linear models, such as the gravity model of trade, to provide meaningful percentage changes (Baier and Bergstrand 2007 [3] and Head and Mayer 2014) [18]. The empirical results of PPML reported in the model 1 shows that tax treaty is positive and statistically significant at 1% level. The coefficient of the tax treaty signifies that signing a tax treaty increases bilateral trade by approximately $\{(e^{0.021}$-1) × 100} 2.12% compared to those without a tax treaty. This significant positive impact suggests that tax treaties help reduce trade barriers and foster economic exchange. These results are in line with the results of Egger *et al.* (2006) [9] and Pham *et al.* (2019) [27]. The coefficient of tax treaty in model 2 and model 3 increases significantly and remains positive, suggesting that tax treaties have a stronger positive impact on trade when controlling for both time and country-specific factors. These treaties create a more predictable legal environment by reducing the risk of double taxation, resolving jurisdictional uncertainties, and providing dispute resolution frameworks, which enhances firms' willingness to engage in cross-border trade (Camarero *et al.* 2020; Nguyen *et al.* 2020) [7, 26]. Furthermore, they signal institutional credibility and commitment to international

norms. This implies that India should not only maintain but actively modernize and strategically expand its DTAA network, especially with emerging economies and underutilized trade partners.

The coefficient of common border is negative and statistically significant across all three models. This is contrary to standard gravity expectations but can be understood in the context of geopolitical frictions (e.g., India-China, India-Pakistan). The coefficient of common official language is positive and significant across all models. The magnitude of the coefficient increases significantly in model 3, suggesting a stronger positive impact of common official language on India's bilateral trade when country and time fixed effects are introduced in the model. This implies that encouraging English-language business education, bilingual trade documentation, and institutional support in multilingual jurisdictions could enhance trade efficiency, especially with Anglophone economies (Melitz, J. 2008) [24]. The variable colonial relationship shows mixed effects. It is negative in Models 1 and 2 but positive in Model 3 suggesting that the colonial relationship becomes trade-enhancing once time and country-specific effects are controlled (Head, Mayer, & Ries, 2010) [19]. This implies that while colonial ties may initially reflect extractive trade patterns, over time they also create legal, institutional, and linguistic commonalities that foster long-term commercial ties.

Moreover, the results of the PPML model depict that the model 1 has an R-square value of 0.805 which indicates that approximately 80.5% of the variance in India's bilateral trade can be explained by the variables included in the model. Model 3 shows an increase in the R-squared value to 0.872, indicating that 87.2% of the variance in bilateral trade is explained by the model when both time and country fixed effects are included. This substantial increase suggests that unobserved heterogeneity at the country level plays a significant role in determining trade flows. By controlling for both time-specific and country-specific factors, Model 3 provides the most accurate and comprehensive explanation of the factors influencing India's bilateral trade.

Table 7: Estimated Results OF the PPML Model

Variable	Model 1	Model 2	Model 3
lnGDPind	0.0521***	0.0515***	0.0501***
lnGdpPtr	0.0478***	0.0476***	0.0678***
lnTOPind	0.0540***	0.0542***	0.0370***
lnTOPptr	0.0240***	0.0247***	0.0394***
lnDist	-0.1140***	-0.1140***	-0.2900***
DTT	0.0210***	0.0214***	0.0374***
ComB	-0.0783***	-0.0781***	-0.0923***
ComOL	0.0578***	0.0578***	0.210***
ColRel	-0.0468***	-0.0467***	0.0978***
Constant	-1.2890***	-1.3030***	-2.2300***
Observations	378	378	378
R-squared	0.805	0.822	0.872
Country FE		Yes	Yes
Year FE			Yes
("* $p<.10$, ** $p<.05$, *** $p<.01$")			

Source: *Author's computation From Stata 17.*

4.5 Robustness Check: Feasible Generalized Least Squares (FGLS)

The study uses the Feasible Generalized Least Squares estimate technique to confirm the robustness of the baseline Poisson Pseudo Maximum Likelihood (PPML) results. FGLS is particularly suitable for panel data where autocorrelation and heteroskedasticity is present, which are already confirmed in this study by the Wooldridge and Breusch-Pagan tests. FGLS transforms the data by estimating the error structure and adjusting the model accordingly, yielding efficient and unbiased estimates under generalized least squares assumptions.

The empirical findings of FGLS model are presented in Tables 8. The results of the FGLS model are similar to those presented in PPML model confirming the robustness of the results. The results of the FGLS estimator indicate that a 1% increase in GDP of India and GDP of partner countries will lead to an increase in India's bilateral trade by 0.80% and 0.845% respectively. This reinforces the importance of sustained economic growth and macroeconomic stability as essential conditions for trade expansion. Similarly, a 1% increase in trade openness of India and its partner countries increases the trade by 1.068% and 0.318% respectively. This implies that India's trade liberalization policy produces stronger effects on its global trade activities than liberal trade policies implemented by its trading partners. The variable for distance remains negative and significant, affirming the conventional gravity model finding that geographic distance decreases trade. Most importantly Double Taxation Treaty variable shows a positive impact which holds statistical significance indicating countries that have DTTs experience trade growth in addition to their role in combating double taxation. The results of the other variables in this model are in line with the results of the PPML model. The FGLS robustness check confirms the consistency and reliability of the primary findings of the study. It supports the view that India's network of double taxation treaties positively contributes to its bilateral trade, and policy efforts to expand, modernize, and align these treaties with trade objectives are likely to yield substantial economic benefits.

Table 8: Estimated Results of FGLS Model

Variable	Coefficient	Robust Std. Err	P-value
lnGDPind	0.800	0.092	0.000
lnGdpPtr	0.845	0.075	0.000
lnTOPind	1.068	0.078	0.000
lnTOPptr	0.318	0.068	0.000
lnDist	-1.717	0.304	0.000
DTT	0.108	0.059	0.006
ComB	-0.985	0.292	0.001
ComOL	0.803	0.209	0.000
ColRel	-0.798	0.284	0.005
Constant	-13.449	3.055	0.000
Observations	378		
Chi-square	859.117		

Source: *Author's computation From Stata 17.*

5. Conclusion and Policy Implications

The focus of this study intended to use an augmented gravity model to examine the trade-enhancing implications of India's Double Taxation Avoidance Agreements (DTAAs). The analysis employed panel data on bilateral trade between India and its 18 largest trading partners from 2000 to 2020. Poisson Pseudo Maximum Likelihood (PPML) estimate was used as the baseline method, and Feasible Generalized Least Squares (FGLS) was used to confirm robustness. The empirical results constantly

demonstrate that the existence of a DTAA between India and a trading partner exerts a positive and statistically significant effect on bilateral trade. The PPML model, especially when incorporating time and country fixed effects, reveals that DTAAs are associated with approximately $\{(e^{0.03745}-1) \times 100\}$ 1.038% increase in bilateral trade compared to those without a tax treaty, while the FGLS estimates suggest an even stronger impact of around $\{(e^{0.108}-1) \times 100\}$ 11.40%. These results are robust across model specifications and confirm that tax treaties act not only as instruments of fiscal coordination but also as catalysts for trade facilitation.

The study presents insights to policy makers about how DTAAs create strategic tools for enhancing Indian participation in worldwide trading frameworks. India should build upon its existing network through tax treaty enhancements which must be directed toward national trade policy priorities. The process requires renegotiating and modernizing treaties through precise dispute settlement rules along with eliminating treaty benefit hindrances and following international standards from OECD BEPS base practices. The results also highlight the importance of coherence between tax and trade policymaking. India should strengthen existing treaties and pursue new agreements with emerging and under-traded economies where trade potential remains untapped. Moreover, aligning treaty negotiation priorities with India's broader trade strategy such as its development of FTAs or participation in regional trade blocs can help ensure that DTAAs are designed to support long-term economic and trade objectives. Even if DTAAs lower cross-border tax barriers, they may not be as successful if there are no accompanying domestic reforms. India must thus keep enhancing its digital trade platforms, logistical systems, port infrastructure, and customs effectiveness in order to fully reap the institutional advantages brought forth by tax treaties.

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