ANALYZING INDIA'S BILATERAL TRADE DYNAMICS WITHIN THE QUAD: A GRAVITY MODEL APPROACH

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ABSTRACT

This paper aims to analyze India's bilateral trade flows within QUAD concerning the Gravity Model of International Trade. The study includes distance and GDP as essential factors of trade relations and other quantitative variables. The results show the influence of importing nations' GDP and Population on India's exports, which underscores the significance of market size and demand in shaping trade relations. The presence of free trade agreements between India and its trading partners has also been found to facilitate trade activities. Contrary to conventional expectations, distance has been found to have a statistically insignificant impact on trade flows among the Quad countries. This suggests that advancements in communication and transportation technologies have mitigated the barriers posed by geographic distance, enabling countries to engage in trade relations irrespective of their physical proximity. The study suggests that policymakers are encouraged to bolster economic relations through initiatives like free trade agreements, recognizing the pivotal role of economic prowess in shaping bilateral trade within the QUAD. Additionally, investing in infrastructure and technology can help overcome geographic barriers, fostering smoother trade interactions among QUAD nations. Market access promotion, tariff reduction, and customs procedure streamlining are suggested measures to stimulate trade and enhance economic collaboration in the Indo-Pacific region.

KEYWORDS: *QUAD Countries, Panel Data, Gravity Model, Trade Potential.*

Declaration of Interest Statement

We, the authors of the manuscript **Analyzing India's Bilateral Trade Dynamics within the QUAD: A Gravity Model Approach** declare that we have no conflicts of interest to disclose.

We affirm that no financial, personal, or professional interests could be perceived as influencing the research findings or interpretations presented in this manuscript.

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1.1 INTRODUCTION

Trade is a foundation of the global economy, easing innovation, specialization, and the exchange of goods and services across borders. In an era of increasing globalization, trade has become integral to sustaining economic competitiveness and fostering growth. Grossman et al. (2015) emphasize how globalization fosters economic growth through information dissemination, market expansion, and technology transfer. Trade between nations fosters economic development and growth, bringing numerous benefits to the countries involved (Ijirshar, 2022). The determinants and explanations of export flows have been thoroughly analyzed and explored by policymakers and scholars since the beginning of globalization (Atif et al (2017). However, understanding the factors that influence bilateral trade dynamics within specific regional agreements is crucial for formulating effective trade policies and enhancing economic cooperation (Kumar & Ahmed, 2015). One such regional agreement is the QUAD, consisting of India, the United States, Japan, and Australia. The QUAD, also known as the Quadrilateral Security Dialogue, brings together four major democracies in the Indo-Pacific region and aims to promote cooperation on security and economic issues.

The basic logic behind the formation of the quad is to prevent China's influence across the Indo-Pacific region by uniting the countries around the Pacific region (Eisentraut, S., & Gaens, B. (2018),Hanada, R. (2019), Bayram, D. Ç. (2022), Deb and Wilson (2021)). Since the member countries cooperatehighly with defense and security issues, it is also argued that Quad needs to continue expanding its agenda beyond diplomacy and defense. Expanding its agenda in trade, finance, foreign investment, commercial technology, and information security would help to build the Pacific region stronger (Jaishankar, D., & Madan, T. (2021)). Motivated by China's efficient international trade practices, these strong economies work together to strengthen their trade relations (Agarwal, 2022).

Trade plays a crucial role in promoting economic growth and development, especially in developing countries like India (Kadir & Ozan, 2010). International trade, particularly within regional alliances like the QUAD, has the potential to generate significant economic benefits for India (GULNAZ & Manglani, 2022). While diplomatic relations and strategic alliances are important aspects of the QUAD, exploring the trade aspects within this alliance is equally essential. The role of India among the Quad countries is different as it is the only developing country in the Quad, which gives immense scope for the country to utilize the platform better in trade and finance within the Quad nation as the other three countries are technologically, financially, economically advanced (Panda, J. P. (2020). Apart from the diplomatic roles of Quad countries, the possible trade enhancement with other Quad members and India is underestimated. The comparative advantage of India will be high for many of the goods and services produced in India as it is unique and has a vast potential market in those developed nations (Goswami, B., & Nath, H. K. (2021). When discussing trade with India and other quad countries, the study looks towards the feasibility of trade between those countries. This thought has arisen because,

considering the cooperation between the countries in defense and diplomacy, the countries have an advantage of trade liberalization among the nations, which can be good for exports.

Consequently, this paper seeks to enrich the current literature on trade flows by investigating the trade relations among the Quadrilateral Security Dialogue (Quad) countries—India, the United States, Japan, and Australia. The focus is on analyzing the research question of how distance, GDP differentials, and other quantitative variables impact trade relations between India and the developed nations of the Quadrilateral Security Dialogue (Quad), comprising the United States, Japan, and Australia.

In this context, a notable research gap exists for identifying the factors affecting the trade dynamics between India and other QUAD members. While the Quad aims to strengthen cooperation among its members, little research has delved into how factors affect trade flows, particularly between the developing country of India and the advanced economies within the Quad. By employing the Panel data Gravity model, this study aims to address this gap and provide crucial insights for policymakers aiming to foster economic cooperation and trade relations in the Indo-Pacific region.

The Gravity Model of International Trade is a widely used framework in economics that provides insights into the determinants of trade flows between countries. It considers factors such as the size of economies, the distance between countries, and other socio-economic variables that influence trade patterns. While geographic distance continues to influence trade patterns, advancements in communication and transportation technologies have mitigated its impact. The role of distance as a trade barrier has evolved in the context of modern trade dynamics, challenging traditional perceptions. This contrasts with the expectation that reduced communication costs diminish the significance of distance in trade. Karpiarz et al. (2014) prove that the gravity model shows an increasing distance coefficient over time. This suggests that distance plays a growing role in trade dynamics. However, the effects of distance on trade relations vary across countries and industries, highlighting the need to refineits role in shaping trade flows.

As mentioned, the Gravity Model by Shepherd et al. (2019) presents a valuable tool for comprehending and shaping global trade dynamics. Its application in policy research has reshaped the landscape, influencing the types of goods traded, the participating countries, and trade barriers. Supporting, Chaney (2018) emphasizes the role of economic scale and distance in bilateral trade flows through the empirical evidence supporting the panel data Gravity Model. This model of international trade has emerged as a fundamental framework for understanding the patterns and determinants of trade relations between countries. It posits that the volume of trade between two countries is inversely correlated with their economic mass and directly related to their geographic proximity (Anderson and Wincoop (2003)). However, the impact of various factors such as distance, transportation costs, and the nature of goods and services traded on trade relations remains a subject of ongoing research and debate.Despite the growing importance of the QUAD in the international arena, there is limited research on the specific impacts of bilateral trade flows within this alliance. This paper aims to analyze India's bilateral trade flows within the QUAD concerning the Gravity Model of International Trade.

1.2 Review of literature

The research papers reviewed span a wide range of topics within international trade, with a significant focus on applying and analyzing the Gravity Model. The studies highlight the differential effects of distance on trade flows, particularly between developing and developed countries, and the importance of considering internal trade costs alongside bilateral distance estimations. Additionally, the studies explore methodological aspects of the Gravity Equation, factors beyond distance that influence trade, such as trade policies, and the consequences of globalization on trade. The studies also examine the applicability of the Gravity Model to specific countries' trade relationships and the impact of globalization on manufacturing trade.

Ramos et al. (2007) and Yotov (2012) emphasize the differential effects of distance on trade flows, particularly between developing and developed countries, and suggest considerations of internal trade costs alongside bilateral distance estimations. Salvatici (2013) delves into the methodological aspects of the gravity equation, stressing factors beyond distance, such as trade policies, that influence trade. Greene (2013) and Costinot et al. (2014) investigate the consequences of globalization on trade, including the impact of trade policies and market liberalization gains. Karpiarz et al. (2014) and Malik et al. (2014) explore paradoxes in distance and geopolitical factors affecting trade dynamics. Sejdini (2014) and Stay et al. (2016) examine the applicability of the Gravity Model to specific countries' trade relationships, while Borchert et al. (2017) and Thai-Ha Le (2017) focus on the impact of globalization on manufacturing trade and the significance of economic factors in bilateral trade and FDI flows.

Other studies, such as Natale et al. (2015) and Maciejewski et al. (2019), analyze trade dynamics in specific sectors or regions using the Gravity Model, highlighting product characteristics and regional trade dynamics. Shahriar et al. (2019) and Baier et al. (2020) review the Gravity Model's theoretical foundations and estimation methodologies, stressing its continued relevance and the importance of methodological innovations. Zhang (2023) affirms the gravity model's effectiveness in understanding bilateral trade relationships. Stevens et al. (2020) explore the economic geography of cities and workplace dynamics, offering insights into trade-related factors like gender and power dynamics. Bhatt (2019) indicates that India's international trade is significantly influenced by trading partners, logistics performance index, and distance using the augmented gravity model. Lastly, Agarwal et al. (2022) examine the impact of political shocks on trade, focusing on India's relations with Quad countries and China's economic influence. These studies collectively contribute to a comprehensive understanding of international trade dynamics, emphasizing the multifaceted role of financial, geopolitical, and methodological factors in shaping trade patterns.

Itprovides a deeper understanding of the Gravity Model's applicability across various contexts. They emphasize the importance of considering multiple factors in understanding trade flows, including distance, trade policies, and internal trade costs. The studies also highlight the significance of methodological innovations and continued research on the Gravity Model to enhance our understanding of international bilateral trade dynamics.

1.3 Econometric model, approach, and data sources

1.3.1 Econometric Model

The gravity model of trade is one of the empirical tools used to explain the international trade flows among economic partners. Gravity models are used in various fields, such as environment,

migration, transportation, health and education, stock market behavior, and trade flow (Kabir et al., 2017). Although the model was initially used by E.G. Ravenstein in 1889 to know the impact of the country's size and migration lead, it was first introduced in the empirical studies of International Trade by Tinbergen (1962) and Poyhonen (1963). Its origin in 1687 arose through a Newtonian Physics belief, i.e., the two bodies' mutual attraction is determined by the product of their masses divided by the square of the separation between their gravity centers. It led to the following equation:

$$F = G \frac{m_1 \times m_2}{r^2}$$

The trade equation is comparable to the law, stating that the trade between two nations is inversely correlated with their distance from one another and directly proportional to the GDP of each nation. The gravity model can be written in its basic form as follows:

$$Trade_{ij} = \alpha \frac{GDP_i \times GDP_j}{Distance_{ij}}$$

Where $Trade_{ij}$ is represented as the Volume of Trade between i and j countries; GDP_i and GDP_j are indicated as the national income of i and j countries respectively, and $Distance_{ij}$ is the distance between the two countries (substituted for Trade Costs).

For the regression analysis, the equation is usually converted into the linear log form, written as:

$$\log \log(Trade_{ij}) = \alpha + \beta_1 \log \log(GDP_i \times GDP_j) + \beta_2 \log \log(Distance_{ij}) + \mu_{ij}$$
(1)

The given log-linear equation is the basic gravity model equation where trade is predicted to be a positive function of income and a negative function of distance from trading partners. Reducing trade barriers to maximize trade gains is one of the main goals of every trade deal. The variables that impede the smooth flow of commodities from exporters to importers, also known as transaction costs, include indirect barriers to trade and direct barriers, such as introducing tariffs. Trade costs are a category that includes trade barriers in the literature. The cost of transportation (including freight and time costs), border-related barriers (including linguistic, financial, informational, and security barriers), policy barriers (including tariffs and non-tariff), and the cost of retail and wholesale distribution are the main elements of trade cost, according to Anderson and Wincoop (2004). Distance can be used as a possible substitute for trade costs due to their broader impact on trade flows alone as proposed by Anderson and Wincoop (2004) and De (2007). In the model, distance is a substitute variable for transportation costs. This assumption posits that the transportation cost from the importer country to the exporter country is considered equivalent to the cost from the exporter country to the importer country, where the distance costs are the linear function of the distance. Ramos et al. (2007) explain that because of the tendency to be fixed for the demand and supply situation in the market and their doubtful representation of cultural proximity, information costs, and their perceived closeness, the transportation costs can only be assumed to be the distance in the model.

This basic model can be extended by incorporating other factors that can impact the bilateral trade between the countries (Frankel et al, 1997). The study also accounts for the following

factors: Population, RFE, trade openness, and a dummy if the nations are a part of any common free trade agreement. Therefore, the gravity model used in this study can be given by:

$$Trade_{it} = \beta_0 \text{GDP}_{it}^{\beta_1} \text{GDP}_{jt}^{\beta_2} POP_{it}^{\beta_3} POP_{jt}^{\beta_4} \text{Distance}_{ij}^{\beta_5} REF_{ij}^{\beta_6} TO_{it}^{\beta_7} FTA_{ij}^{\beta_8} \text{quad}^{\beta_9} \tag{2}$$

Taking the natural logarithm of eq. (2), we get:

$$\ln(Trade_{it}) = \beta_0 + \beta_1 \text{GDP}_{it} + \beta_2 \text{GDP}_{jt} + \beta_3 POP_{it} + \beta_4 POP_{jt} + \beta_4 \text{Distance}_{ij} + \beta_5 REF_{ij} + \beta_6 TO_{it} + \beta_7 FTA_{ij} + \beta_8 quad + \mu_{it} \tag{3}$$

Where, POP_{it} and POP_{jt} represent the population of i and j countries in t period, REF is the relative factor endowment that represents the difference in the sample countries in terms of the factor endowments, TO is a trade openness representing the openness of India with the world, FTA is a dummy taking value of 1 if India and trading partner are a part joint free trade agreement and 0 otherwise, and Quad is a dummy taking value 1 for the years after 2007 when Quadrilateral Security Dialogue (Quad) was formed between India, US, Australia, and Japan. μ_{it} is the error term and follows a normal distribution.

1.3.2 Econometric approach

Cross-sectional data is mainly used to estimate the trade effects and trade relationships for a particular period. However, the cross-sectional data over different periods, referred to as panel data, is more relevant for the estimation. This panel data methodology calculates the relatable relationship between the variables. According to Egger (2000), unraveling time-invariants and country-specific effects is the most appropriate. It also allows the reduction of bias prompted by heterogeneity across countries. Thus, this study uses panel data methods for the evidential gravity model of trade flows. To analyze the determinants of the trade flow (export and import flows), exports, imports, and total trade are acceptable as dependent variables.

The panel data gravity model can be estimated using OLS, fixed-effects, and random-effects panel data models. However, applying OLS to the gravity model can lead to biased estimates, mainly due to heteroscedasticity and omitted variable bias (Kalirajan, 2008; Silva and Tenreyro, 2006). Though the fixed-effects model helps to account for the unobserved heterogeneity (Nasrullah et al., 2020), it is unable to evaluate the presence of some of the time-invariant variables. The random effects model overcomes these issues of the fixed effects model. Thus, the Hausman Test is applied for the appropriate choice of random and fixed-effect, which assumes a null of no significant correlation between the explanatory variable and the error term. The statistically significant coefficient rejects the null hypothesis and produces evidence that the fixed effect model would be the best-fitted model.

Further, the Lagrange Multiplier test of Breusch and Pagan (1979) is used, which follows the Chi-square distribution with 1 degree of freedom. The test has a null hypothesis that the variance of individual-specific effects is zero. The null hypothesis is rejected in case of a statistically significant coefficient on the Lagrange test and indicates that random heterogeneity is present in the model.

However, these techniques fail to consider the impact of "behind-the-border" restrictions on exporting nations, which results in inaccurately estimated coefficients. Kalirajan (2008) introduced the SFGA technique to address this problem by simulating the combined effect of all "behind-the-border" factors on bilateral between the nations. These characteristics may arise due to many socio-political-institutional elements that vary among countries and are within the power of exporting and importing countries. These "behind-the-border" factors create the disparity between the actual and potential trade of the two nations. These variables are accounted for in the single-sided error term (ε_t). Thus, our model can be written as:

$$\ln(Trade_{it}) = \beta_0 + \beta_1 \text{GDP}_{it} + \beta_2 \text{GDP}_{jt} + \beta_3 POP_{it} + \beta_4 POP_{jt} + \beta_4 \text{Distance}_{ij} + \beta_5 REF_{ij} + \beta_6 TO_{it} + \beta_7 FTA_{ij} + \beta_8 quad + (v_t - \varepsilon_t)$$

(4)

If it ε_t takes a value other than 0, it shows that such restrictions would prevent actual exports from reaching their full potential (Kalirajan, 2007). Therefore, assessing the effects of such restrictions is crucial to reducing export restrictions. Additionally, the double-sided error term (v_t) evaluates other variables, including measurement errors. The SFGA method shows significant improvements over the conventional methods of measuring the gravity model.

1.3.3 Data sources

The data on bilateral trade flows between India and other quad nations (Australia, the US, and Japan) for the period from 2000 to 2021 are collected from two sources: (i) the World Trade Integrated Solution (WTIS) tool of the United Nations Conference on Trade and Development (UNCTAD) and the World Bank; and (ii) Centre for Prospective Studies and International Information (CEPII) that provides data to estimate gravity equations. The Gross Domestic Product (GDP), Trade openness, and Population data are collected from the World Development Indicators database. Information on free trade agreements, relative factor endowments, and distance are collected from the CEPII database.

RFE has been calculated using the formula mentioned hereafter. RFE is used to calculate how much a pair of countries vary from one another in terms of relative factor endowment. A larger difference in RFE indicates the presence of a higher volume of inter-industry trade, and the opposite is also true. The natural logarithm of the capital-labor ratio's absolute difference is typically used to measure this variable. GDP is utilized in place of the capital-labor ratio due to the lack of statistics per capita. The presumed sign of the variable is positive. Therefore, the Relative Factor Endowment is extracted as:

$$RFE_{ij} = lnPGDP_i - lnPGDP$$

1.4 Empirical results

1.4.1 Pre-estimation analysis

Using the panel data models, we estimate the gravity model equations (cf. eq. 1, 2, and 3). The sensitivity analysis (cf. Table 1) suggests the inapplicability of the fixed effects model to our export's dataset as the F-statistic associated with the fixed effects model is statistically insignificant at the conventional significance levels. Therefore, we choose between pooled OLS and the random effects model based on the estimated coefficient of the *Lagrange Multiplier test of Breusch and Pagan (1979)*. We note a statistically insignificant coefficient with a p-value of

1.000; thereby, we do not reject the null hypothesis $Var(v_i) = \sigma_v^2 = 0,$, which indicates the absence of random heterogeneity in the model. Thus, pooled OLS is the most appropriate method for our export dataset. Likewise, we apply all three tests for our imports and total trade dataset, and it is noted that the fixed effects model turns out to be the most effective (cf. Table 1). The estimated results for exports (OLS), imports (fixed effects), and total trade (fixed effects) gravity equations are provided in Models 1 and 2 of Tables 3, 4, and 5, respectively.

Nevertheless, the fixed effects model does not provide the estimates of time-invariant variables like distance, foreign trade agreements, or dummy variables for free trade agreements and Quad. Furthermore, the pooled OLS or fixed effects model neglects the impact of the exporting country's "behind-the-border" constraints, resulting in unbiased estimators. As noted in Table 2, the value of gamma and ilgtgamma is statistically significant for the exports and total trade models, suggesting the role of "behind the border" factors in explaining the variations in the exports and total trade models. Moreover, the negative and statistically significant values of *eta* indicate that the degree of inefficiencies in the exports and total trade models increases over time. The significant value of *mu* also shows the applicability of the SFGA model as it depicts the truncated normal distribution. These sensitivity checks denote the applicability of the SFGA model.

Further, we also apply the pre-estimation tests for heteroscedasticity and autocorrelation to get efficient and unbiased estimates. The Bruesch-Pagan (1979) test is used to test heteroscedasticity, which is based on regressing the squared error term on explanatory variables (i.e., running auxiliary models). Estimating such auxiliary models will help to examine if any significant relationship exists between the squared error term and independent variables. The test assumes a null hypothesis of homoscedastic variance of the error term (i.e., $var(\varepsilon_{it}) = \sigma_\varepsilon^2).$ The statistically significant coefficient on the *F*-statistic rejects the null hypothesis.

 Furthermore, it is also crucial to check for serial correlation as estimates are inefficient, and standard errors are biased in the presence of autocorrelation. Drukker (2003) shows that the Wooldridge (2002) test of autocorrelation has good power and size properties and recommends testing if idiosyncratic error terms are serially correlated in the panel data model. This test is based on a null hypothesis of no first-order autocorrelation in residuals generated from the first-differenced regression. Specifically, it hypothesizes the correlation between residual from the first difference regression is equal to 0.5 (i.e., $corr(\Delta\varepsilon_{it}\Delta\varepsilon_{it-1}) = -0.5).$ This null hypothesis is rejected with the statistically significant coefficient on *F*-statistics. However, as the estimates show, none of our gravity models depict the presence of first-order autocorrelation, while heteroscedasticity is present in the variance of the error term of the export gravity model (cf. Table 3). Thus, we utilize White's heteroscedasticity-corrected robust standard errors for the export gravity model that allows for heteroscedasticity without affecting the magnitude of coefficients.

1.4.2 Main Findings

1.4.2.1 Export gravity model

The estimates of the export gravity model are provided in Table 4. We compute the model using both OLS and SFGA models for robustness purposes. Models 1 and 3 represent the basic gravity model, and Models 2 and 4 represent the augmented gravity models. The estimates of OLS and

SFGA are almost similar in terms of the magnitude and direction of the relationship. Thus, given the applicability and suitability of SFGA to our dataset, we explain our estimates using SFGA estimates. It is noted that the GDP and population of importing nations significantly influence India's exports. Specifically, the estimates show that the higher the income and population of the importing country, the higher the export value of India.

Regarding the influence of the domestic country, we note a positive influence of the Population of India on its exports; it implies that as the population increases by 1%, Indian exports increase by approx. 4.7% as it stimulates the development capacity. Likewise, the positive coefficient on the GDP of India indicates that a 1% increase in GDP leads to approx.—0.38% increase in India's exports.

Further, it was found that exports were higher if India had a free trade agreement with the trading partner. Furthermore, India's (an exporting country's) openness has a positive and statistically significant impact on its exports, which may be boosted because trade openness encourages technology transmission, efficient resource allocation, and knowledge spillovers (Wei, 2017). Though it is expected that a smaller distance reduces transportation costs and thus promotes trading activities (Bui, 2017), our SFGA and OLS estimates depict a statistically insignificant impact of distance between India and its trading partners on India's exports. This suggests that trade openness, free trade agreements, and other economic factors influence trading ties more than the distance between trading partners. Besides, the dummy for the origin of the Quad has no significant impact on the trading activities.

1.4.2.2 Import gravity model

Table 5 shows the estimates of the import gravity model. Both OLS and SFGA models have been used for the estimation to provide strong results. Models 1 and 3 represent the basic gravity model, whereas models 2 and 4 represent the augmented gravity model.

As found in the preliminary analysis, the fixed-effects model is the most appropriate for estimating the imports gravity model when compared to the SFGA estimated; therefore, we explain our estimates using the fixed-effects model. Regarding the influence of exporting nations, India's GDP and population significantly impact its imports. Specifically, it is noticed that a 1% increase in the population of trading partners leads to a 0.68% increase in their exports to India. Likewise, higher GDP also enhances the imports of the countries to India. Concerning the domestic factors, the GDP of India is noted to have a positive and statistically significant influence on its imports, while the population is noted to exert no significant impact.

In addition, it was found that if India had a free trade agreement with a trading partner, there would have been no imports among the countries. India's openness as an importing country is positive and statistically significant on its imports by approx. 0.07% to foster international relations based on technology and knowledge, but much less when compared to India as an exporting country (as explained in the export gravity model). Our fixed effects model shows no significant impact of distance on the volume of imports by our domestic country and the SFGA estimates further reiterate that distance does not hinder the trade relations among the countries. Furthermore, a dummy for the origin of the Quad has a negative but significant influence.

1.4.2.3 Total trade gravity model

The estimates of the total trade gravity model are provided in Table 6. The model is estimated using the fixed effects and SFGA models. However, given the applicability and superiority of the SFGA model over the fixed effects model (cf. Table 2), we focus on the estimated results of the SFGA model.

According to the findings, GDP and population significantly impact India's total trade. Notably, India's GDP and trading partners significantly impact the total trade between quad nations. For the population, consistent with our previous findings, only the population of trading partners significantly increases the volume of total trade, while the Indian Population has no significant impact. In addition, it is observed that India's Free Trade Agreement with other countries encourages total trade among the countries. India's openness as a total trade country is significant and positively justified by the impact of approximately 0.21% as it empowers the economies inside out.

Considering the distance to be the significant part according to theory, it is noted that it plays a statistically insignificant and positive relationship with SFGA estimates and does not put on any results with the fixed-effect model, this leads to the result of distance not obstructing the total trade among the countries. This concludes that other several important factors influence total trade among the countries, not just distance. This finding is consistent across all our gravity models. Also, a dummy for the origin of the Quad shows a negative but insignificant impact on the activity.

1.5 Conclusion and Policy Implications

The gravity model of international trade provides valuable insights into the factors influencing trade flows between India and other QUAD nations, highlighting the role of economic mass, geographic proximity, and other determinants (Anderson and Wincoop (2003)). Key findings from export, import, and total trade gravity models reveal several notable trends. First, the influence of importing nations' GDP and Population on India's exports underscores the significance of market size and demand in shaping trade relationships. Similarly, the GDP of India and its trading partners significantly affects imports, indicating the importance of economic strength in driving bilateral trade (Frankel and Romer (2017)). Free trade agreements between India and its trading partners have also been found to facilitate trade activities, emphasizing the role of trade policies in fostering economic cooperation. Contrary to conventional expectations, distance has been found to have a statistically insignificant impact on trade flows among Quad countries. This suggests that advancements in communication and transportation technologies have mitigated the barriers posed by geographic distance, enabling countries to engage in trade relations irrespective of their physical proximity.

Furthermore, the analysis highlights the role of India's openness as both an exporting and importing country in facilitating trade relations with the Quad nations. India's willingness to engage in international trade and embrace globalization has enhanced trade activities, fostering regional economic growth and cooperation. Overall, the findings underscore the multifaceted nature of international trade and the need for a comprehensive understanding of the factors that drive trade relations between countries (Helpman et al, 2008). By elucidating the determinants of trade flows between India and the Quad countries, this study contributes to the existing literature on international trade dynamics (Anderson, 2011). It informs policymakers about strategies to

promote economic cooperation and prosperity in the Indo-Pacific region. This study was constrained to a static model within this econometric framework. While recognizing that the GDP of the previous year can influence the current year's GDP, this study, due to its static nature, exclusively considers the GDP for the current year. This limitation opens opportunities for future research to explore dynamic models encompassing the temporal impact of the previous year's GDP on the current year's economic indicators.

The following policy implications are derived from the study. Policymakers can focus on strengthening economic ties with these countries by pursuing free trade agreements and other economic partnerships, thereby leveraging the significant influence of economic strength in driving bilateral trade. the study also suggests that, invest in infrastructure development and technological advancements to enhance communication and transportation networks, which can mitigate the traditional barriers posed by geographic distance and facilitate trade relations among Quad countries. Policymakers can promote market access and trade facilitation measures, such as reducing tariffs and streamlining customs procedures, to encourage trade activities and foster economic cooperation in the Indo-Pacific region.

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1.7 Tables

Table 1: Specification tests for panel data models			
	Pooled OLS and FE	FE and RE	RE and OLS
	F-test	Hausman test	Breusch Pagan test
Exports	1.03 (0.365)	0.20 (0.905)	0.07 (1.00)
Imports	30.19*** (0.000)	23.07*** (0.000)	0.09 (1.00)
Total trade	16.05*** (0.000)	13.46*** (0.001)	0.010 (1.00)
Notes: OLS is ordinary least squares, FE is fixed effects mode, and RE is a random effects model; *** denotes the statistical significance at 1% level.			
Source: Authors' calculations.			

Table 2: Sensitivity tests for the estimates of SFGA			
	Exports	Imports	Total trade
lnsigma2	-2.003*** (0.171)	-4.607*** (0.104)	-4.155*** (0.307)
ilgtgamma	-5.256*** (1.017)	-4.914 (8.957)	-7.695*** (0.180)
mu	-0.992*** (0.084)	-0.319 (2.231)	-0.081*** (0.0005)
eta	0.236*** (0.079)	0.185 (0.523)	0.028*** (0.006)
Sigma2	0.134 (0.060)	0.009 (0.001)	0.0156 (0.004)
Gamma	0.005 (0.005)	0.007 (0.064)	0.0004 (0.00008)
Sigma_u2	0.0006 (0.0009)	0.00007 (0.0006)	0.00007 (0.00009)
Sigma_v2	0.134 (0.059)	0.009 (0.001)	0.0156 (0.004)
log-likelihood	-30.56	56.82	42.85
Wald Chi-square (p-value)	737.59*** (0.000)	5906.56*** (0.000)	6955.90*** (0.000)
Notes: SFGA is a stochastic frontier gravity approach; *** denotes the statistical significance at 1% level.			
Source: Authors' calculations.			

Table 3: Test for heteroscedasticity and autocorrelation

	BP HTS test	Wooldridge autocorrelation test
Exports model	13.16*** (0.0003)	0.154 (0.732)
Imports model	1.31 (0.251)	13.26 (0.167)
Total trade model	1.19 (0.274)	4.570 (0.166)
Notes: *** denotes the statistical significance at 1% level.		
Source: Authors' calculations.		

Table 4: Estimates of Exports Gravity Model for the period 2000-2021

	OLS estimates		SFGA estimates	
Variable	Model 1: Base model	Model 2: Augmented model	Model 3: Base model	Model 4: Augmented model
lnGDP$_i$	1.236** (0.580)	-0.393 (0.480)	1.236** (0.580)	0.388*** (0.140)
lnGDP$_j$	0.270 (0.378)	0.459 (0.533)	0.270 (0.378)	0.481*** (0.033)
lnPOP$_i$	-2.489 (3.133)	5.066 (3.390)	-2.489 (3.133)	4.748*** (0.961)
lnPOP$_j$	0.444 (0.354)	1.249 (1.012)	0.444 (0.354)	1.244*** (0.367)
lnDIST	-2.698 (3.265)	4.761 (9.013)	-2.698 (3.265)	5.150 (5.753)
RFE	-	0.613* (0.319)	-	0.631* (0.329)
FTA	-	11.181* (5.917)	-	11.418*** (1.430)
Dummy(quad)	-	-0.037 (0.174)	-	-0.026 (0.144)
OPEN	-	0.765 (0.512)	-	0.702** (0.318)
Constant	78.341 (102.365)	-204.93** (92.471)	78.341 (102.365)	-199.735*** (27.883)
F-stat./Wald	2191.95***	1493.49***	2191.95***	1493.49***
R-squared	0.920	0.925		
Obs.	66	66		
Notes: *, **, and *** denote the statistical significance level at 10%, 5%, and 1% respectively.				
Source: Authors' calculations.				

Table 5: Estimates of Imports Gravity Model for the period 2000-2021

	Fixed effects estimates		SFGA estimates	
Variable	Model 1: Base model	Model 2: Augmented model	Model 3: Base model	Model 4: Augmented model
lnGDP$_i$	0.392* (0.216)	-0.239 (0.283)	0.549*** (0.189)	-0.239 (0.352)
lnGDP$_j$	0.841*** (0.100)	1.335*** (0.108)	0.872*** (0.102)	1.335*** (0.134)
lnPOP$_i$	0.887 (1.439)	1.590 (1.629)	0.189 (1.416)	1.590 (2.121)
lnPOP$_j$	0.681** (0.388)	0.150 (0.301)	-0.119 (0.108)	0.150 (0.185)
lnDIST	-	-	2.432** (1.061)	17.518*** (3.070)
RFE	-	0.928***	-	0.927***

		(0.135)		(0.161)
FTA	-	-	-	11.754*** (2.402)
Dummy(quad)	-	-0.073 (0.077)	-	-0.088** (0.036)
OPEN	-	0.073 (0.112)	-	0.073 (0.106)
Constant	-41.598 (39.431)	-46.700 (42.970)	-30.275 (37.053)	-213.207*** (68.362)
F-stat./Wald	265.13***	266.68***	6950.00***	733.28***
R-squared	0.864	0.842		
Obs.	66	66		
Notes: *, **, and *** denote the statistical significance level at 10%, 5%, and 1% respectively.				
Source: Authors' calculations.				

Table 6: Estimates of total trade Gravity Model for the period 2000-2021

	Fixed effects estimates		SFGA estimates	
Variable	Model 1: Base model	Model 2: Augmented model	Model 3: Base model	Model 4: Augmented model
lnGDP$_i$	0.519** (0.244)	-0.294 (0.351)	0.690*** (0.222)	-0.294 (0.267)
lnGDP$_j$	0.688*** (0.114)	1.125*** (0.134)	0.722*** (0.117)	1.125*** (0.090)
lnPOP$_i$	0.603 (1.625)	2.631 (2.025)	-0.158 (1.568)	2.630 (1.811)
lnPOP$_j$	0.893** (0.439)	0.395 (0.374)	0.018 (0.120)	0.395* (0.234)
lnDIST	-	-	1.190 (1.165)	14.630*** (3.403)
RFE	-	0.858*** (0.168)	-	0.858*** (0.174)
FTA	-	-	-	11.555*** (1.440)
Dummy(quad)	-	-0.053 (0.095)	-	-0.053 (0.046)
OPEN	-	0.219 (0.139)	-	0.219*** (0.057)
Constant	-36.941 (44.543)	-76.887 (53.404)	-11.304 (43.110)	-217.115*** (45.711)
F-stat./Wald	222.30***	183.96***	4133.55***	6955.90***
R-squared	0.827	0.717		
Obs.	66	66		
Notes: *, **, and *** denote the statistical significance level at 10%, 5%, and 1% respectively.				
Source: Authors' calculations.				