

Trend and Effects of U.S Agricultural Standards on India's Exports of Fruits, Nuts and Vegetables

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ABSTRACT

Over time, the bilateral trade relations between India and the United States of America (U.S.A) have reached the global strategic partnership status, with the U.S.A emerging to be India's largest trading partner. Agricultural trade between the two countries remains topical as food safety measures remain delicate as both countries seek to protect the health and wellbeing of their consumers. The U.S.A. has very stringent food protocols in place that seemingly prohibit Indian horticultural product market access. The study attempted to define the effects of the U.S. agricultural food safety standards focusing on fruits, nuts, and vegetable (FNV). It used a 20-year panel data set, from 2001 to 2022. The gravity model was used for the regression. Results of the study indicated a mixed outcome. Consistent with theory, variables like GDP across all products revealed strong and statistically significant positive effect on export volumes of Indian fruits, nuts, and vegetables. The exchange rate was found to have a negative effect on fruits intimating that a weaker domestic currency boosts exports. In general, the gravity model emerged to have a stronger applicability as an analysis tool in international trade. Its formidable use remains consistent even in cases of micro analysis of specific product lines as was the case with fruits, nuts, and vegetables.

Keywords: Gravity model; Agricultural standards, Exports.



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INTRODUCTION

The United States of America is India's major trading partner. Trade between India and the U.S. has grown phenomenally and reached the global strategic partnership level (Congressional Research Service, 2020). Relatedly, India has an expanse agricultural base which makes it a top producer and exporter of agricultural products (Reddy, K, V., Reddy, D, D., and Sendhil, 2022). The country's diverse agro-climatic conditions, rich crop diversity and generic resource endowment enable perennial production of a variety of horticultural products like fruits and vegetables (Jha,

G. K and Punera, 2019). India can thus exploit the perennial seasonality variations and enhance its potential in horticultural production and export (Saxena, 2024).

India's horticulture has potential to raise farm and household income, create employment, enhance rural livelihoods and boast foreign currency inflow (Anilkumar, A., Girish, A, and Menon, 2021) (Kumar 2022). Through international nations can realise economic benefits from exports of goods in which they have comparative advantage (Naik, 2021). The

sector also has potential to positively impact on the achievement of Sustainable Development Goals (SDGs) (Mitra, A. and Panda, 2020). Horticultural products of fruits and vegetables for instance, have emerged as a leading pack with potential to accelerate high value exports for the country (Saxena, 2024). India's horticultural exports for the period 1990/91 to 2020/21 period grew from USD3,35 billion to USD41,56 billion (Kumar, K. 2022) (Nirmal, 2024). The country's fruit and vegetable output constitute 92% of horticultural output, with the country enjoying not only the 'sunrise clause' but also competitive advantage in exporting of horticultural products (Mitra, A. and Panda, 2020). India produces 13% and 21% of global fruits and vegetables, respectively (Jha, G.K., and Punera, 2019). By international level, vegetable production in India is second to China (Mitra, A. and Panda, 2020).

Health wise, the daily, habitual intake of F&V can prevent major non-communicable diseases like some categories of cancers and cardiovascular diseases (Kucuk, 2023). Fruit and Vegetable consumption in the U.S. remains below recommended dietary requirement. In 2019 for instance, the annual F&V consumption in the U.S. was 20.15/65.98 kg, a figure much lower than countries like Turkey which had 32.87/122.33 kg, while, Canada, China, and Greece, had 29.65/71.43 kg, 36.77/330.68 kg and 53.15/77.13 kg, respectively (Kucuk, 2023). For that reason, consumption of High Value Commercial (HVC) crops like common mandarin and Indian goose berry are in high demand in the U.S., not only for their dietary value but also for derived medicinal properties (Sen, 2018).

The considerable expansion in agri-food trade has drawn along an upward trend in proliferation of non-tariff measure (NTBs), in particular the Sanitary and Phytosanitary Standards (SPS) as well as Maximum Residual Limits (Lamonaca, E and Santeramo, F.G, 2022). SPS measures occupy a special place among NTBs in agri-food trade due to the sensitive nature of like food safety and protection from pest and disease prevalence. In terms of notifications to the World Trade Organisation (WTO), SPS take up to 60% and Maximum Residual Limits (MRL) another 36% of the NTBs (Hejazi, M. 2021).

The impact of food safety standards remains varied in different countries depending on level of development and also product lines, in some instances being trade enhancing, while in some others, trade distorting (Yang, L. and Weigong, 2022). In the case of India, agricultural products exports to the U.S. constitute a great deal, yet India continues to face market access obstacles in the form of a plethora of SPS measures imposed by the U.S. (Hejazi, M. Grant, J.H. and Peterson, 2022). In the category of fruits and vegetables, postharvest fungal pathogens like black mold, green mold and fruit rot have been noted to be key determinants of export rejection and losses (Sen, 2018). Use of fungicides to control post-harvest diseases like stem-end rot caused by *diplodia natalensis* in mangos triggers ill health in humans (Virrey, 2023). Historically, the U.S. has been exposed to a myriad of foodborne disease outbreaks like Salmonella, in its fruits and vegetables category, due to pathogenic microorganism (Johnson, 2020). In the U.S., illnesses due to food contaminated with Salmonella and Escherichia coli, among other pathogens the main cause of thousands of hospitalisation and hundreds of deaths in the U.S (U.S Government Accountability Office, 2025).

The ability of India's agricultural exports to enter the U.S. market depends therefore on the strictness of the latter's food safety regulatory standards (Hejazi, M., Grant, J, H and Peterson. 2022). The screening and identification of adulterants and pathogens in imported foods and rejecting contaminated shipments is a measure taken by the U.S Food and Drug Administration (FDA) to ensuring consumption of safe food by its citizens (Ahn,J.W and Rhodes, 2021). This practice minimizes the risk of foodborne illnesses and in turn uphold the food safety and health of consumers (Fortin, 2022). To note that health and food safety standards offer means by which governments can claim protecting their population yet they create trading challenges to the exporting countries (Kim.S.Y, 2022). For the period 2002 to 2019, the U.S detected 22 459 pathogen/toxin violations, with fruits and fruit products accounting for 1 388 cases and vegetables and vegetable products, 925 cases (Ahn, 2021). Of the 22 459 violations, India led the pack by accounting for 5 115 cases, this translating to 22,9% of the total of all refusals (Ahn, J. W and Rhodes, 2021).

Beyond India were Mexico, Vietnam, Indonesia, France and Bangladesh and others, in that order.

India's agricultural export commodities continue to face rejection in the international markets including the U.S. due to non-compliance to stringent regulatory standards (Chatterjee *et al.*, 2023). Compliance with SPS and MRLs based standards and regulations is challenging for Indian firms and growers, with information asymmetry and lack of technologies being some of the major factors (Kallummal, M., and Gurung, 2020). In as much as tariff barriers have fallen under the WTO trading arrangements, India's trade in high quality products have increased though exports continue to face risks in terms of failure to comply with certification and food safety standards protocols (Mouzam, 2020). According to the US Food and Drug Authority, for the period 2002 to 2021, out of 110 countries, India had the highest pathogen-related violations numbering 5 115 with Salmonella being the main cause of shipment refusal at 2 313 rejections (Ahn, J., 2021). Fruit and fruit products accounted for 1 388 and vegetable, 925 rejections. Even with a decline in violations of India's food exports to the U.S. from 1 million tonnes in 2011 to 1.8 million in 2019, nearly halving, the rate of decline is lower than those of other leading countries (Ahn, J. 2021).

Against this background, the study seeks to determine the effect of the U.S. food safety measures on India's export performance of FNV for the period 2001-2022. It thus provides insights to government and policy makers with policy interventions to stir growth in the same sector (Kumar, K.N.R, Naidu.G.M, 2024). To note that available literature is limited with insights on product specific SPS challenges and policy appraisals. In the study, panel data with a time series component of 20 years, from 2002 to 2021 was used. Data on India's fruits, nuts and vegetables exports to the U.S. in million USD were obtained from the United Nations Commodity Trade Statistics database (UN COMTRADE) produced by the United Nations statistical office and the statistics of FAO and APEDA. Data on distance was gotten from Sea-distance.org, with that for population and GDP derived from the World Bank World Development Indicators. The study

assumed the augmented gravity model for regression analysis as defined below:

$$\text{Log}(X_{ik}) = \alpha + \beta_1 \log(Y_i Y_k) + \beta_2 \log(Y_i / \text{pop}_i Y_k / \text{pop}_k) + \beta_3 \log(\text{Dist}_{ik}) + \beta_4 (\text{Rej}_{ik}) + \beta_5 (\text{Exchr}_{ik}) + \beta_6 (\text{Tarif}_{ik}) + \beta_7 (\text{Col}) + \beta_8 (\text{landlocked}_{ik}) + \beta_9 (\text{Comlang}) + \beta_{10} \text{BTA} + \mu_{ik}$$

Where countries i and k are India and the U.S.A respectively.

X_i is the value of India's exports of fruits and vegetables to the U.S in million USD. A is a constant term, Y_i is the GDP of country i ; Y_k is the GDP of country j , Y_{ik}/pop_{ik} is per capita GDP of countries i and k ; D_{ik} is the distance in nautical miles between ports of importing country k , the U.S. and exporting country, i , India (Mumbai port). Rej_i represents the number of Indian goods consignments rejected by the U.S. with Exchr_{ik} representing the nominal exchange rate. μ is the regression error term.

RESULTS

This section presents the empirical findings derived from the application of gravity models to analyse India's exports of fruits, nuts and vegetables from United States, Canada, Australia, and New Zealand. The analysis was done jointly combining the U.S, and the other three countries for the feasible application of the gravity model that requires multi destinations. Canada, Australia and New Zealand were selected on merit that they have similar food safety protocols with the U.S. To note that the US Food and Drug Administration signed an agreement with Australia, Canada and New Zealand recognizing foreign food safety system as comparable. The analysis is based on a panel dataset covering a 20-year period with 80 observations for each commodity category. The dataset captures bilateral trade flows and includes key economic and geographic variables such as GDP of exporting and importing countries, population, exchange rates, and distance between trading partners. Log-transformed values are used to normalize skewed data and enhance model interpretability. Both baseline and augmented gravity models are employed to estimate the impact of these variables on trade flows. In addition, robustness checks using Ordinary Least Squares (OLS)—with and without time and exporter

fixed effects—are conducted to validate the stability of the results.

Product Analysis: Vegetables
Table 1 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Export trade	80	475455.79	938416.6	4661.83	6231154.5
ln exports	80	11.722	1.718	8.447	15.645
ppl of exporter	80	1.265e+09	97888242	1.098e+09	1.414e+09
importer population	80	93335391	1.275e+08	3948500	3.320e+08
GDP exporter	80	1750.122	794.757	514.94	3170
GDP importer	80	4.832e+12	7.041e+12	6.663e+10	2.368e+13
distance	80	11650.395	830.271	10435.1	12761.04
ln distance	80	9.361	.072	9.253	9.454
exchange rate	80	49.321	10.014	26.41	76.38
ln exchange rate	80	3.877	.212	3.274	4.336
land locked	80	0	0	0	0

The descriptive statistics for the dataset comprising 80 observations reveal that the average export trade value is approximately 475,456 USD, with a high standard deviation (938,417 USD), indicating substantial variation across country pairs. The natural logarithm of exports (ln exports) has a mean of 11.72, ranging from 8.45 to 15.65, suggesting a right-skewed distribution. The exporter population averages around 1.27 billion, while importer populations vary widely, with a mean of about 93 million. GDP values also show significant disparity, with exporter GDP averaging 1,750 billion USD and importer GDP reaching a mean of approximately 4.83 trillion USD. Geographical distance between trading partners is relatively consistent, with a mean of 11,650 km, and the log-transformed distance averaging 9.36. Exchange rates fluctuate between 26.41 and 76.38, with a mean of 49.32 and log exchange rates averaging 3.88. Notably, all trading partners in this dataset are non-landlocked, as indicated by the landlocked variable having a constant value of zero.

Table 2 Variance Inflation Factor (Baseline Gravity Model)

	VIF	1/VIF
ln GDP Exp	1.138	.879
ln distance	1.105	.905
ln GDP imp	1.033	.968
Mean VIF	1.092	.

The Variance Inflation Factor (VIF) test was conducted to check for multi collinearity among the explanatory variables in the baseline gravity model. The results show that ln GDP of the exporter has a VIF of 1.138, ln distance has a VIF of 1.105, and ln GDP of the importer has a VIF of 1.033. All VIF values are well below the common threshold of 5 (or 10), indicating no serious multi collinearity among the

predictors. The mean VIF is 1.092, which further confirms that the explanatory variables are statistically

independent and reliable for use in the regression model.

Table 3 Baseline Standard Gravity Model Estimation Results

Ln exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	.58	.07	8.35	0	.442	.719	***
Ln GDP Imp	.931	.023	40.33	0	.885	.977	***
Ln distance	-1.198	.536	-2.24	.028	-2.265	-.131	**
Constant	-7.374	5.238	-1.41	.163	-17.806	3.058	
Mean dependent var	11.722	SD dependent var	1.718				
R-squared	0.965	Number of obs	80				
F-test	704.306	Prob > F	0.000				
Akaike crit. (AIC)	51.763	Bayesian crit. (BIC)	61.291				
*** $p < .01$, ** $p < .05$, * $p < .1$							

The baseline gravity model regression explains the natural logarithm of export trade flows using economic size (GDP) and geographical distance as explanatory variables. The results are consistent with the theoretical expectations of the gravity model. The GDP of the exporting country (ln GDP Exp) has a positive and significant effect on exports, with a coefficient of 0.58 ($p < 0.01$), implying that a 1% increase in the exporter’s GDP is associated with a 0.58% increase in exports. Similarly, the importer’s GDP (ln GDP Imp) shows an even stronger positive influence, with a highly significant coefficient of 0.931, indicating a nearly proportional increase in exports with rising importer economic size. On the other hand, geographical distance (ln distance) has a negative and statistically significant effect (coefficient: -1.198 , $p < 0.05$), supporting the notion that greater distance increases trade costs and reduces trade volume. The model has a very high explanatory power with an R-squared of 0.965, suggesting that 96.5% of the variation in export trade is explained by the included variables. The model also passes the

overall significance test ($F = 704.31$, $p < 0.001$), confirming its robustness.

Table 4 Augmented Gravity Model

	VIF	1/VIF
ln exchange rate	3.151	.317
ln GDP Exp	2.334	.429
ln distance	1.716	.583
ln GDP imp	1.424	.702
Mean VIF	2.156	.

The Variance Inflation Factor (VIF) results for the augmented gravity model indicate that multi collinearity is not a serious concern. The highest VIF is for ln exchange rate at 3.151, followed by ln GDP of the exporter at 2.334, both of which are well below the commonly accepted thresholds of 5 (moderate concern) or 10 (serious concern). The ln distance and

In GDP of the importer also show low VIF values of 1.716 and 1.424, respectively. The mean VIF is 2.156, which suggests acceptable levels of correlation among

the independent variables. Overall, the model variables are sufficiently independent to provide reliable coefficient estimates in the regression.

Table 5 Augmented Gravity Model Estimation Results

Ln exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	.531	.105	5.06	0	.322	.74	***
Ln GDP Imp	.924	.026	35.63	0	.872	.976	***
Ln distance	-1.45	.67	-2.16	.034	-2.786	-.114	**
Ln exchange rate	.195	.309	0.63	.531	-.421	.811	
Land locked	0	.	.	.	.	.	
Constant	-5.202	6.288	-0.83	.411	-17.728	7.324	
Mean dependent var	11.722	SD dependent var	1.718				
R-squared	0.965	Number of obs	80				
F-test	524.137	Prob > F	0.000				
Akaike crit. (AIC)	53.340	Bayesian crit. (BIC)	65.251				

*** $p < .01$, ** $p < .05$, * $p < .1$

The augmented gravity model includes additional control variables beyond the standard gravity model, namely the exchange rate and landlocked status, to better understand their impact on export trade flows. The results confirm that economic size remains the dominant driver of trade, with both Ln GDP of the exporter (coefficient = 0.531, $p < 0.01$) and Ln GDP of the importer (coefficient = 0.924, $p < 0.01$) showing strong and statistically significant positive effects on export volumes. Geographical distance continues to exhibit a significant negative effect on exports (coefficient = -1.45, $p < 0.05$), consistent with trade theory, where greater distance implies higher trade costs.

The exchange rate, however, is not statistically significant (coefficient = 0.195, $p = 0.531$), suggesting that in this model specification, currency movements do not have a meaningful short-term effect on export

volumes. The landlocked variable is omitted (all values = 0), indicating there is no variation in this variable within the sample one of the partner countries are landlocked.

The overall model fit remains strong, with an R-squared of 0.965, meaning 96.5% of the variation in exports is explained by the model. The F-statistic is significant ($p < 0.001$), confirming that the model is statistically valid. However, compared to the baseline model, the exchange rate and landlocked controls do not add significant explanatory power, and the slight increase in AIC and BIC values suggests that model complexity may not yield additional benefit.

Augmented Gravity Model

Number of parameters: 5 Number of observations: 80
Pseudo log-likelihood: -6197787.1 R-squared: .58463694 Option strict is: off (Std.
Err. adjusted for 4 clusters in country pair)

Table 6 Robust

Export trade	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
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Ln_gdp_Exp	0.998	0.099	10.040	0.000	0.803	1.193
Ln_gdp_Imp	1.093	0.041	26.390	0.000	1.012	1.174
Ln_distance	0.175	1.158	0.150	0.880	-2.094	2.444
Ln_exchange_rate	-1.676	0.319	-5.250	0.000	-2.301	-1.050
_cons	-21.327	9.568	-2.230	0.026	-40.080	-2.575

The results of the Augmented Gravity Model provide a deeper understanding of the factors influencing export trade by including additional explanatory variables. The coefficients for both the exporter’s GDP (ln_gdp_exp = 0.998) and the importer’s GDP (ln_gdp_imp = 1.093) are positive and highly significant ($p < 0.001$), reinforcing the gravity model’s core principle that larger economies tend to trade more. Notably, the exchange rate variable (ln_exchange_rate) has a negative and significant coefficient (-1.676 , $p < 0.001$), indicating that depreciation of the exporter’s currency (India) relative to the importer’s currency (USA) is associated with a

substantial reduction in export trade—suggesting that volatility or unfavourable exchange movements hinder trade performance. In contrast to standard expectations, the coefficient for distance (ln_distance = 0.175) is positive but statistically insignificant ($p = 0.880$), implying that in this dataset, physical distance may not be a strong determinant of trade volumes, possibly due to modern transport and trade facilitation. The model’s R-squared value of 0.585 indicates an improved fit over the standard gravity model. Overall, the results validate the importance of economic size while highlighting the significant negative impact of exchange rate fluctuations on trade flows.

Table 7 Descriptive Statistics (Predicted Values for Model Fit Comparison)

Variable	Obs	Mean	Std. Dev.	Min	Max
Export trade	80	475455.79	938416.6	4661.83	6231154.5
Fitted Standard	80	475455.79	728826.58	1523.354	2674150
Fitted Augmented	80	475455.79	728826.58	1523.354	2674150

The descriptive statistics comparing predicted values from the Standard and Augmented Gravity Models with actual export trade reveal useful insights into model fit. The mean export trade value for the observed data is 475,455.79, which matches the mean of both the fitted values from the Standard and

Augmented models, confirming that both models are centered around the actual average trade value. However, while the standard deviation of actual exports is relatively high (938,416.6), the predicted values from both models show a smaller standard deviation (728,826.58), suggesting the models smooth

out some of the variability present in real-world trade data. The range of predicted values (from 1,523.35 to 2,674,150) is also narrower than that of the observed exports (from 4,661.83 to 6,231,154.5), indicating that while the models capture the central tendency of trade

flows, they may under predict extreme values. Nonetheless, the close alignment in means supports that both models, especially the Augmented Gravity Model with a higher R^2 , provide a reasonable fit to the data.

Robustness Check – OLS with Log Transformation
Table 8 Without Fixed Effects

Ln Exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	.58	.045	13.01	0	.492	.669	***
Ln GDP Imp	.931	.029	32.10	0	.874	.989	***
Ln distance	-1.198	.381	-3.14	.002	-1.957	-.439	***
Constant	-7.374	4.185	-1.76	.082	-15.71	.962	*
Mean dependent var	11.722	SD dependent var	1.718				
R-squared	0.965	Number of obs	80				
F-test	763.059	Prob > F	0.000				
Akaike crit. (AIC)	51.763	Bayesian crit. (BIC)	61.291				

*** $p < .01$, ** $p < .05$, * $p < .1$

The robustness check using an Ordinary Least Squares (OLS) regression with log-transformed export values confirms the validity of the gravity model framework. The coefficients for both the exporter’s GDP (0.58) and the importer’s GDP (0.931) are positive and statistically significant at the 1% level, reinforcing the strong positive relationship between economic size and trade flows. The coefficient for distance (−1.198) is negative and highly significant ($p = 0.002$), aligning

with the traditional gravity model assumption that greater distance reduces trade, likely due to higher transportation and transaction costs. The constant term (−7.374) is marginally significant at the 10% level. The model explains 96.5% of the variation in export trade ($R^2 = 0.965$), indicating a very strong fit. These results further strengthen confidence in the gravity model's predictive power, even without fixed effects, and provide a consistent basis for comparison with the fixed and random effects models.

Table 9 With Time & Exporter Fixed Effects

Ln exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	0	.	.	.	.	.	
Ln GDP Imp	.941	.033	28.41	0	.872	1.01	***
Ln distance	-.823	.561	-1.47	.159	-1.998	.351	

Ln Exchange rate	-.299	.287	-1.04	.312	-.901	.303	
Land Locked	0	.	.	.	.	.	
Constant	-5.725	5.088	-1.13	.274	-16.374	4.923	
Mean dependent var	11.722	SD dependent var	1.718				
R-squared	0.975	Number of obs	80				
F-test	917.483	Prob > F	0.000				
Akaike crit. (AIC)	11.317	Bayesian crit. (BIC)	18.463				

*** $p < .01$, ** $p < .05$, * $p < .1$

The robustness check using Ordinary Least Squares (OLS) with log-transformed exports and the inclusion of time and exporter fixed effects provides a refined understanding of the gravity model relationships. The model shows a very high explanatory power, with an R-squared of 0.975, indicating that 97.5% of the variation in export trade is explained by the included variables and fixed effects. The coefficient for the importer’s GDP remains positive and highly significant (0.941, $p < 0.001$), reaffirming the strong positive influence of the importing country’s economic size on trade flows. However, the coefficient for distance (−0.823) becomes statistically

insignificant ($p = 0.159$), suggesting that after controlling for fixed effects, physical distance loses its explanatory power—possibly due to structural or technological factors mitigating the effect of geography. Similarly, the exchange rate variable has a negative but insignificant coefficient (−0.299, $p = 0.312$), indicating no robust evidence of its effect in this model specification. The exporter’s GDP is absorbed by the fixed effects, as expected, and is thus omitted. Overall, the model confirms the robustness of the gravity framework while highlighting how fixed effects can absorb some explanatory variation, particularly for variables that are relatively stable across time or exporter identity.

Product Analysis: Fruits
Table 10 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Export Trade	80	3293.304	3601.528	4.13	13153.95
Population of Exporter	80	1.265e+09	97888242	1.098e+09	1.414e+09
Population Importer	80	93335391	1.275e+08	3948500	3.320e+08
GDP exporter	80	1750.122	794.757	514.94	3170
GDP importer	80	4.832e+12	7.041e+12	6.663e+10	2.368e+13
Common Language	80	1	0	1	1
Colony	80	0	0	0	0

Distance	80	11650.395	830.271	10435.1	12761.04
Exchange rate	80	49.321	10.014	26.41	76.38
ln export	80	7.267	1.596	1.418	9.484
ln GDP i	80	7.342	.536	6.244	8.061
ln GDP j	80	27.966	1.696	24.922	30.796
ln distance	80	9.361	.072	9.253	9.454
ln exchange rate	80	3.877	.212	3.274	4.336

The descriptive statistics for fruit export trade provide insights into the characteristics and variation of key variables across 80 observations. The average export trade value is approximately 3,293 units, with a considerable standard deviation of 3,601.5, indicating substantial variability, ranging from as low as 4.13 to as high as 13,153.95. Exporter countries have a large population base, averaging around 1.27 billion, while importer populations vary widely, averaging about 93 million but ranging up to 332 million. Exporter GDP averages at 1,750 billion USD, whereas importer GDP shows an extremely high average of 4.83 trillion USD, with significant dispersion. Interestingly, all trading pairs in the dataset share a common language, but none share a colonial relationship. The average geographical distance between trading partners is around 11,650 kilometers. Exchange rates vary from 26.41 to 76.38, with a mean of 49.32. The natural logarithm transformations, used to normalize skewed distributions, show that the mean of log exports is 7.27, and log GDP values for exporters and importers are 7.34 and 27.97 respectively. The log of distance and exchange rate also show relatively low variability, suggesting stable reporting or consistent measurement across observations. Overall, the dataset reflects diverse trade conditions and significant variation in economic and demographic indicators among fruit-exporting and importing countries.

Table 11 Variance Inflation Factor (Baseline Gravity Model)

	VIF	1/VIF
ln GDP Imp	1.138	.879
ln distance	1.105	.905
ln GDP Exp	1.033	.968
Mean VIF	1.092	.

The Variance Inflation Factor (VIF) results from the baseline gravity model indicate that multi collinearity is not a concern in the analysis. The VIF values for all the explanatory variables ln GDP of importer (1.138), ln distance (1.105), and ln GDP of exporter (1.033)—are well below the commonly accepted threshold of 10, and even the more conservative threshold of 5. This suggests that there is very low correlation among the independent variables included in the model. The mean VIF of 1.092 further confirms that the variables are statistically independent enough to produce reliable coefficient estimates in the regression. Therefore, the model does not suffer from multi collinearity, ensuring the robustness and interpretability of the estimated effects.

Table 12 Baseline Standard Gravity Model Estimation Results

Ln Export	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exporter	1.343	.137	9.80	0	1.07	1.615	***
Ln GDP Importer	.701	.045	15.42	0	.611	.792	***

Ln distance	1.745	1.056	1.65	.102	-.357	3.848	
Constant	-38.546	10.319	-3.74	0	-59.098	-17.994	***
Mean dependent var	7.267	SD dependent var	1.596				
R-squared	0.844	Number of obs	80				
F-test	136.921	Prob > F	0.000				
Akaike crit. (AIC)	160.259	Bayesian crit. (BIC)	169.787				

*** $p < .01$, ** $p < .05$, * $p < .1$

The baseline standard gravity model estimation results reveal several key determinants of fruit exports. The coefficient for ln GDP of the exporter is 1.343 and statistically significant at the 1% level ($p < 0.001$), indicating that a 1% increase in the GDP of the exporting country is associated with an approximate 1.34% increase in exports. Similarly, ln GDP of the importer shows a significant positive impact on exports with a coefficient of 0.701 ($p < 0.001$), suggesting that larger importer economies are associated with higher levels of trade.

However, the coefficient for ln distance is 1.745 and not statistically significant ($p = 0.102$), implying that in this model, distance does not have a conclusive effect on export volumes, which may be due to modern logistics or limited variability in distance within the sample. The constant term is negative and significant, indicating the presence of other unobserved factors that lower trade volumes.

The model explains a high proportion of the variance in export levels, with an R-squared of 0.844, meaning 84.4% of the variation in exports is accounted for by the model. The F-statistic (136.921) and its p-value (< 0.001) confirm the overall statistical significance of the regression. Additionally, the relatively low values of the Akaike Information Criterion (AIC = 160.259) and Bayesian Information Criterion (BIC = 169.787)

suggest a good model fit. Overall, GDP of both trading partners significantly influences trade flows, while distance appears less critical in this baseline specification.

Table 13 Variance Inflation Factor (Augmented Gravity Model)

	VIF	1/VIF
ln exchange rate	3.151	.317
ln GDP Exp	2.334	.429
ln distance	1.716	.583
ln GDP Imp	1.424	.702
Mean VIF	2.156	.

The Variance Inflation Factor (VIF) results for the augmented gravity model indicate that multi collinearity among the explanatory variables remains within acceptable limits. The highest VIF is observed for ln exchange rate (3.151), followed by ln GDP of exporter (2.334), ln distance (1.716), and ln GDP of importer (1.424). All VIF values are well below the conventional threshold of 10, and even below the more conservative threshold of 5, suggesting that multi collinearity is not severe in the model. The mean VIF of 2.156 further supports the conclusion that there is no serious multi collinearity problem affecting the reliability of coefficient estimates. Therefore, the augmented gravity model is statistically sound with respect to the independence of its explanatory variables.

Table 14. Baseline Standard Gravity Model Estimation Results

Ln Export	Coef.	St.Err.	t-value	p-value	[95% Conf Interval]	Sig
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ln GDP Exp	2.081	.173	12.03	0	1.737	2.426***
ln GDP Imp	.811	.043	18.97	0	.726	.896***
Ln distance	5.518	1.105	4.99	0	3.316	7.719***
Ln Exchange rate	-2.915	.51	-5.72	0	-3.93	-1.9***
Constant	-71.047	10.364	-6.86	0	-91.692	-50.401***
Mean dependent var	7.267	SD dependent var	1.596			
R-squared	0.891	Number of obs	80			
F-test	153.731	Prob > F	0.000			
Akaike crit. (AIC)	133.295	Bayesian crit. (BIC)	145.205			

*** $p < .01$, ** $p < .05$, * $p < .1$

The results from the augmented gravity model estimation provide a deeper understanding of the factors influencing fruit export flows. All included variables are statistically significant at the 1% level, highlighting their strong influence on trade. The ln GDP of the exporter has a positive and substantial impact on exports, with a coefficient of 2.081, indicating that a 1% increase in the exporter's GDP is associated with a 2.08% increase in export trade. Similarly, the ln GDP of the importer shows a positive effect (0.811), reinforcing the expectation that larger economies import more.

The coefficient for ln distance is unexpectedly positive (5.518) and highly significant, which deviates from traditional gravity model expectations where distance typically has a negative effect due to transportation and transaction costs. This suggests that in the context of this dataset, other factors (like air freight or high-value perishable goods) may override the friction of distance.

The ln exchange rate has a significant negative impact (-2.915), implying that depreciation of the exporter's currency (making goods cheaper internationally) is associated with an increase in export volumes.

The model demonstrates a very strong fit, with an R-squared of 0.891, meaning that nearly 89.1% of the variation in export values is explained by the model. The F-statistic (153.731) and associated p-value (0.000) indicate the model is statistically significant overall. Additionally, the lower Akaike Information Criterion (AIC = 133.295) and Bayesian Information Criterion (BIC = 145.205) compared to the baseline model suggest improved model performance. Overall, the augmented gravity model confirms the significant role of economic size and exchange rate movements, while also revealing unexpected dynamics in how distance relates to trade in this sector.

Augmented Gravity Model

Number of parameters: 5 Number of observations: 80
Pseudo log-likelihood: -21492.608 R-squared: .82926933 Option strict is: off (Std.
Err. adjusted for 4 clusters in country pair)

Table 14. Robustness

Export trade	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
Ln GDP Exp	1.600	0.208	7.680	0.000	1.192	2.008
Ln GDP Imp	0.572	0.113	5.060	0.000	0.351	0.794
Ln distance	4.373	2.969	1.470	0.141	-1.447	10.193
Ln Exchange rate	-1.759	0.395	-4.450	0.000	-2.534	-0.984
_cons	-54.322	27.546	-1.970	0.049	-108.312	-0.333

The results from the augmented gravity model offer a more comprehensive understanding of the factors influencing export trade. Based on 80 observations and 5 parameters, the model shows strong explanatory

power, with an R-squared of 0.829, an improvement over the standard model. The pseudo log-likelihood also improves to -21,492.608, indicating a better model fit. Key variables remain statistically

significant. The $\ln$ GDP of the exporter has a coefficient of 1.600 ($p < 0.001$), suggesting that a 1% increase in the exporting country’s GDP leads to a 1.6% rise in exports. Similarly, the $\ln$ GDP of the importer has a positive and significant coefficient of 0.572 ($p < 0.001$), reinforcing the role of economic size in facilitating trade. The $\ln$ exchange rate enters the model with a significant negative coefficient of -1.759 ($p < 0.001$), implying that depreciation of the exporter’s currency boosts exports, likely due to increased price competitiveness. The coefficient for $\ln$ distance is positive (4.373) but remains statistically insignificant ($p = 0.141$), suggesting that geographic

distance does not significantly deter trade in this context—possibly due to advances in transport or the nature of traded goods. The constant term is negative and marginally significant ($p = 0.049$), capturing unobserved trade frictions or fixed effects not explicitly included in the model. Overall, the augmented model strengthens the conclusions drawn from the standard gravity model by confirming the importance of economic size and exchange rate dynamics in explaining export trade, while continuing to suggest that distance plays a less consistent role in this dataset.

Table 16. Descriptive Statistics (Predicted Values for Model Fit Comparison)

Variable	Obs	Mean	Std. Dev.	Min	Max
Export Trade	80	3293.304	3601.528	4.13	13153.95
Fitted Standard	80	3293.304	3488.743	88.465	14911.69
Fitted Augmented	80	3293.304	3488.743	88.465	14911.69

The descriptive statistics in Table 8 present a comparison between actual and predicted export trade values for evaluating model fit. The mean export trade value is 3,293.30, which exactly matches the means of both the fitted values from the standard and augmented gravity models, confirming that both models predict the average level of exports accurately. The standard deviations of the fitted values for both models are nearly identical to the actual data (3,488.74 vs. 3,601.53), suggesting that both models closely capture the variability in the observed data.

of the actual export data range (4.13 to 13,153.95). This close alignment in descriptive statistics indicates that both the standard and augmented gravity models provide a good fit to the data. However, to distinguish between the two models further, one would need to rely on other metrics such as R-squared, pseudo log-likelihood, or prediction error measures. Nonetheless, based on the descriptive comparison alone, both models appear to replicate the central tendency and distribution of export trade effectively.

The minimum and maximum predicted values range from 88.47 to 14,911.69, which are within the bounds

Robustness Check – OLS with Log Transformation

Table 15 Without Fixed Effects

Ln Exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	1.343	.171	7.86	0	1.003	1.683	***
Ln GDP Imp	.701	.041	17.27	0	.621	.782	***
Ln distance	1.745	.768	2.27	.026	.215	3.275	**
Constant	-38.546	6.855	-5.62	0	-52.199	-24.893	***

Mean dependent var	7.267	SD dependent var	1.596				
R-squared	0.844	Number of obs	80				
F-test	106.955	Prob > F	0.000				
Akaike crit. (AIC)	160.259	Bayesian crit. (BIC)	169.787				

*** $p < .01$, ** $p < .05$, * $p < .1$

The robustness check using Ordinary Least Squares (OLS) with log-transformed export values, presented in Table 9 (without fixed effects), reinforces the validity of the baseline gravity model findings. All three explanatory variables $\ln$ GDP of exporter, $\ln$ GDP of importer, and $\ln$ distance are statistically significant, indicating their strong influence on export performance.

The coefficient for $\ln$ GDP of the exporter is 1.343 ($p < 0.01$), suggesting that a 1% increase in the exporter's GDP leads to a 1.34% rise in exports. Similarly, $\ln$ GDP of the importer has a coefficient of 0.701 ($p < 0.01$), affirming that larger importing economies are associated with higher trade volumes. Notably, $\ln$

distance has a positive coefficient of 1.745 and is significant at the 5% level ($p = 0.026$), which, although contrary to traditional gravity model expectations, may reflect specific characteristics of the dataset such as trade in high-value perishables or strong long-distance trading relationships. The model fit is strong, with an R-squared of 0.844, indicating that 84.4% of the variation in export trade is explained by the model. The F-statistic (106.955) is highly significant ($p < 0.001$), confirming the joint significance of the regressors. Model selection criteria like AIC (160.259) and BIC (169.787) suggest reasonable model performance. Overall, the OLS robustness check supports the baseline model results, confirming the significance of economic size and distance in shaping trade flows, even in the absence of fixed effects.

Table 16. With Time & Exporter Fixed Effects

Ln Exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	1.344	.203	6.62	.007	.698	1.99	***
Ln GDP Imp	1.839	.619	2.97	.059	-.132	3.809	*
Land Locked	0	.	.	.	.	.	
Ln Exchange rate	-2.234	.301	-7.42	.005	-3.192	-1.275	***
Constant	-45.363	14.826	-3.06	.055	-92.545	1.82	*
Mean dependent var	7.267	SD dependent var	1.596				
R-squared	0.892	Number of obs	80				
F-test	286.515	Prob > F	0.000				
Akaike crit. (AIC)	58.449	Bayesian crit. (BIC)	65.595				

*** $p < .01$, ** $p < .05$, * $p < .1$

The robustness check using OLS with log transformation and the inclusion of time and exporter fixed effects (Table 10) offers further validation and refinement of the gravity model results. The model

shows strong explanatory power, with an R-squared of 0.892, indicating that approximately 89.2% of the variation in export volumes is explained by the included variables and fixed effects. The model fit is further supported by a highly significant F-statistic (286.515, $p < 0.001$) and lower AIC (58.449) and BIC

(65.595) values compared to models without fixed effects, demonstrating improved performance.

The $\ln$ GDP of the exporter remains significant and positive (1.344, $p < 0.01$), reaffirming that stronger exporter economies drive higher export volumes. The $\ln$ GDP of the importer also shows a large positive coefficient (1.839), significant at the 10% level ($p = 0.059$), suggesting a strong, albeit less precisely estimated, influence of importer economic size on trade.

The $\ln$ exchange rate has a significant negative impact (-2.234, $p < 0.01$), reinforcing the idea that currency

depreciation boosts exports by making goods more competitively priced in international markets. The landlocked variable appears to have no variation or is omitted due to perfect multi collinearity or lack of data (all values zero or constant), hence no coefficient is reported. The constant term is marginally significant ($p = 0.055$), capturing residual trade determinants not explicitly modelled. Overall, this robustness check strengthens the credibility of earlier findings, emphasizing the importance of economic size and exchange rate dynamics in determining export trade. The inclusion of fixed effects helps account for unobserved heterogeneity across exporters and over time, further improving model reliability.

Product Analysis: Nuts
Table 17 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Export Trade	80	55050.938	121318.78	761.48	823469.81
Population of Exporter	80	1.265e+09	97888242	1.098e+09	1.414e+09
Importer Population	80	93335391	1.275e+08	3948500	3.320e+08
GDP exporter	80	1750.122	794.757	514.94	3170
GDP importer	80	4.832e+12	7.041e+12	6.663e+10	2.368e+13
common language	80	1	0	1	1
Colony	80	0	0	0	0
Distance	80	11650.395	830.271	10435.1	12761.04
Tariff	80	0	0	0	0
Land locked	80	0	0	0	0
Exchange rate	80	49.321	10.014	26.41	76.38
$\ln$ export	80	8.947	1.907	6.635	13.621
$\ln$ GDP Exp	80	7.342	.536	6.244	8.061
$\ln$ GDP Imp	80	27.966	1.696	24.922	30.796
$\ln$ distance	80	9.361	.072	9.253	9.454
$\ln$ exchange rate	80	3.877	.212	3.274	4.336

The descriptive statistics for the nuts export dataset provide an overview of the key variables influencing trade flows across 80 observations. The average export trade value is approximately 55,050.94, but with a very high standard deviation of 121,318.78, indicating significant variability in trade volumes, ranging from 761.48 to 823,469.81. Exporting countries are characterized by large populations, averaging around 1.27 billion, while the importer populations average about 93 million, with considerable dispersion. The GDP of exporters averages \$1,750.12 billion, and the GDP of importers is markedly higher, averaging \$4.83 trillion, highlighting trade between large economies.

Variables such as common language are constant (value = 1), and there are no instances of colonial relationships, landlocked status, or tariffs, suggesting a relatively open and accessible trade context in this sample. The average distance between trading partners is about 11,650 kilometers, showing that trade in nuts often occurs over long distances. The exchange rate varies from 26.41 to 76.38, with a mean of 49.32, and its logarithmic transformation ($\ln$ exchange rate) shows limited variation. The natural log of export trade ($\ln$ export) has a mean of 8.95, with a wide range reflecting the substantial variation in raw export values. Overall, the data suggest a diverse trading

environment for nuts, characterized by large economic partners, consistent language ties, and long trade

distances, providing a strong foundation for applying gravity model estimations.

Table 20. Variance Inflation Factor (Baseline Gravity Model)

	VIF	1/VIF
ln GDP Imp	1.138	.879
ln distance	1.105	.905
ln GDP Exp	1.033	.968
Mean VIF	1.092	.

The Variance Inflation Factor (VIF) results from the baseline gravity model for nuts indicate no significant multi collinearity among the explanatory variables. The VIF values for ln GDP of the importer (1.138), ln distance (1.105), and ln GDP of the exporter (1.033) are all well below the commonly accepted threshold of

10, and even below the stricter threshold of 5. The mean VIF is 1.092, confirming that the independent variables are not highly correlated with each other. This suggests that the model's coefficient estimates are reliable and not distorted by multi collinearity, ensuring robust and interpretable regression results.

Table 21. Baseline Standard Gravity Model Estimation Results

Ln Export	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exporter	-.724	.188	-3.85	0	-1.099	-.35	***
Ln GDP Importer	1.063	.062	17.04	0	.939	1.187	***
Ln distance	5.429	1.448	3.75	0	2.546	8.313	***
Constant	-66.28	14.151	-4.68	0	-94.464	-38.097	***
Mean dependent var	8.947	SD dependent var	1.907				
R-squared	0.794	Number of obs	80				
F-test	97.789	Prob > F	0.000				
Akaike crit. (AIC)	210.787	Bayesian crit. (BIC)	220.315				

*** $p < .01$, ** $p < .05$, * $p < .1$

The baseline gravity model estimation for nuts exports reveals significant and somewhat unconventional relationships between trade and its key determinants. The ln GDP of the importer has a strong and positive effect (1.063, $p < 0.01$), indicating that trade increases with the economic size of the importing country,

consistent with gravity model expectations. However, the ln GDP of the exporter shows a statistically significant negative coefficient (-0.724 , $p < 0.01$), suggesting that as the exporter's GDP increases, nut exports decrease a result that diverges from traditional gravity model theory. This may reflect factors such as rising domestic consumption or export substitution effects in higher-GDP exporting

countries. Interestingly, $\ln$ distance has a positive and significant coefficient (5.429, $p < 0.01$), contrary to standard gravity model predictions where distance typically acts as a trade barrier. This result could suggest that nuts are exported primarily to distant but high-demand markets, or that transport and logistics in the nut trade mitigate distance-related costs. The model fits the data well, with an R-squared of 0.794, indicating that approximately 79.4% of the variation in the log of export values is explained by the model. The F-statistic (97.789) and its p-value (0.000) confirm the model's overall statistical significance. Additionally, the AIC (210.787) and BIC (220.315) values provide benchmarks for comparing alternative model specifications. Overall, while the importer GDP effect aligns with standard theory, the negative effect of exporter GDP and the positive effect of distance suggest unique dynamics in the global trade of nuts that warrant further investigation.

Table 22. Variance Inflation Factor (Augmented Gravity Model)

	VIF	1/VIF

In exchange rate	3.151	.317
In GDP Imp	2.334	.429
In distance	1.716	.583
In GDP Exp	1.424	.702
Mean VIF	2.156	.

The Variance Inflation Factor (VIF) results for the augmented gravity model of nut exports indicate that multi collinearity is not a concern in the analysis. All VIF values are comfortably below the critical threshold of 10, and even below the more conservative threshold of 5. The highest VIF is observed for $\ln$ exchange rate (3.151), followed by $\ln$ GDP of the importer (2.334), $\ln$ distance (1.716), and $\ln$ GDP of the exporter (1.424). The mean VIF of 2.156 suggests that the explanatory variables are sufficiently independent of each other, ensuring that the regression coefficients are stable and interpretable. Overall, the multi collinearity diagnostics confirm the statistical soundness of the augmented gravity model.

Table 23. Baseline Standard Gravity Model Estimation Results

Ln Export	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
$\ln$ GDP Exp	-.575	.283	-2.03	.046	-1.14	-.011	**
$\ln$ GDP Imp	1.085	.07	15.49	0	.946	1.225	***
$\ln$ distance	6.192	1.81	3.42	.001	2.585	9.798	***
$\ln$ Exchange rate	-.589	.835	-0.71	.483	-2.252	1.074	
Constant	-72.847	16.977	-4.29	0	-106.666	-39.028	***
Mean dependent var	8.947	SD dependent var	1.907				
R-squared	0.796	Number of obs	80				
F-test	72.981	Prob > F	0.000				
Akaike crit. (AIC)	212.258	Bayesian crit. (BIC)	224.168				

*** $p < .01$, ** $p < .05$, * $p < .1$

The augmented gravity model estimation for nut exports provides further insights into the trade determinants by including the exchange rate variable. The $\ln$ GDP of the importer remains positive and highly significant (1.085, $p < 0.001$), reinforcing the idea that larger importing economies demand more nut imports. Interestingly, the $\ln$ GDP of the exporter continues to show a negative and statistically significant effect (-0.575, $p = 0.046$), suggesting that higher-GDP exporting countries may experience reduced nut export volumes—possibly due to increased domestic consumption or structural shifts in production.

The $\ln$ distance variable shows a positive and significant coefficient (6.192, $p = 0.001$), again counter to traditional gravity model expectations, which typically associate greater distance with trade reduction. This result may reflect a concentration of nut exports to distant but high-value markets where efficient logistics and product value mitigate distance-related costs. The $\ln$ exchange rate, while having a

negative coefficient (-0.589), is statistically insignificant ($p = 0.483$), indicating that fluctuations in exchange rates do not have a clear or consistent impact on nut exports within this model. With an R-squared of 0.796, the model explains nearly 80% of the variance in export values, suggesting a strong fit. The F-statistic (72.981) and its p-value (0.000) confirm overall model significance. Model comparison metrics such as AIC (212.258) and BIC (224.168) remain in line with previous specifications. Overall, the augmented model reinforces the importance of importer economic size and highlights unusual patterns in exporter GDP and distance effects, while showing that exchange rate effects on nut exports are limited in this context.

Augmented Gravity Model

Number of parameters: 5 Number of observations: 80
Pseudo log-likelihood: -1139239.5 R-squared: .54339191 Option strict is: off (Std.
Err. adjusted for 4 clusters in country pair)

Table 25. Robust

Ln GDP Exp	Coef.	Std.Err.	Z	P>z	[95%Conf.	Interval]
Ln GDP Imp	-0.218	0.090	-2.420	0.015	-0.394	-0.041
Ln distance	1.357	0.188	7.230	0.000	0.989	1.725
Ln Exchange rate	3.404	4.956	0.690	0.492	-6.309	13.116
Ln GDP Exp	-0.447	0.142	-3.150	0.002	-0.726	-0.169
_cons	-57.536	42.391	-1.360	0.175	-140.621	25.549

The augmented gravity model for nut exports provides a nuanced picture of trade determinants with the inclusion of the exchange rate variable. With 80 observations and 5 parameters, the model maintains a similar explanatory power as the baseline, reflected in an R-squared of 0.543 and a slightly improved pseudo log-likelihood of -1,139,239.5. Surprisingly, the $\ln$ GDP of the exporter continues to show a negative and statistically significant coefficient (-0.447, $p = 0.002$), consistent with earlier models. This suggests that as the exporting country’s GDP increases, nut exports decline—possibly due to increased domestic demand or a shift away from export-oriented production in

wealthier nations. Likewise, $\ln$ GDP of the importer, which traditionally has a positive effect, appears here with a negative coefficient (-0.218, $p = 0.015$). This counterintuitive result might reflect specific characteristics of importing countries in the sample, such as self-sufficiency or non-price-sensitive demand structures. The $\ln$ distance variable is positive and highly significant (1.357, $p < 0.001$), suggesting that nut exports are more likely to go to distant markets—possibly due to the niche or premium nature of the product and global demand centers being far from producing regions. The $\ln$ exchange rate, despite having a large positive coefficient (3.404), is

statistically insignificant ($p = 0.492$), indicating no conclusive effect of currency fluctuations on export volumes within this dataset. The constant term is again negative and statistically insignificant, and the wide confidence intervals on some estimates (especially exchange rate) point to substantial variability across observations.

In sum, the augmented gravity model suggests that nut trade is influenced by factors that deviate from standard gravity model expectations—especially with the inverse GDP effects and the consistent positive impact of distance. These results highlight the need for deeper exploration of product-specific trade dynamics and potential structural or regional influences.

Table 26. Descriptive Statistics (Predicted Values for Model Fit Comparison)

Variable	Obs	Mean	Std. Dev.	Min	Max
Export Trade	80	55050.938	121318.78	761.48	823469.81
Fitted Standard	80	55050.938	89118.066	213.739	257704.23
Fitted Augmented	80	55050.938	89118.066	213.739	257704.23

The descriptive statistics comparing actual and predicted values for the nut export models show a close alignment in terms of central tendency, indicating both models effectively replicate the overall trade levels. The mean of actual export trade is 55,050.94, which exactly matches the mean of the fitted values from both the standard and augmented gravity models. This reflects that, on average, both models predict export volumes accurately. However, differences emerge in variability. The standard deviation of the actual export data is 121,318.78, whereas the predicted values from both models have a

lower standard deviation of 89,118.07, suggesting the models under predict some of the extreme fluctuations in export values. The minimum and maximum of the predicted values (213.74 to 257,704.23) also fall short of capturing the full range of the actual data (761.48 to 823,469.81), indicating a tendency to underestimate high-value outliers. Overall, while both models capture the average export levels well, they may smooth out the volatility present in real trade data, highlighting a potential limitation in fully explaining the most extreme trade flows in the nuts export sector.

Robustness Check – OLS with Log Transformation

Table 27. Without Fixed Effects

Ln Exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	-.724	.298	-2.43	.018	-1.319	-.13	**
Ln GDP Imp	1.063	.085	12.45	0	.893	1.233	***
Ln distance	5.429	1.325	4.10	0	2.791	8.068	***
Constant	-66.28	13.235	-5.01	0	-92.641	-39.92	***
Mean dependent var	8.947	SD dependent var	1.907				
R-squared	0.794	Number of obs	80				
F-test	89.774	Prob > F	0.000				
Akaike crit. (AIC)	210.787	Bayesian crit. (BIC)	220.315				

*** $p < .01$, ** $p < .05$, * $p < .1$

The robustness check using OLS with log-transformed exports and without fixed effects (Table 30) reinforces the main findings of the gravity model for nut exports,

while also highlighting some atypical patterns. The model demonstrates strong explanatory power with an R-squared of 0.794, indicating that approximately 79.4% of the variation in nut export volumes is explained by the model's predictors. The overall model

significance is confirmed by a high F-statistic (89.774, $p < 0.001$). The $\ln$ GDP of the importer shows a strong positive and highly significant effect (1.063, $p < 0.001$), consistent with gravity theory, which posits that larger importing economies demand more goods. Conversely, the $\ln$ GDP of the exporter has a negative and significant coefficient (-0.724 , $p = 0.018$), which contradicts traditional expectations. This may reflect specific sectoral or structural factors such as increased domestic consumption or reduced export reliance in high-GDP countries.

Additionally, the $\ln$ distance variable shows a positive and significant relationship (5.429, $p < 0.001$), again contrary to standard gravity models, which typically associate distance with trade deterrence. This suggests that nut exports may be concentrated in high-value distant markets, or that logistical advancements offset distance costs. The constant term is also significant and negative, and the model diagnostics, including AIC (210.787) and BIC (220.315), are consistent with earlier models. Overall, the OLS results without fixed effects confirm the robustness of key coefficients while highlighting product-specific trade behaviours that deviate from classical gravity assumptions.

Table28. With Time & Exporter Fixed Effects

Ln Exports	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Ln GDP Exp	.11	1.04	0.11	.923	-3.2	3.419	
Ln GDP Imp	.126	1.242	0.10	.926	-3.827	4.078	
Land Locked	0	.	.	.	.	.	
Ln Exchange rate	-1.211	1.065	-1.14	.338	-4.6	2.178	
Constant	9.322	28.774	0.32	.767	-82.251	100.896	
Mean dependent var	8.947	SD dependent var	1.907				
R-squared	0.041	Number of obs	80				
F-test	6.630	Prob > F	0.079				
Akaike crit. (AIC)	191.904	Bayesian crit. (BIC)	199.050				

*** $p < .01$, ** $p < .05$, * $p < .1$

The OLS robustness check with time and exporter fixed effects (Table 31) for nut exports presents markedly different results compared to models without fixed effects. The inclusion of fixed effects appears to absorb much of the variation previously attributed to key explanatory variables, resulting in all main coefficients becoming statistically insignificant. Specifically, the coefficients for $\ln$ GDP of the exporter (0.11, $p = 0.923$) and $\ln$ GDP of the importer (0.126, $p = 0.926$) are both near zero with wide confidence intervals, suggesting no detectable effect

when controlling for unobserved heterogeneity across exporters and time periods. Similarly, the $\ln$ exchange rate has a negative but insignificant effect (-1.211 , $p = 0.338$), and the landlocked variable is omitted due to lack of variation.

The model's R-squared drops sharply to 0.041, indicating that only 4.1% of the variation in export values is explained by the included variables and fixed effects. Despite the overall F-statistic being 6.630, it is only marginally significant ($p = 0.079$), suggesting limited explanatory power. The AIC (191.904) and

BIC (199.050) are slightly improved compared to previous models, but the loss of significance in core predictors suggests that the fixed effects may be over-controlling for key trade-influencing factors. In inclusion of time and exporter fixed effects significantly weakens the explanatory power of the gravity model for nuts, possibly due to collinearity or lack of within-group variation. This suggests that fixed effects may not be appropriate or necessary in this context, or that additional data or variables are needed to better capture trade determinants under fixed-effects specifications.

CONCLUSION:

The results of the gravity model analysis offer meaningful insights into the key factors influencing India's exports of fruits, vegetables, and nuts to countries such as the United States, Canada, Australia, New Zealand. Consistent with theoretical expectations, the economic size of the importing countries plays a significant role in driving trade flows, as larger economies tend to import more. However, an interesting deviation from the traditional gravity model is observed in the case of exporter GDP, where the relationship with exports is negative in several models. This may reflect domestic consumption demands or structural changes within India's agricultural sector. The effect of distance, typically expected to hinder trade, appears either insignificant or positively related in some cases, indicating that advancements in transportation, global supply chains, or product-specific demand (particularly for high-value perishables like nuts) may reduce the friction of distance. While exchange rate movement show varied effects across models, they tend to support the idea that a weaker domestic currency enhances export competitiveness. The robustness checks further confirm the consistency of these findings across different model specifications, although the inclusion of fixed effects absorbs much of the variation and renders some variables insignificant. Overall, the discussion highlights how standard gravity variables perform well in explaining India's agricultural export patterns, while also revealing sector-specific nuances that suggest the need for tailored policy and trade facilitation strategies. In conclusion, the study affirms the applicability of the gravity model to India's agricultural exports while

highlighting product-specific trade behaviours that deviate from conventional theory, particularly with respect to exporter GDP and distance. Importer GDP is the most consistent and significant driver of exports across all product categories. Larger and wealthier economies tend to import more from India, affirming the core principle of the gravity model. Exporter GDP (India's economic size) shows a negative or insignificant relationship with export volumes, especially for nuts. This suggests that as India's economy grows, a larger share of production may be consumed domestically or diverted to non-traditional markets, reducing the emphasis on certain agricultural exports.

REFERENCES:

1. Ahn, J.W and Rhodes, M. . (2021) *Examining Pathogen-Based Import Refusals: Trends and Analysis From 2002 to 2019*.
2. Ahn, J. and and M. . R. (2021) *Examining Pathogen-Based Import Refusals: Trends and Analysis from 2002 to 2019. Economic Research Report, U.S Department of Agriculture, Economic Reserach Service*.
3. Anilkumar, A. Girish, A and Menon, L. . (2021) 'Determinants of the Exports of India: Trade Blocs, Trade Theory and the Gravity Model', *International Journal of Recent Advances in Multidisciplinary Topics*, Vol. 2(Issue 6), pp. 279–284.
4. Chatterjee, S. *et al.* (2023) 'Mycotoxin Monitoring, Regulation and Analysis in India: A Success Story', *Foods*. doi: 10.3390/foods12040705.
5. Congressional Research Service (2020) *U.S.-India Trade Relations. In Focus*. Washington D.C.
6. Fortin, N. . (2022) *Food Regulation: Law, Science, Policy and Practice*. 3rd edn. New Jersey: John Wiley and Sons Inc.
7. Hejazi, M. Grant, J.H and Peterson, E. (2022) 'Food Policy', *Trade impact of maximum residue limits in fresh fruits and vegetables*, 106.
8. Hejazi, M. G. J. . and P. . (2021) 'Trade impact of maximum residue limits in fresh fruits and vegetables', *Food Ploicy*, 106, pp. 1–12.
9. Hoffman, S. and J. . A. (2021) *US Department of Agriculture, Economic Research Service*,

- Economic Burden of Foodborne Disease, 2018 Estimates.*
10. Jha, G.K, Punera, B. and S. . (2019) 'Growth of horticulture sector in India: Trends and prospects', *Indian Journal of Agricultural Sciences*, 89(2), pp. 314–321.
 11. Johnson, .R (2020) *U.S Food aand Agricultural Imports: Safeguards and Selected Issues.* Washington D.C.
 12. Kallummam,M. and Gurung, H.. (2020) *Urgent Need for Market Accesss Disciplininh of Agricultural Trade: Proliferation of stringent and Non Codex SPS based MRL standards.* CWS/WP/200/60. New Delhi.
 13. Kallummam. M, Mendiratta.D and Sangita,S, M. (2018) *US Import Refusal of Agricultural Products and Their Impact on the Participation of Indian Firms*, *Journal of Political Economy*.
 14. Kim.S.Y (2022) *The Politics of FTAs in Asia. The role of China and implications for EU trade policy.*, In *A Geo-Economic Turn in Trade Policy?* Palgrave Macmillan, Cham.
 15. Kucuk, N. (2023) 'Fruit and vegetable consumption across population segments: evodence from a national household survey', *Journal of Health, Population and Nutrition*, 42(54), pp. 1–20.
 16. Kumar, K.N.R, Naidu.G.M, and S. A. . (2024) 'Exploring the drivers of Indian agricultural exports: a dynamic panel data approach', *Cogent Economics and Finance*, 12(1), pp. 1–18.
 17. Kumar.K, N. R. (2022) 'Competitiveness of Indian Agricultural Exports: A Constant Market Share Analysis.', *Research on World Agricultural Economy*, 3(2), pp. 25–38.
 18. Kumar, A. et al. (2022) 'Examining Export Advanatges in Indian Hpticulture: An Approach based on product mapping and seasonality.', *Journal of Agribusiness in Developing and Emerging Economies*, pp. 1–32.
 19. Lamonaca.E and Santeramo.F.G (2022) 'On the trade effects of bilateral SPS measures in developed and developing countries.', *World Economy, John Wiley and Sons Ltd*, 45, pp. 3109–3145.
 20. Mitra, A. and Panda, S. (2020) 'Horticulture and economic growth in India: An econometric analysis', *Journal of Applied Horticulture*, 22(3), pp. 240–245.
 21. Mouzam, S. . (2020) 'Trade Competitiveness and Market Access Issues in India's Coconut and Cashew Nut Trade', *Indian Journal of Agricultural Economics*, 75(Octber-December 2020), pp. 587–599.
 22. Naik, G. (2021) 'Agricultural Trade with special reference to plantantion crops and international trade agreements', *Indian Journal of Agricultural Economics*, 76(1), pp. 109–143.
 23. Nirmal, K. et al (2024) 'Exploring the drivers of Indian agricultural exports: A dynamic panel data approach', *Cogent Economics and Finance*, 12(1), pp. 1–17.
 24. Reddy, K.V, Reddy, D.D and Sendhil, R. (2022) 'An Assesment of Agricultural Export Competitiveness of Commercial Crops: Pathways to Augument Indian Agricultural Exports', *Indian Journal of Economics and Development*, 18(May, 2022), pp. 436–444.
 25. Saxena, R. et al (2024) 'Examining Export Advantage in Indian horticulture: An approach based on product mapping and seasonality', *Journal of Afgribusiness in Developing and Emerging Economies*, 14(2), pp. 161–192. doi: 10.1108/JADEE-12-2021-0310.
 26. Sen, S. et al (2018) 'Management of postharvest green mold decay in common mandarin and Indian gooseberry with *Bacillus Licheniformis* SR-14', *Journal of Applied Horticulture*, 20(2), pp. 129–135.
 27. Son,D.A and Vang-Phu, T. (2021) 'Regulation of the European Union onthe Maximum Residue Levels of pesticides-Comments and criticisms', *Journal of legal, ethical and Rrgulatory issues*, 24(1), pp. 1–5.
 28. U.S Government Accountability Office (2025) *Food Safety: Status of Foodborne Illness in the U.S.* Washington D.C.
 29. Virrey, E. . (2023) 'Antifungal activity of Citronella essential oil against stem-end rot of mango', *Journal of Applied Horticulture*, 25(2), pp. 130–134.
 30. Yang,. L and Weigong, D. (2022) 'International Studies of Economics', *Catalyst or barrier? Heterogenenous effects of standards on agricultural trade between China and the Belt*

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and Road countries, (18), pp. 53–79. doi:
10.1002/ise3.25.