Indian Journal of Agricultural Economics 80: 3 (2025):1130-1151
DOI:10.63040/25827510.2025.03.031

Regional Trade Agreements and Agri-Food Export Efficiency in India: An Analysis Using Stochastic Frontier Gravity Model

V. Reshma[1] , Manikandan K.[1], Pradeesh K.[2] and Shaharshad C. T.[1]

ABSTRACT

There has been an increase in the number of trade agreements (TAs) signed by India, especially in recent years, to boost exports. In this context, using the Stochastic Frontier Gravity Model (SFGM), the present study examines how the selected RTAs, such as GSTP, APTA, SAPTA, SAFTA, ASEAN, and MERCOSUR, and the regulatory quality of the partner nations, impact the efficiency of imports of Indian agricultural food products to 67 trading partners between 1995 and 2022. To verify the robustness of the results, the study also estimates fixed effects (FE), ordinary least squares (OLS), pseudo-Poisson maximum likelihood (PPML), and the Heckman selection approach. The results of the SFGM reveal that the GDP of India and its importing partner nations, the population of the importing country, and the exchange rate positively correlate with India's export efficiency. Whereas, distance and population of India have a negative effect. In terms of RTAs, all agreements except SAPTA are found to be significant, suggesting that the export efficiency of India's agri-food products has improved by signing such trade agreements. On average, free trade agreements (FTAs) such as SAFTA and ASEAN (72 per cent) significantly outperform preferential trade agreements (PTAs) like GSTP, APTA, SAPTA, and MERCOSUR (50 per cent), highlighting that India benefits more as an exporting nation through FTAs. However, its exports are still below the potential frontier. The study recommends prioritising agreements with politically and economically stable partners, expanding the geographic scope of integration, reducing trade barriers, and broadening sectoral coverage in RTAs to strengthen India's agricultural export performance.

Keywords: Agri-food products, export efficiency, India, RTAs, SFGM

JEL Code: C23, F10, F15, Q17

I

INTRODUCTION

International trade serves as an instrument and catalyst for economic growth (Frankel & Romer, 1999). Even classical and neoclassical economists perceived trade as a means to contribute to a nation's development. This is because international trade generates foreign exchange in addition to quantitative benefits such as contributions to GDP (Chenery & Strout, 1966). Miller et al. (2020) reported that nations with more trade autonomy have achieved higher levels of food security. Against the backdrop of the spatial disparity between food production and consumption, international agricultural trade is crucial for achieving global food stability (Kinnunen et al., 2020). The international trade of agricultural products is significant, given India's sizable agrarian economy. Since 55 per cent of the population depends on agriculture, there are several advantages to participating in international trade (Agriculture Statistics at a Glance, 2023). Like any other emerging nation, India's trade can contribute to more significant economic growth because of its untapped potential, especially in the agricultural sector. Owing to its abundant land resources, India can fulfil its significant local demand for essential commodities such as wheat

[1] Department of Economics, The Gandhigram Rural Institute (DTBU), Gandhigram, Dindigul; [2]Department of Commerce, Government College Chittur, Palakkad

and rice while making excess supplies available for export. India's competitive advantage in the global market was further enhanced by opening its economy with LPG programmes in 1991. As a member of the WTO, India gains access to a set of regulations that support fair, transparent, and predictable economic ties (Khalid et al., 2020). Building on the significance of international trade for economic development and India's unique agricultural potential, it is important to examine the performance of the agri-food sector, which reflects both structural shifts in the domestic economy and changing global trade dynamics.

1.1 India's Agri-Food Export: An Overview

India's agri-food sector is considered the primary sector of the economy. A close examination of Figure 1 reveals that the proportion of agricultural income in India's GDP decreased from 24.26 per cent in 1995 to 16.55 per cent in 2022. The percentage of employment in the agricultural sector has declined from 1995 to 2022. This is attributed to the fact that India has diversified sources of income, leading to the neglect of the agricultural sector. An increase in population growth and the explosive expansion of the service sector (Ravi Kumar et al., 2024a). At the same time, India's exports reached USD 778.21 billion in 2023-24, marking a historic rise from USD 466.22 billion in 2013-2014, a 67 per cent increase. The value of agricultural product exports rose from USD 22.70 billion in 2013-14 to USD 48.15 billion in 2023-24 (Ministry of Commerce and Industry, 2025). India was the eighth-largest exporter of agricultural products globally during that year.

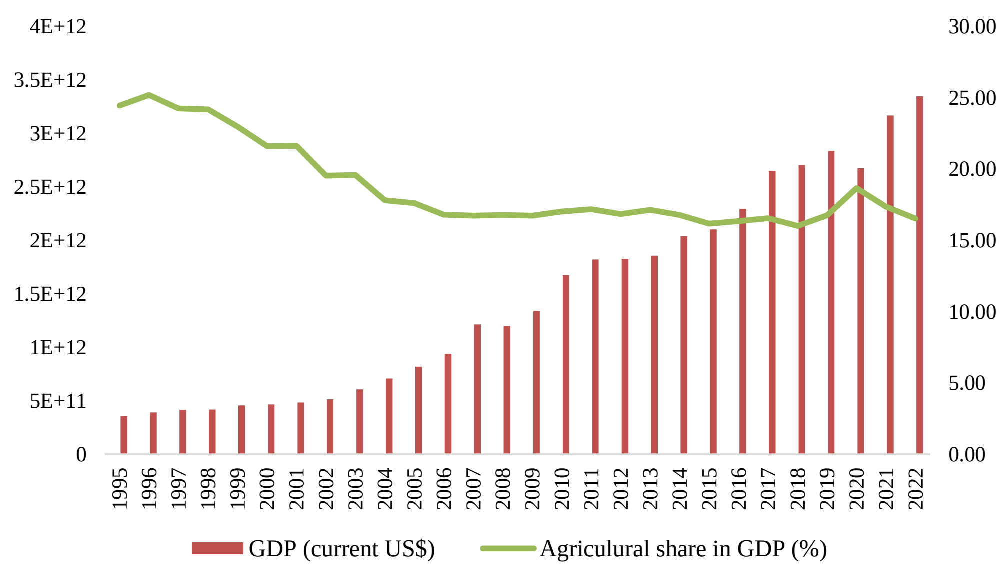

FIGURE 1. INDIA'S GDP AND SHARE OF AGRICULTURE IN GDP

Figures 2 and 3 highlight the major regions for Indian agri-food exports and the major Indian agri-food import markets. Based on the export value (1995-2022), the United States of America is India's top trading partner country in agri-food exports (with an export value of 2038041.89 thousand USD), followed by Vietnam, the UAE, Saudi Arabia, and Bangladesh, with values of 1514694.72, 1334304.46, 1081584.286, and 921059.5 thousand USD, respectively. Similarly, five countries, including Indonesia, Malaysia, Argentina, Ukraine, and the United States of America, are among India's major agri-food destinations. In 2021-22, agriculture and allied exports increased by 20.79 percentage points to a value of Rs. 3,74,611.64 crores. Major commodities that registered the highest growth in exports were wheat (279.71%), dairy products (98.40%), sugar (66.17%), and coffee (42.59%) (Government of India, 2025). Table 1 displays the performance of the Indian agri-food sector during the period 1995-2022 and reveals that food imports and exports accounted for 4.52 and 10.85 per cent of India's total imports and exports, respectively. India experienced a positive turnover in its agri-food industry during the research period (see Table 1).

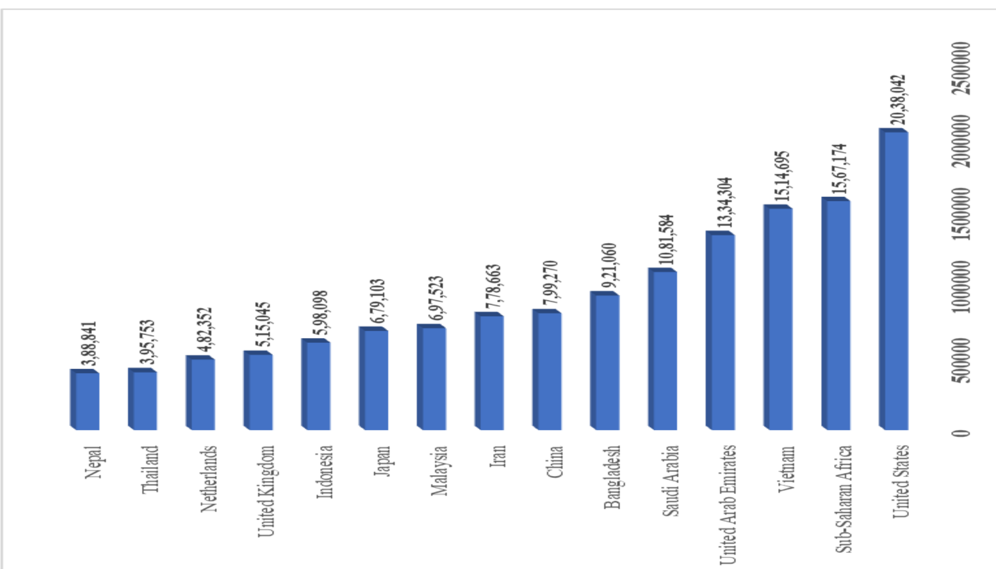

FIGURE 2. INDIA'S TOP FIFTEEN EXPORT MARKETS, MEAN, 1995–2022: EXPORTS (1,000 USD).

Source. WITS

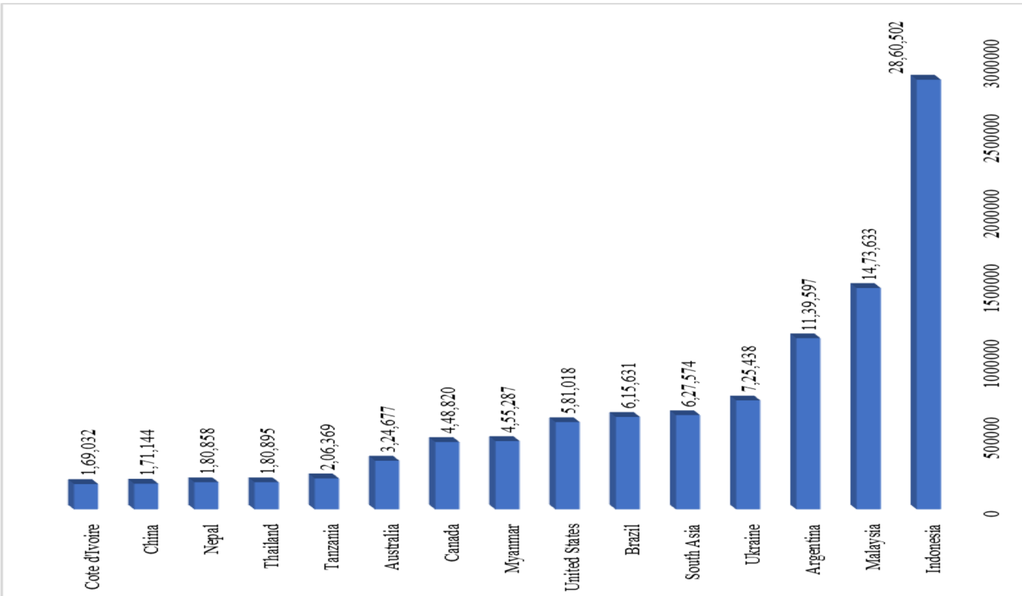

FIGURE 3. INDIA’S TOP FIFTEEN IMPORT MARKETS, MEAN, 1995–2022: IMPORTS (1,000 USD)

Source. WITS

In light of observed trends in India’s agri-food export performance, it becomes imperative to explore the key determinants influencing growth and sustaining it, particularly using the gravity model. One such earlier study was undertaken by Tinbergen (1962). He developed the gravity model in the early 1960s to conduct an empirical macro-level analysis of global trade. The traditional model posits that bilateral trade between any two nations is inversely proportional to geographic distance and directly proportional to each country’s size, as proxied by its GDP.

Other than the traditional factors such as GDP, distance, and population, as mentioned in studies (Ševela, 2002 in Czech; Shuai, 2010 in China; Aguirre González et al., 2018 in Nicaragua; Nsabimana and Tirkaso, 2020 in Eastern and Southern Africa; Kea et al., 2019 in Cambodia; Ravikumar et al., 2024a, 2024b in India), certain research has highlighted the importance of Regional Trade Agreements (RTAs) in enhancing trade efficiency. One such earlier study at the global level was conducted by Kalirajan (2007). Kalirajan (2007) employed the stochastic frontier (SF) version of the gravity model to measure the impact of trade agreements on Australian export efficiency. He reported that TAs increased exports to their importing partner nations by 15 per cent. The effect of East-West integration on trade efficiency was examined by Ravishankar and Stack (2014) using the stochastic frontier gravity model (SFGM), highlighting that the greater the trade integration, the fewer trade restrictions there are between two nations. Similarly, Ebaidalla and Yahia (2014) studied the performance of intra-COMESA trade integration in contrast with ASEAN integration. Two-stage gravity techniques suggest that regional trade integration among COMESA members performs unfavourably.

In the Indian context, Kumar and Prabhakar (2017) found that the ASEAN free trade agreements effectively increased the efficiency of bilateral trade between India and its partner countries, as analysed using data from 2000 to 2014. Whereas Barma (2017) focuses on how RTA agreements, such as ASEAN and SAFTA, and African nations influence the exports of agricultural products at the aggregate level. Kaushal (2022) employed the SFGM to examine the effects of trade agreements on India's overall export efficiency. According to the research, India has been able to significantly increase the efficiency of its exports to importing partner nations through bilateral agreements (BAs) and free trade agreements (FTAs), including those with ASEAN and SAFTA. She further criticised that exports are still below the potential frontier. To conclude, most studies have clearly established that trade agreements have increased the efficiency of exports. It should be highlighted here that the Government of India is entering into various RTAs across the globe. India’s RTAs have gained special attention as a developing superpower, and so it is imperative to analyse the effect of RTAs on export efficiency.

However, the present study differs from the existing studies. Kumar and Prabhakar (2017) and Kaushal (2022) investigated the effect of RTAs on overall trade efficiency, while Barma (2017) examined the impact of RTAs on the export of agricultural products overall. Instead of focusing on agricultural exports in general, the current study utilises panel data from 1995 to 2022 on agri-food exports to 67 trading partner nations as the dependent variable, employing several gravity equations that have not been examined in a single study. That is, the present study utilises a stochastic frontier gravity model (SFGM) to examine the role of India’s selected RTAs, such as the Global System of Trade Preferences among Developing Countries (GSTP), Asia Pacific Trade Agreement (APTA), South Asian Free Trade Agreement (SAFTA), South Asian Preferential Trade Agreement (SAPTA), Association of Southeast Asian Nations (ASEAN), MERCOSUR trade bloc, and the regulatory quality of member nations, along with traditional determinants such as size of economy proxied by nominal GDP, distance, population, and the exchange rate, in enhancing agri-food export efficiency.

The remaining portion of the article is structured as follows. The second part discusses the analytical framework of the stochastic frontier approach, including a description of the variables employed in the analysis and their corresponding data sources. The third section of the paper presents the findings and discussion. The article is summarised, and some policy insights are provided in the fourth section.

TABLE 1. PERFORMANCE OF INDIA AGRI-FOOD EXPORT

Description	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019	2020-2022	Average 1995- 2022
Imports							
Overall imports (thousand USD)	209570156.54	332476479.63	1119833059.68	2226823587.13	2178001339.49	1670948361.36	286579740.14
Agri- food imports (thousand USD)	12912961.80	17316735.22	36509065.42	84090797.82	110636152.34	88465245.51	12960405.86
Share of agri- food in overall imports (%)	6.16	5.21	3.26	3.78	5.08	5.29	4.52
Exports							
Overall exports (thousand USD)	170088210.70	271599402.58	726077230.83	1465612546.64	1464815232.45	1122986631.92	193377009.45
Agri- food exports (thousand USD)	29273584.71	32073015.29	64957842.85	149091063.92	160807234.17	130225264.64	20978815.02
Share of agri- food in overall exports (%)	17.21	11.81	8.95	10.17	10.98	11.60	10.85
Trade							
Overall trade (thousand USD)	379658367.24	604075882.21	1845910290.51	3692436133.77	3642816571.94	2793934993.29	479956749.59
Agri- food trade (thousand USD)	42186546.50	49389750.51	101466908.27	233181861.74	271443386.51	218690510.15	33939220.88
Share of agri- food in overall trade (%)	11.11	8.18	5.50	6.32	7.45	7.83	7.07
Balance of Trade							
Overall trade balance (thousand USD)	-39481945.84	-60877077.04	-393755828.85	-761211040.49	-713186107.04	-547961729.44	-93202730.69
Agri- food trade (thousand USD)	16360622.91	14756280.07	28448777.42	65000266.10	50171081.83	41760019.13	8018409.16

II
METHODOLOGY

2.1 *2.1 Stochastic Frontier Gravity Model: An Overview*

The gravity model has emerged as the predominant framework in international trade, analysing the impact of various variables on trade flows (Abdullahi et al., 2021). The conventional gravity model may be expressed as follows.

$$LnAF_{INDjt} = \alpha + \beta_1 LnGDP_{INDt} + \beta_2 LnGDP_{jt} + \beta_3 LnDis_{INDj} + \varepsilon_{INDjt} \quad (1)$$

AF_{INDjt} represents the bilateral agri-food export trade flows between India and other importing nations for the specified period (t= 1995-2022), where j= 1,2,3,4…….67. GDP_{INDt} and GDP_{jt} indicate the economic size of both nations, while Dis_{INDj} signifies the geographical distance between the capital city of India and that of importing countries.

The extended gravity model of specification (Gros and Gonciarz, 1993) is shown below.

$$LnAF_{INDjt} = \alpha + \beta_1 LnGDP_{INDt} + \beta_2 LnGDP_{jt} + \beta_3 LnDis_{INDj} + \beta_4 LnPOP_{INDt} + \beta_5 LnPOP_{jt} + \sum_{g=1}^{G} \lambda_g Z_{INDj} + \sum_{g=1}^{G} \sigma k AF_{INDjt} + \varepsilon_{INDjt} \quad (2)$$

AF_{INDjt}, GDP_{INDt}, GDP_{jt}, and Dis_{INDj} have the same definition as above. POP_{INDt} and POP_{jt} are the populations of India and the importing nation, respectively. Furthermore, equation (2) comprises the error term, ε_{INDjt}; the time-variant trade explanatory variables vector (distance), Z_{INDj}; and the time-variant trade stimulating (GDP, population) and trade stimulating variables (GSTP, APTA, SAFTA, SAPTA, ASE, MER) affecting AF_{INDjt}.

To address the inherent biases of the traditional time-varying gravity model, which fails to distinguish between individual heterogeneity and inefficiency, the present study employs the stochastic frontier gravity model (SFGM), following Kalirajan (1999). This was further modified by Kalirajan (2007) and Bhattacharya and Das (2014). The SFGM combines gravity and stochastic frontier models (Kaushal, 2022). It is often considered an innovative tool for measuring accurate efficiency scores and the variations between the potential and actual values. Exports are presumed to be 100 per cent technically efficient whenever a nation reaches its maximum trading capability. Since the inefficiency component of the error term u_i is the log difference between the maximum output and actual output, u_i x 100 per cent is the percentage that, in the case of perfectly efficient production, the actual output may be increased with the same inputs (Doan & Xing, 2018). The estimated value of u_i represents output-oriented technical inefficiency, and production is considered completely efficient when the value approaches the estimated u_i value (Kaushal, 2021).

To estimate India's agri-food export trade, we developed a time-varying export SFGM in this work by converting the traditional gravity model in equation (2), which is expressed as follows.

$$LnAF_{INDjt} = \alpha + \beta_1 LnGDP_{INDt} + \beta_2 LnGDP_{jt} + \beta_3 LnDis_{INDj} + \beta_4 LnPOP_{INDt} + \beta_5 LnPOP_{jt} + \sum_{g=1}^{G} \lambda_g Z_{INDj} + \sum_{g=1}^{G} \sigma k AF_{INDjt} + V_{INDjt} - U_{INDjt} \quad (3)$$

Ln denotes natural logarithm.

In equation (3), V_{INDjt} indicates the statistical noise caused by measurement error, and U_{INDjt} represents the trade efficiency or performance.

This study uses a built-in STATA tool to estimate U_{INDjt} based on Battese and Corelli's (1995) inefficiency model. A hypothetical trade frontier that represents the highest trade ability possible under the assumption of free trade is necessary for estimating trade efficiency. Previous studies have used a two-stage SF technique, which can lead to the omitted variable bias problem (Wang and Schmidt, 2002). Therefore, to increase the reliability of the results, the fixed effect (FE) model (based on the Hausman test), ordinary least squares (OLS), Poisson pseudo maximum likelihood (PPML), and the Heckman model were also utilised in the study. The FE approach considers the unobserved variable and manages the Multilateral Trade Resistance (MTR) phenomenon in the gravity model (Shahriar et al., 2019). OLS does average and two-sided residual functions (Abdullahi et al., 2021). It also produces accurate estimates of slope parameters. To solve the zero-trade situation, this study employs the Heckman model and the PPML method (Shahriar et al., 2019), which also solves the issues of heteroscedasticity and multicollinearity. The above strategies were employed to ensure the robustness of the SFGM.

2.2 Sources of Data, Variables and Postulates

The panel dataset spans 28 years, from 1995 to 2022, and includes bilateral agri-food exports between India and 67 trading partner countries (N = 67 × T = 28 = 1,876). Indian agri-food exports to these 67 nations accounted for 95 per cent of the total exports during the selected research period. The year 1995 was chosen as the base year due to its importance in global trade, as the World Trade Organisation (WTO) was created in that year. The data used in the present study were obtained from various sources, as shown in Table 2. The natural log has been used for all the variables except for dummies.

TABLE 2. VARIABLES DESCRIPTION

Variable	Description	Unit	Source
AF_{INDjt}	Total agricultural products export from nation 'IND' (India) to country 'j' for time period 't'	1000 USD	WITS*
GDP_{INDt}	Nominal GDP of the exporting nation 'IND' (India) at the time period 't'	1000 USD	World Bank Indicators+
GDP_{jt}	Nominal GDP of the importing nation 'j' at time period 't'	1000 USD	World Bank Indicators+
Dis_{INDj}	Distance between the capitals of the nation 'IND' and country 'j'.	Kilometers	CEPII^
Ex_{jt}/ Ex_{INDt}	Ratio of the exchange rate of nation 'j' at time period 't' and the exchange rate of nation 'IND' at time period 't'	LCU per US dollar	World Bank Indicators+
POP_{INDt}	Population of the nation 'IND' (India) at the period 't'	1000 persons	World Bank Indicators+
POP_{jt}	Population of nation 'j' at the period 't'	1000 persons	World Bank Indicators+
$GSTP_{INDjt}$	Dummy variable with value 1 if the GSTP trade agreement is active at time period 't', 0, otherwise.	Binary	WTO#
$APTA_{INDjt}$	Dummy variable with value 1, if the APTA trade agreement is active at time period 't', 0, otherwise.	Binary	WTO#
$SAFTA_{INDj}$	Dummy variable with value 1 for active SAFTA agreement at time period 't', 0, otherwise	Binary	WTO#
ASE_{INDjt}	Dummy variable with value 1 for active ASEAN agreement at time period 't', 0, otherwise	Binary	WTO#
MER_{INDj}	MERCOSUR trade agreement with value 1 for PTA India has signed with four South American nations at time 't', 0, otherwise	Binary	WTO#
RQ_{jt}	Regulatory quality of the importing nation 'j' at time period 't'	Regulatory quality index	WTO#

Source. Authors' own evaluation

Note.* World Integrated Trade Solutions- UNSD Commodity Trade Database; +World Development Indicators, World Bank; ^Centre *d'Etudes* Prospectives et *d'Informations Internationales*- Database, France; #World Trade Organisation

The present study employs India's GDP (LnGDPINDt) and the GDP of the importing nation (LnGDPjt) as proxies for economic size. India's GDP is considered the ability of a nation to supply or export, while the importer's GDP is related to the demand for certain products in the international market. Higher GDP is associated with increasing purchasing power, market potential, and economic integration (Ravi Kumar et al., 2024a). The influence of economic size on trade is represented in various ways in the gravity model. Some researchers have employed the GDP of the importing nation alone (Ahsan & Chu, 2014), whereas others have utilised the combined impact of the GDP of importing and exporting nations (Kea et al., 2019; Irshad et al., 2018). But the studies by Jambor and Tarok (2013) and Atif et al. (2016) utilised the GDP of importing nations and exporting nations separately to distinguish between supply and demand impacts. Certain studies (Kaushal, 2022; Shepherd et al., 2019) suggest that when country-pair-specific numeraires are required but not readily available, the use of accurate GDP data instead of nominal GDP can lead to bias due to the use of a single common numeraire. Nonetheless, this issue is resolved by utilising the nominal GDP to determine temporal effects (Baldwin & Taglioni, 2006). Therefore, in the current gravity model, nominal GDP is considered an independent variable and is expected to have a positive impact on India's exports to its trading partner nations.

While exporting, there are often three different types of costs: (i) shipping costs, (ii) interaction costs (also known as unfamiliarity costs), and (iii) time-related costs (Linnemann, 1966). Many studies (Kahouli, 2016; Kea et al., 2019) have employed distance as a proxy for transportation expenses. The greater the distance, the greater the costs related to transportation. The present study expects that distance (LnDisINDj) has a detrimental effect on agricultural export efficiency.

In certain economic studies, in addition to GDP and distance, the populations of exporting and importing nations are also included as important variables influencing agricultural product trade (Abdullahi et al., 2021). Owoo (2021) observes that a rise in the population of exporting nations will reduce agricultural exports due to the strong demand for food from the domestic market. Moreover, an increase in the population of the importing nation often raises the need for agricultural products (Abdullahi et al., 2021). The current study considers the population of India (LnPPINDt) and its trading partner nation (LnPPjt). A positive effect of importing countries' populations and a negative relationship of India's population on agri-export efficiency are expected.

Exchange rates are used in the augmented gravity model to account for variation in bilateral trade (Bergstrand, 1985; Abdullahi et al., 2021; Xu et al., 2022). The present study measures the exchange rate via the exchange rate specification given by Binh (2013).

$$\text{ExINDjt} = \frac{\text{Yearly average of the national currency unit of India per USD}}{\text{Yearly average of the national currency unit of nation ‘j’ per USD}}$$

The ratio examines India’s yearly mean exchange rate per unit of the importing nation’s exchange rate ($LnEx_{jt}/Ex_{INDt}$). Theoretically, a rise in this ratio indicates a decline in India’s exchange rate. Thus, enhancing exports (Kaushal, 2021).

Regulatory quality (RQ) is considered to have a substantial impact on trade at present. The regulatory quality of importing nations is also considered when estimating the inefficiency equation of trade (Nabeshima & Obashi, 2021). Regulatory quality reflects the attitudes of the importing countries' governments and the capacity of state authorities to create and implement policies that safeguard and promote the growth of private sector actors (Miao et al., 2020). Although the possible impact of the variable is unknown a priori (Kaushal, 2022), the study assumes that the greater regulatory quality of the importing country (RQ_{jt}) will have a favourable impact on India's export efficiency.

The agreements outlined in section 1 are taken into consideration in this study. These were selected due to their relevance in shaping India’s agri-food trade with developing and emerging economies. These agreements represent India’s key regional and plurilateral trade partnerships that promote market access, reduce tariff and non-tariff barriers, and enhance trade cooperation.

III

RESULTS AND DISCUSSION

The present study estimates the SFGM using a two-stage technique to determine the factors influencing India’s agricultural product export efficiency to its major trading partners. Furthermore, fixed effect (FE), OLS, PPML, and Heckman selection models were utilised. Tables 3 and 4 display the traditional and extended SFGM results. The application of the SFGM is supported by both the LR and the $\lambda = 0.997$ (Table 4). Similarly, the Hausman test favours the FE approach over the random model. According to the findings in both Tables 3 and 4, economic size, proxied by the GDP of both exporting (LnGDPINDt) and importing nations (LnGDPjt), has a positive effect on export efficiency. At the same time, the distance is having a detrimental impact. This often confirms the hypothesis in the traditional gravity model developed by Tinbergen (1962). A 1 per cent rise in India's GDP increases export efficiency by 2.10 per cent, as evident from the extended model. In contrast, a 1 per cent rise in the importing nation's GDP increases Indian agri-export efficiency by 0.578. These positive results were consistent across all the models. The results show that wealthier nations import more due to their increased capacity for consumption and diversified dietary preferences. This finding aligns with existing studies by Atif et al. (2016), Abdullahi et al. (2021), and Kaushal (2022). It is worth noting that India's domestic consumption has increased substantially by over 21 per cent over the last three decades, driven by the growth of the nation’s middle class, rising purchasing power, infrastructure development, and the expansion of service and technology industries. However, India’s economic development is driven mainly by domestic consumption rather than exports, as evident from the greater impact of India’s GDP on export efficiency compared to that of its importing partner nations.

From Tables 3 and 4, it is evident that distance (LnDisINDj) has a negative influence on the export efficiency of Indian agri-food products. The longer the distance, the higher the transportation costs, the longer the transit times, and the greater the logistical barriers. Indian agri-exports are less competitive with those of distant regions. The perishable nature of agri-food products demands that they be delivered on time to preserve their quality. Even if trade agreements exist, inadequate infrastructure and connection issues might impede smooth trade flows. This finding is consistent with those of Miankhel et al. (2014), Abdullahi et al. (2016), and Kea et al. (2019). The coefficient value of the exchange rate (LnExjt/LnExINDt) has a significant, favourable but insignificant effect in all models except in FE, as in Table 4. Exports have advantages due to the depreciation of the Indian currency, as it decreases the amount required to purchase Indian goods and services for foreigners. As a result, India’s competitiveness increases as the rupee's value decreases, allowing foreign buyers to purchase more Indian products for the same amount in their own currency. This apparent correlation between exchange rate fluctuations and trade performance is demonstrated by empirical data showing that a 1 per cent rise in the depreciation of the Indian rupee leads to a 0.2 per cent rise in exports, and this is in conformity with Venkatraja (2018) and Kaushal (2022). Such an insignificant effect under the FE model may be due to various reasons. First, the effect of exchange rate changes on trade often materialises with a lag, as export contracts are usually predetermined. Second, many of India’s export sectors are import-dependent, and depreciation raises the cost of imported raw materials, thereby reducing the net benefit of a weaker currency. Lastly, fluctuations in global demand and the low-price elasticity of certain export products limit the responsiveness of trade flows to currency changes.

The coefficient value of LnPPINDt is negative in all the models, with a coefficient value of -0.423 in SFGM, and is statistically significant in all the models except the OLS and Heckman selection models (Table 4). India, being the second-largest nation in terms of population, is likely to influence export efficiency inversely due to its high domestic consumption, which lowers the amount of surplus available for export. The demand for essential goods, including industrial and agricultural products, increases significantly as the population grows. The number of commodities accessible for foreign markets is limited by this preference for local requirements over exports, which lowers export efficiency. Ravi Kumar et al. (2024a) reported that limiting the production capacity for exports and increasing population expansion also stress resources such as land, water, and raw materials. LnPPjt has a significant positive coefficient value in all the models. India’s agri-product export efficiency increased at a rate of 1.347 as the population of importing nations increased by 1 per cent. A larger population in importing countries opened up new markets, enabling Indian exporters to achieve economies of scale. Barma (2017) documented similar results for India, and this outcome was also observed in many studies (Kea et al., 2019; Ravi Kumar et al., 2024b; Miankhel et al., 2014; Abdullahi et al., 2021).

In the case of regulatory quality (RQjt), the results support the notion that India's RQjt declines its export efficiency. This finding, which contradicts Ricker (2022), revealed a negative effect of regulatory quality. Ricker (2022), while analysing how regulatory quality affects the efficiency of manufactured goods trade in the U.S., reported that improving the quality of regulation increases the export performance and productivity of manufactured goods. However, in the case of India, stricter standards and compliance requirements increase costs, create non-tariff barriers, and necessitate the use of advanced products. These challenges limit India’s competitiveness, particularly for low-technology exports, thereby offsetting the potential benefits of trade facilitation.

In the case of RTAs, except for SAPTA, all other TAs considered in the current study influence export efficiency. The coefficient value of SAPTA is negative in all the models, but it is insignificant. The FTAs (ASEAN and SAFTA) had positive and significant coefficients in all the models. Free trade agreements (FTAs) with significant trading partners have raised imports, but export growth sometimes lags, leaving certain regions with persistent trade imbalances. The benefits of FTAs vary by sector, and concerns are raised about the long-term advantages of FTAs for India’s economic stability.

ASEAN and SAFTA have positive impacts, with coefficient values of 4.63 per cent and 2.39 per cent, respectively, indicating an increase in export efficiency. This finding aligns with those of Barma (2017). Preferential access to important South Asian markets, including Indonesia, Malaysia, and Vietnam, is made possible by the ASEAN-India FTA. Indian agricultural products, especially processed foods and spices, are in great demand in these nations. In the case of SAFTA members, including Bangladesh and Nepal, there is proximity, and the cost of transportation is also lower, resulting in a high demand for Indian agricultural and food products. This indicates that easing its “behind-the-border” restrictions leads to an increase in exports (Barma, 2017). Kaushal (2022) argued that structural inefficiencies, non-tariff barriers, and limited product diversification hindered India's ability to benefit from these agreements fully.

In the case of PTAs, except APTA, both GSTP and MERCOSUR, efficiency is negatively influenced. Agri-food products have greater elasticity of substitution than processed products do. As a result, trade agreements have less impact on primary Products.

TABLE 3. REGRESSION RESULT OF TRADITIONAL GRAVITY MODEL

Variables	SFGM $Ln(AF_{INDjt})$		FE $Ln(AF_{INDjt})$		OLS $Ln(AF_{INDjt})$		PPML $Ln(AF_{INDjt})$		Heckman $Ln(AF_{INDjt})$	
	Coeff.	p>|z|	Coeff.	p>|z|	Coeff.	p>|z|	Coeff.	p>|z|	Coeff.	p>|z|
$LnGDP_{INDt}$	1.108***	0.003	0.369***	0.000	0.824**	0.023	0.911***	0.004	0.766**	0.002
$LnGDP_{jt}$	0.443***	0.000	0.952**	0.007	0.694**	0.015	0.692**	0.025	0.269**	0.007
$LnDis_{INDj}$	-0.102	0.051			-0.323	0.029	-0.799	0.045**	-0.451	0.329
Constant	16.895***	0	-42.336	0.000	19.284**	0.023	19.254**	0.006	20.996**	0.024
LR Test	1059.36		--		--		--		--	
λ	0.998		--		--		--		--	
Hausman Test	--		0.000***		--		--		--	
R^2	--		0.256		0.395		0.301		--	
No. of Observations	1876		1876		1876		1876		1876	

Note. *** and ** represents statistical significance at the 1%, and 5% level, respectively.
Source. Authors' own evaluation

The coefficient value of GSTP is negative (-5.473), indicating that such an agreement reduces the export efficiency of Indian agri-food products. This may be because GSTP primarily covers developing nations with similar agricultural production patterns, which could have a negative impact. The effectiveness of exports is negatively influenced by the logistical and non-tariff restrictions mandated by several member nations. MERCOSUR has a negative coefficient value (-3.179). India faces high trade restrictions concerning MERCOSUR, including import permits, criteria for market entry, antidumping duties, evaluation, labelling, and certification, as well as the provision of export subsidies and support to domestic MERCOSUR producers. Further, India has a strong economic growth rate, which is sometimes comparable with that of China. However, Latin American nations which are part of MERCOSUR display greater instability and fluctuations (Bartesaghi, 2019). The coefficient of the APTA is positive and significant. The agreement aims to increase bilateral trade by fully utilising trade potential, expanding production capacities, and enhancing economic growth (Agarwal et al., 2017). This was found true by the outcome of the present study. A study by Bhasin and Manocha (2015) reported similar positive results. They found that the APTA provided better market opportunities to India than did the SAARC.

In sum, India's agri-food export efficiency is significantly influenced by GDP, population, distance, exchange rate, and regulatory quality. While India's domestic consumption limits surplus for exports, a larger GDP and population in importing nations positively impact trade. RTAs such as ASEAN, SAFTA, APTA, GSTP and MERCOSUR enhance export efficiency, whereas SAPTA shows negative or insignificant effects. The findings highlight that India’s agri-food export performance is shaped more by partner-country demand factors and regional trade agreements than by domestic supply conditions alone. Strengthening surplus generation, aligning with favourable RTAs, and addressing regulatory and efficiency barriers are essential to sustain competitiveness in global markets.

By employing Battese and Corelli’s (1995) criteria in the SF measuring approach, export efficiency is computed. The results are presented in Table 5 and Fig. 4. RTAs, such as GSTP, SAFTA, and MERCOSUR, are significant at the 5 per cent level, whereas APTA and ASEAN are significant at the 10 per cent level. India has been effectively increasing its exports to all member countries, except those in the SAPTA nations. There is an imbalance between imports and exports, with imports from SAPTA nations exceeding exports from India to SAPTA members. India’s overall export efficiency with importing member nations is 62 per cent, which is comparatively more than the average efficiency of exports with non-member nations (57 per cent). As Table 4 indicates, ASEAN has the greatest realised potential for exports (72 per cent), followed by SAFTA (71 per cent), APTA (67 per cent), GSTP (61 per cent), and MERCOSUR (51 per cent). That is, on average, in comparison to PTAs (GSTP, APTA, SAPTA, MERCOSUR (with India)) (50 per cent), FTAs (SAFTA, ASEAN) (72 per cent) have significantly increased total export efficiency. That is, India will reap more benefits as an exporting nation that has entered the FTA.

TABLE 4. STOCHASTIC FRONTIER GRAVITY MODEL ESTIMATION

Variables	SFGM $Ln(AF_{INDjt})$		FE $Ln(AF_{INDjt})$		OLS $Ln(AF_{INDjt})$		PPML $Ln(AF_{INDjt})$		Heckman $Ln(AF_{INDjt})$	
	Coeff.	p>|z|	Coeff.	p>|z|	Coeff.	p>|z|	Coeff.	p>|z|	Coeff.	p>|z|
$LnGDP_{INDt}$	2.146**	0.002	2.038***	0.000	1.967**	0.011	2.357**	0.009	1.964**	0.010
$LnGDP_{jt}$	0.578***	0.000	1.929**	0.013	1.762**	0.015	0.692**	0.021	1.757**	0.013
$LnDis_{INDj}$	-0.923**	0.050	-0.741**	0.036	-0.642**	0.031	-1.632***	0.000	-0.634	0.32
$LnEx_{jt}$/ $LnEx_{INDt}$	0.831**	0.043	0.661**	0.067	0.572**	0.002	0.942***	0.001	0.569***	0.001
$LnPP_{INDt}$	-0.423***	0.001	-1.314**	0.023	-1.001**	0.007	-0.531**	0.003	-1.003**	0.006
$LnPP_{jt}$	1.347**	0.032	1.618**	0.041	1.467**	0.082	1.543**	0.012	1.465**	0.051
$LnGSTP_{INDjt}$	-5.473**	0.003	-4.189**	0.040	-3.968**	0.031	-5.919**	0.029	-3.964**	0.032
$LnAPTA_{INDjt}$	4.629**	0.021	3.497**	0.027	2.998**	0.040	4.992**	0.033	2.995**	0.042
$LnSAFTA_{INDj}$	2.389**	0.044	1.908**	0.003	1.660***	0.000	2.946**	0.002	1.659***	0.001
$LnSAPTA_{INDj}$	-13.468	0.478	-10.143	0.516	-9.432	0.326	14.576	0.169	-9.430	0.324
$LnASE_{INDjt}$	4.709**	0.036	3.812**	0.028	3.514**	0.016	5.002**	0.014	3.515**	0.017
$LnMER_{INDj}$	-3.179***	0.000	-2.198***	0.001	-2.002***	0.001	-3.942***	0.000	-2.004**	0.002
$LnRQ_{jt}$	-5.117**	0.038	-4.524***	0.001	-4.004**	0.003	-5.829***	0.000	-4.003**	0.003
Constant	14.003***	0.001	-36.158***	0.000	14.744**	0.014	12.611**	0.023	18.654**	0.035
LR Test	1149.06		--		--		--		--	
λ	0.997		--		--		--		--	
Hausman Test	--		0.000***		--		--		--	
R^2	--		0.351		0.445		0.497		--	
No. of Observations	1876		1876		1876		1876		1876	

Note. *** and ** represents statistical significance at the 1%, and 5% level, respectively.

Source. Authors' own evaluation

One of the main reasons PTAs do not change India's export efficiency is the shallow nature of the agreement, which involves only a limited amount of trade liberalisation.

TABLE 5. MEASUREMENT OF EXPORT EFFICIENCY ESTIMATES

Trade Agreements	Average Export Efficiency
GSTP	0.614
APTA	0.672
SAFTA	0.711
SAPTA	0.568
ASEAN	0.729
MERCOSUR	0.513
Non-members	0.575
Overall Efficiency	0.626

Source. Authors' own evaluation

In the case of GSTP, owing to reduced tariffs, Indian exporters can gain better prices, especially for agri-food products. It is crucial in supporting trade-related matters between India and the global south (Yaguy and Sun, 2025). Although the APTA was found to increase the export efficiency of India's agri-food products, the extent to which it remains is a major question. This may be because, although tariff rates in the agricultural and related sectors are often lower than the applied rates, they have not been drastically reduced under the APTA. Moreover, the number of commodities offered under the APTA is also low (Arthashastra Intelligence, 2023).

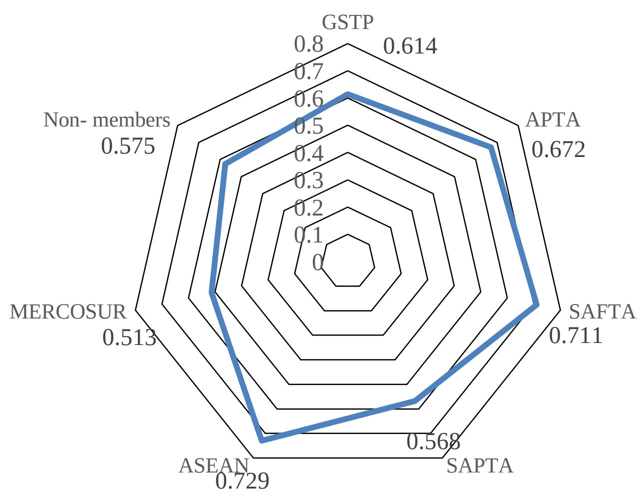

FIGURE 3. AVERAGE EXPORT EFFICIENCY
SOURCE: AUTHOR'S OWN EVALUATION

India's SAFTA trade remains extremely low at approximately 5 per cent of the total trade in the area. The primary reason is the high transportation costs associated with moving commodities across regional borders. As Akhtar and Ejaz

(2010) reported, if SAARC nations, including India, signed FTAs with non-member nations, the potential for trade development through SAFTA would decrease or be negligible. They added that SAFTA has more long-term benefits than short-term benefits. Similarly, ASEAN agreements have been identified as a means to increase the export efficiency of PTAs. This is evident from the fact that India and ASEAN countries had a remarkable relationship in the trade of agricultural products, with over 10 per cent of exports and 30-40 per cent of exports outside the world (Renjini & Kar, 2016). Despite India's modest trade liberalisation, MERCOSUR member nations have extremely protective trade policies. It seems that tariff reductions are insufficient to achieve genuine market integration. According to a special report by Bartesaghi (2019), between 2001 and 2018, India's average exports to MERCOSUR increased by 15.3 per cent, and the tariff charged by MERCOSUR was 10 per cent greater than the global average. So, the present agreement between India and MERCOSUR needs to be strengthened. Hence, India's agri-food export efficiency improves significantly under FTAs, especially with ASEAN, SAFTA, and APTA. PTAs remain less effective due to limited liberalisation. High tariffs and non-tariff barriers in MERCOSUR hinder potential. Strengthening agreements is crucial for India to realise its full export potential in global markets.

IV

POLICY IMPLICATIONS AND CONCLUSION

The present study, employing the stochastic frontier gravity model, aims to understand how the selected RTAs influence India's agricultural product exports from 1995 to 2022, alongside traditional trade determinants such as GDP, population, distance, exchange rate, and regulatory quality. To address concerns of endogeneity, as improvements in the terms of trade lead to an increase in exports, which can in turn foster more favourable conditions for securing additional trade agreements, this study adopts rigorous econometric techniques, including the stochastic frontier gravity model (SFGM). Also, it employs the fixed effect model, OLS, PPML, and the Heckman selection model to verify the results obtained via the SFGM. These methods help isolate the causal impact of trade agreements on agri-food export efficiency by controlling for reverse causality and the potential bias from omitted variables. The use of time-invariant fixed effects and robust estimation techniques, such as the Poisson pseudo-maximum likelihood and Heckman selection model, ensures unbiased results. Hence, the influence of trade agreements is shown to be exogenous and statistically valid, ruling out significant endogeneity concerns to an extent.

The study found that the GDP of India and its importing nations, the population of the importing nations, and the exchange rate positively influence export efficiency. The distance and population of India negatively affect exports. The regulatory quality of its importing trading partners increases India's export efficiency. To promote trade across regions and ensure economies gain global competition, harmonising regulatory norms and reducing unintentional trade barriers are needed. Furthermore, the study reveals that India's agricultural product export efficiency has improved significantly, averaging 50 per cent with PTA partners (GSTP, APTA, SAPTA, and MERCOSUR) and 72 per cent with FTA partners (SAFTA and ASEAN). However, with regard to non-member countries, India's export efficiency has been exceptionally low compared to its trading with partner countries.

As RTAs play a crucial role in improving the potential export flow between member nations, establishing free trade agreements (FTAs) is crucial for strengthening ties with other regions and boosting export flows. The following steps need to be taken to enhance deep integration among trading partner nations: (1) expand the geographic scope of integration and eliminate the trade barriers among the partner nations; (2) offer a mechanism to support exporters who encounter difficulties in transferring goods and expand sectoral coverage in the RTA procedure. To promote exports and boost economic growth, government institutions such as the Ministry of Commerce and Industry must create and implement policies that are business-friendly, encourage both local and international exporters, and improve the trading environment. Given the positive effect of GDP on agri-food export, enacting macroeconomic policies to increase India's economic size (domestic efficiency) would encourage agri-food export efficiency. Furthermore, there is a need to enhance trade relations between India and the GSTA, APTA, SAPTA, and MERCOSUR. Given the adverse effects of distance, India should increase its agricultural exports to neighbouring countries. Given the positive effect of the exchange rate, export efficiency can be facilitated by a comparatively lower but stable currency rate. Policymakers should pay more attention to entering TAs with a trading partner, considering their political and economic stability record. The present exercise has identified the scope for future studies to determine export efficiency at a more disaggregated level, i.e., at the individual agricultural product level in India.

REFERENCES

Abdullahi, N. M., Huo, X., Zhang, Q., & Bolanle Azeez, A. (2021). Determinants and potential of agri-food trade using the stochastic frontier gravity model: Empirical evidence from Nigeria. *Sage Open*, *11*(4). https://doi.org/10.1177/21582440211065770

Agarwal, V., Kaur, R., & De, D. (2017). Scenario analysis of textile industry in Asia-Pacific trade agreement (APTA). Procedia Computer Science, 122, 685-690. https://doi.org/10.1016/j.procs.2017.11.424

Agriculture statistics at a glance. (2023). Department of Agriculture and Farmers Welfare. Ministry of Agriculture and Farmers Welfare, Government of India. https://desagri.gov.in/document-report-category/agriculture-statistics-at-a-glance/

Aguirre González, M., Candia Campano, C., & Antón López, L. (2018). A gravity model of trade for Nicaraguan agricultural exports. Cuadernos de Econom, 37(74), 391- 428.

Ahsan, M.R., & Chu, S.N. (2014). The Potential and Constraints of the Exports of Environmental Goods: The Case of Bangladesh. Working Paper No. 05. Australia South Asia Research Centre, Australian National University.

Akhtar, N. N., & Ejaz. N. G. (2018). Regional Integration in South Asia: An analysis of trade flows using the Gravity Model. The Pakistan Development Review, 105–118. https://doi.org/10.30541/v49i2pp.105-118

Arthashastra Intelligence. (2023, June 23). Impact of Asia Pacific trade agreement (APTA) on India-China trade. AI Insights. https://insights.arthashastra.ai/impact-of-apta-on-india-china-trade/

Atif, R. M., Haiyun, L., & Mahmood, H. (2016). Pakistan's agricultural exports, determinants and its potential: An application of stochastic frontier gravity model. The Journal of International Trade & Economic Development, 26(3), 257-276. https://doi.org/10.1080/09638199.2016.1243724

Baldwin, R., & Taglioni, D. (2006). Gravity for dummies and dummies for gravity equations. NBER Working Paper No. 12516.

Barma, T. (2017). Efficiency of India's agricultural exports. South Asia Economic Journal, 18(2), 276-295. https://doi.org/10.1177/1391561417713130

Bartesaghi I. (2019). India's Relations with MERCOSUR. Extraordinary and Plenipotentiary Diplomatist, 7(9), 13-16. https://www.ucu.edu.uy/aucdocumento.aspx?1217,2322

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, 20(2), 325–332. https://doi.org/10.1007/BF01205442

Bergstrand, J. H. (1985). The gravity equation in international trade: Some microeconomic foundations and empirical evidence. The Review of Economics and Statistics, 67(3), 474. https://doi.org/10.2307/1925976

Bhasin, N., & Manocha, R. (2015). Impact of regional trade agreements on India's agricultural exports. FOCUS: Journal of International Business, 2(2). https://doi.org/10.17492/focus.v2i2.8624

Bhattacharya, S., and G. Das. (2014). Can South–South Trade Agreements Reduce Development Deficits? an Exploration of SAARC during 1995–2008. Journal of South Asian Development 9 (3), 253–285. doi:10.1177/0973174114549129

Binh, P. T. (2013). Unit root tests, cointegration, ECM, VECM, and causality models. Topics in Time Series Econometrics.

CEPII. (2025, March 15). Data Visualization. Retrieved March 30, 2025, from https://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp

Chenery, H. B., & Strout, A. M. (1966). Foreign assistance and economic development. The American Economic Review 56 (4): 679–733, 56(4), 679- 733.

Doan, T. N., & Xing, Y. (2018). Trade efficiency, free trade agreements and rules of origin. Journal of Asian Economics, 55, 33-41. https://doi.org/10.1016/j.asieco.2017.12.007

Ebaidalla, E. M., & Yahia, A. M. (2014). Performance of Intra-COMESA trade integration: A comparative study with ASEAN's trade integration. African Development Review, 26(S1), 77-95. https://doi.org/10.1111/1467-8268.12094

Frankel, J. A., & Romer, D. (1999). Does trade cause growth? American Economic Review, 89(3), 379-399. https://doi.org/10.1257/aer.89.3.379

Government of India. (2025). Department of Agriculture & farmers welfare. Retrieved July 27, 2025, from https://agriwelfare.gov.in/en/AgricultureTrade

Gros, D., & Gonciarz, A. (1996). A note on the trade potential of central and Eastern Europe. European Journal of Political Economy, 12(4), 709-721. https://doi.org/10.1016/s0176-2680(96)00024-9

Irshad, M. S., Xin, Q., & Arshad, H. (2018). Competitiveness of Pakistani rice in international market and export potential with global world: A panel gravity approach. Cogent Economics & Finance, 6(1), 1486690. https://doi.org/10.1080/23322039.2018.1486690

Jambor, A., & Torok. A. (2013). Intra-Industry Agri-Food Trade of the Baltic Countries [Paper presentation]. 87th Annual Conference of the Agricultural Economics Society, University of Warwick, UK.

Kahouli, B. (2016). Regional integration agreements, trade flows and economic crisis: A static and dynamic gravity model. International Economic Journal, 30(4), 450-475. https://doi.org/10.1080/10168737.2016.1204338

Kalirajan, K. (1999). Stochastic varying coefficients gravity model: An application in trade analysis. Journal of Applied Statistics, 26(2), 185-193. https://doi.org/10.1080/02664769922520

Kalirajan, K. (2007). Regional cooperation and bilateral trade flows: An empirical measurement of resistance. The International Trade Journal, 21(2), 85-107. https://doi.org/10.1080/08853900701266555

Kaushal, L. A. (2022). Impact of regional trade agreements on export efficiency – A case study of India. Cogent Economics & Finance, 10(1). https://doi.org/10.1080/23322039.2021.2008090

Kea, S., Li, H., Shahriar, S., Abdullahi, N. M., Phoak, S., & Touch, T. (2019). Factors influencing Cambodian rice exports: An application of the dynamic panel gravity model. Emerging Markets Finance and Trade, 55(15), 3631-3652. https://doi.org/10.1080/1540496x.2019.1673724

Khalid, M. W., Kayani, A. S., Alotaibi, J. M., Muddassir, M., Alotaibi, B. A., & Kassem, H. S. (2020). Regional trade and food security challenges: The case of SAARC countries. Agricultural Economics (Zemědělská ekonomika), 66(7), 335-344. https://doi.org/10.17221/3/2020-agricecon

Kinnunen, P., Guillaume, J. H., Taka, M., D'Odorico, P., Siebert, S., Puma, M. J., Jalava, M., & Kummu, M. (2020). Local food crop production can fulfil demand for less than one-third of the population. Nature Food, 1(4), 229-237. https://doi.org/10.1038/s43016-020-0060-7

Kumar, S., & Prabhakar, P. (2017). India's trade potential and free trade agreements: A stochastic frontier gravity approach. Global Economy Journal, 17(1). https://doi.org/10.1515/gej-2016-0074

Linnemann, H. (1966). An econometric study of international trade flows. Amsterdam, North-Holland.

Miankhel, A. K., Kalirajan, K. P., & Thangavelu, S. M. (2014). Australia's export potential: An exploratory analysis. Journal of the Asia Pacific Economy, 19(2), 230-246. https://doi.org/10.2139/ssrn.1692612

Miao, M., Lang, Q., Borojo, D. G., Yushi, J., & Zhang, X. (2020). The impacts of Chinese FDI and China–Africa trade on economic growth of African countries: The role of institutional quality. Economies, 8(3), 53. https://doi.org/10.3390/economies8030053

Miller, T., Kim, A. B., Roberts, J. M., & Tyrrell, P. (2020). Highlights of the 2020 Index of Economic Freedom. Washington, DC: The Heritage Foundation.

Ministry of Commerce and Industry. (2025). India: Leading agricultural product exporters | Discover India's agri-export growth. India Brand Equity Foundation. https://www.ibef.org/exports/agriculture-and-food-industry-india

Nabeshima, K., & Obashi, A. (2021). Impact of regulatory burdens on international trade. Journal of the Japanese and International Economies, 59, 101120. https://doi.org/10.1016/j.jjie.2020.101120

Nsabimana, A., & Tirkaso, W. T. (2019). Examining coffee export performance in eastern and southern African countries: Do bilateral trade relations matter? Agrekon, 59(1), 46-64. https://doi.org/10.1080/03031853.2019.1631864

Owoo, N. S. (2021). Demographic considerations and food security in Nigeria. Journal of Social and Economic Development, 23, 128–167.

Ravi Kumar, K. N., Naidu, G. M., & Shafiwu, A. B. (2024a). Exploring the drivers of Indian agricultural exports: A dynamic panel data approach. Cogent Economics & Finance, 12(1). https://doi.org/10.1080/23322039.2024.2344733

Ravi Kumar, K. N., Reddy, K. G., Shafiwu, A. B., & Mohan Reddy, M. J. (2024b). Trade determinants and opportunities for Indian rice: A dynamic panel gravity model perspective. Cogent Economics & Finance, 12(1). https://doi.org/10.1080/23322039.2024.2312367

Ravishankar, G., & Stack, M. M. (2014). The gravity model and trade efficiency: A stochastic frontier analysis of eastern European countries' potential trade. The World Economy, 37(5), 690-704. https://doi.org/10.1111/twec.12144

Renjini, V., & Kar, A. (2016). Composition, intensity and competitiveness of agricultural trade between India and ASEAN. Indian Journal of Economics and Development, 12(2), 249. https://doi.org/10.5958/2322-0430.2016.00133.5

Ricker D. (2022). Regulatory Quality and Trade Performance: An Econometric Analysis. Economics Working Paper 2022–10–A. U.S International Trade Commission. https://www.usitc.gov/publications/332/working_papers/ecwp_2022-10-a_regulatory_quality.pdf

Ševela, M. (2002). Gravity-type model of Czech agricultural export. Agricultural Economics, 48(10), 463-466. https://doi.org/10.17221/5353-agricecon

Shahriar, S., Qian, L., Kea, S., & Abdullahi, N. M. (2019). The gravity model of trade. Review of innovation and competitiveness, 5(1), 21-42. https://doi.org/10.32728/ric.2019.51/2

Shepherd, B., Doytchinova, H. S., & Kravchenko, A. (2019). The gravity model of international trade: A user guide [R version]. United Nations ESCAP.

Shuai, C. (2010). Sino–US agricultural trade potential: A gravity model approach. Outlook on Agriculture, 39(3), 169-176. https://doi.org/10.5367/oa.2010.0008

Tinbergen, J. (1962). Shaping the world economy: Suggestions for an international economic policy. Twentieth Century Fund.

Venkatraja, B. (2018). Sensitivity of trade balance to exchange rate depreciation: Evidence from Indo-U.S. Bilateral trade. Asian Economic and Financial Review, 8(5), 691-703. https://doi.org/10.18488/journal.aefr.2018.85.691.703

Wang, H. J., & Schmidt, P. (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. Journal of Productivity Analysis, 18(2), 129-144. https://doi.org/10.1023/A:1016565719882

World Bank. (2025). World development indicators. DataBank | The World Bank. Retrieved March 30, 2025, from https://databank.worldbank.org/source/world-development-indicators

WTO. (2023). WTO Agriculture - gateway. World Trade Organization - Global trade. https://www.wto.org/english/tratop_e/agric_e/agric_e.htm

WTO. (2025). Regional trade agreements Database. Retrieved March 30, 2025, from https://rtais.wto.org/UI/PublicSearchByMemberResult.aspx?membercode=356

Xu, J., Lu, C., Ruan, S., & Xiong, N. N. (2022). Estimating the efficiency and potential of China's steel products export to countries along the “Belt and Road” under interconnection: An application of extended stochastic frontier gravity model. Resources Policy, 75, 102513. https://doi.org/10.1016/j.resourpol.2021.102513

Yaguy, & Sun. (2025, February 1). GSTP - Global System of Trade Preference. Tax Management India.com. https://www.taxmanagementindia.com/visitor/detail_article.asp?ArticleID=13450#:~:text=Enhanced%20Competitiveness%3A%20Preferential%20treatment%20under,better%20pricing%20in%20developing%20countries.