



RESEARCH ARTICLE

Factors affecting import of palm oil by India: A gravity model approach

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Received: 23 October 2025; Accepted: 18 May 2026; Available online: Version 1.0: 20 July 2026

Cite this article: Naga LK, Srinivasa RV, Sarada C, Amarender RA, Sreenivasulu KN, Mohan URB. Factors affecting import of palm oil by India: A gravity model approach. Plant Science Today. 2026;13(sp5):01–07. <https://doi.org/10.14719/pst.12390>

Abstract

India leads globally in imports of vegetable oils, a trend set to continue with a growing population and declining domestic production. Of all the vegetable oils imported by India, palm oil occupies the top one positions. This study aimed to determine factors affecting India's palm oil imports from its primary trading partners. This study investigates the determinants of India's palm oil imports from its major trading partners within an augmented gravity model framework, estimated using the poisson pseudo maximum likelihood (PPML) technique, employing panel data for 35 trading partner countries over the period 2001–23, based on the 6-digit harmonised system (HS) code 151190 and analysed using STATA. The analysis focuses on assessing the influence of economic size, trade costs and institutional factors on bilateral import flows, thereby offering deeper insights into the structural drivers of India's palm oil trade dynamics. The results of the Friedman, Pesaran's and Frees tests indicated there is a cross-sectional dependence ($p < 0.01$ or 0.05) within the panel data for palm oil. The empirical findings reveal that the gross domestic product (GDP) of partner countries such as Indonesia, Malaysia and Thailand, along with World Trade Organization (WTO) membership, exert a positive and significant influence on palm oil imports. In contrast, variables such as per capita income, distance, continent and common language demonstrated a negative and significant effect. Understanding these intricate dynamics is crucial for policymakers and stakeholders to address, emphasising the need for prioritising increased domestic production to reduce reliance on edible oil imports and promote sustainability.

Keywords: gravity model; import quantity; palm oil; Poisson Pseudo Maximum Likelihood; trade

Introduction

As of today, India stands as the world's most populous country and boasts the title of the fourth-largest economy globally with a population exceeding 1.4 billion, following closely behind the United States, China and Germany. Its economic trajectory has been remarkable, marked by consistent growth since 1990, earning its place as one of the world's fastest-growing developing economies. A pivotal aspect of this economic ascent has been India's role in the global market for vegetable oil.

India's consumption trends are characterised by shifting patterns of consumption in addition to increased overall consumption. In the early 1980s, for instance, peanut oil accounted for 32 % of all vegetable oil consumption in India, followed by rapeseed oil (21 %), soybean oil (19 %), palm oil (12 %) and other oils like sunflower, cotton and coconut oil (16 %). This distribution of oil consumption reflected traditional patterns of domestic oilseed production. However, in 2022–23, palm oil alone accounted for 40 % of total edible oil consumption, making palm oil the most popular oils (Fig. 1).

The country has achieved self-sufficiency in food grains production, in fact, it has become surplus in rice and wheat with mounting food stocks but still facing serious shortages of oilseed crops (1). Despite having one of the largest areas under oilseed cultivation globally, covering approximately 27–29 million hectares, India continues to depend significantly on imports, meeting nearly 58 % of its total edible oil requirement (about 12 million tonnes) (2).

In the early 2000s, India made a significant imprint on the international stage by becoming the world's leading importer of vegetable oils. India attracted over 15 % of global vegetable oil imports in 2002–03, making it the world's leading importer, ahead of the European Union and China (3). This surge in vegetable oil imports aligns with the domestic narrative of India experiencing a rapid and escalating demand for vegetable oils and fats. This surge is driven by factors such as a consistent increase in per capita income and an elevated standard of living (4).

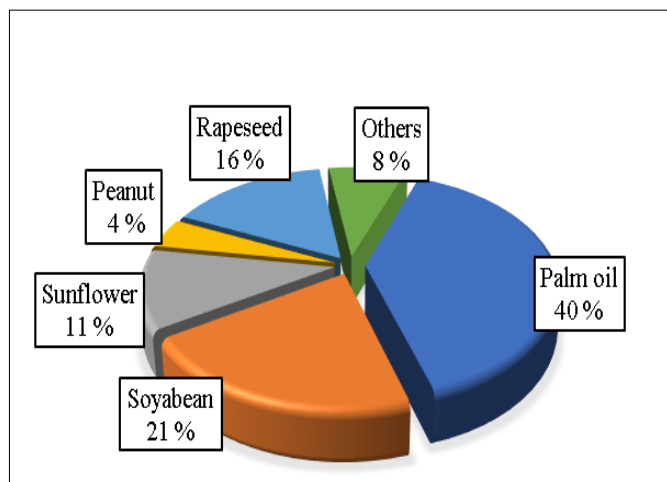


Fig. 1. Share of vegetable oils consumption in India in the year 2022–23. *Source: United States Department of Agriculture.

It is well known that the amount of oils and fats consumed correlates closely with both population size and economic development (5). The average annual intake of oils and fats in Asia has increased over the last 30 years to 23.2 kg, which is still slightly less than the global average of 28 kg per capita. Thus, annual demand is increasing at a 6 % while the amount we produce domestically has been rising at just about 2 %. This gap between consumption and production necessitates substantial imports, making India heavily reliant on the global market. In this regard palm oil stands in the top position in the vegetable oils list importing by India to meet the domestic demand of vegetable oils. For this reason, palm oil was chosen for the research.

Several factors are responsible for driving the oilseed market. Numerous studies have focused on the vegetable oils trade and altogether investigated the determinants using gravity model frameworks (6–12). Notably, these studies collectively provide insights into the complexities of global palm oil trade. However, the intricate factors steering the surge in vegetable oil imports have not been afforded the requisite attention, despite their escalating prominence in global trade dynamics. In the context of vegetable oil trade, the gravity model has been particularly useful. It helps to identify key factors influencing trade, such as the size of the economies involved, geographical distance and possibly other factors like trade agreements, cultural ties and infrastructure (13, 14). By understanding these factors, policymakers and businesses can make informed decisions regarding trade policies, market access strategies and investment decisions.

Despite extensive research on vegetable oil trade, most studies predominantly focus on the export behaviour of producing countries, with limited attention given to importer-side dynamics. Moreover, earlier studies often rely on log-linear estimation techniques, which may produce biased estimates in the presence of heteroscedasticity and zero trade flows.

In this context, the present study contributes to the existing literature in three keyways. First, it applies the Poisson Pseudo Maximum Likelihood (PPML) estimator, which ensures robust and consistent estimation in the presence of heteroskedasticity and zero trade flows, addressing limitations associated with traditional log-linear models. Second, it utilises updated panel data spanning 2001–23, enabling a more comprehensive and policy-relevant analysis of recent trade dynamics. Third, the study adopts an importer-oriented perspective, which remains relatively underexplored in the literature,

thereby offering new insights into India's palm oil import dependence and its underlying determinants.

India's stature as a major player in the global vegetable oil market is not merely a statistical accolade but holds significant economic ramifications. The trade in vegetable oils contributes substantially to the nation's gross domestic product (GDP), employment and foreign exchange earnings. Investigating the factors influencing this trade becomes imperative for policymakers and stakeholders seeking to optimise the economic benefits and mitigate potential risks.

Materials and Methods

Yearly time series data of one of the major vegetable oils i.e. palm oil imports to India in terms of quantity (tonnes) from top 35 partner countries based on the 6-digit harmonised system (HS) code i.e., 151190 was acquired from multiple sources viz., International Trade Centre (ITC) Trade map (<https://www.trademap.org>), World bank portal (<https://data.worldbank.org>) etc. The data collected ranges from the year 2001–23. This section describes the methodology that was employed to conduct this study which includes the cross-dependency test, gravity model with PPML estimation method. The list of all the variables used in this study and sources from where the data is collected is listed in Table 1.

Cross dependency test

Prior to estimating the gravity equation, it is essential to perform a cross-sectional dependency (CD) test to detect and address any potential dependencies. We employ three CD tests:

- 1) Pesaran's residual CD test
- 2) Friedman's test
- 3) Frees test

Many researchers have employed the Pesaran CD test, Friedman test and Frees test to examine the presence of cross-sectional dependence in panel data, as these tests provide complementary evidence on cross-sectional correlation structures (15–19). The above tests play a crucial role in panel data analysis, with specific focuses on residual dependencies, temporal aspects or general cross-sectional dependencies. Their importance lies in their ability to ensure that panel data models are correctly specified and that the statistical inferences drawn from these models are reliable, helping researchers and policymakers make informed decisions.

$$CD = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \sqrt{T_{ij} \hat{\rho}_{ij}} \quad (\text{Peserans residual test})$$

Where, T_{ij} = common time-series observations between units i and j ,

$$\hat{\rho}_{ij} = \frac{\sum_{t \in T_{ij} \cap T_j} (\hat{u}_{it} - \bar{u}_i)(\hat{u}_{jt} - \bar{u}_j)}{\left[\sum_{t \in T_{ij} \cap T_j} (\hat{u}_{it} - \bar{u}_i)^2 \right]^{1/2} \left[\sum_{t \in T_{ij} \cap T_j} (\hat{u}_{jt} - \bar{u}_j)^2 \right]^{1/2}}$$

and

$$\bar{u}_i = \frac{1}{T_{ij}} \sum_{t \in T_{ij} \cap T_j} \hat{u}_{it}$$

Table 1. List of variables used in the study and its source

Sl. No	Variable name	Source
1	Import quantity	ITC TRADE MAP (www.trademap.org)
2	Gross domestic product (GDP)	FAOSTAT (https://www.fao.org/food-agriculture-statistics/en/)
3	Per capita income (PCI)	UN Statistics Division (https://unstats.un.org/unsd/snaama/basic)
4	Production	Ministry of Agriculture and Farmers Welfare (https://agriwelfare.gov.in/en/Agricultural_Statistics_at_a_Glance)
5	Population of India	UN Statistics Division (https://unstats.un.org/unsd/snaama/basic)
6	Population of partner country	UN Statistics Division (https://unstats.un.org/unsd/snaama/basic)
7	Distance	CEPII (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp)
8	Common continent	CEPII (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp)
9	Common language	CEPII (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp)
10	Common colony	CEPII (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp)
11	Landlocked	CEPII (http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele.asp)
12	WTO Membership	World Bank (https://www.worldbank.org/en/home)

ITC: International Trade Centre; CEPII: Centre d'Études Prospectives et d'Informations Internationales.

$$R_{ave} = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{r}_{ij} \quad (\text{Friedmans test})$$

where $r_{ij}^{\wedge}$ is the sample estimate of the rank correlation coefficient of the residuals

$$R_{ave}^2 = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{r}_{ij}^2 \quad (\text{Frees test})$$

The null hypothesis (H_0) in these tests states that there is no cross-sectional dependence in the panel data. This means that the residuals of the model are assumed to be independent across entities, with any observed correlations or dependencies treated as random occurrences. The presence of cross-sectional dependence in the panel data model, however, indicates that the p -value linked to these test statistics is significantly smaller than 0.05, which offers strong evidence to support the alternative hypothesis and reject the null hypothesis.

Gravity model

In this model, it is proposed that bilateral trade between countries is positively associated with the multiplication of their economic sizes (GDPs) and inversely related to the distance that separates them. The gravity model is estimated using the PPML estimator, which serves as the primary econometric approach in this study. The choice of PPML is motivated by its ability to provide consistent estimates in the presence of heteroskedasticity and to accommodate zero trade flows without requiring logarithmic transformation of the dependent variable (20). Given that trade data often contain zero observations and exhibit non-constant variance, PPML is considered the most appropriate and robust estimation technique for gravity model analysis. This economic relationship is represented by the following mathematical expression:

$$X_{ij} = \alpha \cdot (Y_i^{\beta_1} \cdot Y_j^{\beta_2}) D_{ij}^{\beta_3}$$

where, X_{ij} is the flow of exports into country 'j' from country 'i', Y_i and Y_j are country 'i's and country 'j's GDPs and D_{ij} is the geographical distance between the countries' capitals. Expanding on this fundamental concept, the dynamic gravity framework was implemented using a combination of analytical models, including generalised least square (GLS) and PPML.

Poisson Pseudo Maximum Likelihood (PPML) estimation procedure

The PPML is a commonly used method in the gravity model. The PPML estimator introduced, can readily handle zero observations and heteroskedasticity which have been recognised to affect gravity-type estimations (21, 22). It addresses the "Zeros" trade

problem, making it suitable for cases where trade values are zero. It's ideal for modelling count data, handles variations in trade flows (heteroscedasticity), accounts for correlated data and produces highly reliable estimators, especially in large-scale data analysis. This makes it an effective tool for analysing and modelling trade relationships between countries.

$$X_{ijt} = A + \beta_1 \log(GDP_{it}, GDP_{jt}) + \beta_2 \log(PCI_{it}, PCI_{jt}) + \beta_3 \log(PROD_{jt}) + \beta_4 \log(EXCRT_{jt}) + \beta_5 \log(POP_{it}) + \beta_6 \log(POP_{jt}) + \beta_7 \log(DIST_{jt}) + \beta_8 (COContig_{jt}) + \beta_9 (COCOLony_{jt}) + \beta_{10} (COL_{jt}) + \beta_{11} (WTOmem_{jt}) + \beta_{12} (LL_{jt}) + \varepsilon_{ij}$$

Where,

X_{ijt} = Quantity imports of palm oil/ soyabean oil to India ('i') from trading partners ('j') in period 't' (tonnes)

GDP_{it}, GDP_{jt} = Product of GDPs of India ('i') and trading partners ('j') in period 't' (US\$)

PCI_{it}, PCI_{jt} = Product of per capita income of India ('i') and trading partners ('j') in period 't' (US\$)

$PROD_{jt}$ = Production of oil palm/soyabean in trading partners ('j') in period 't' (tonnes)

$EXCRT_{jt}$ = Bilateral exchange rate of 'Rupee' of India in relation to trading partners 'j' in period 't'

POP_{it} = Population in India 'i' in period 't' (Million)

POP_{jt} = Population in trading partners 'j' in period 't' (Million)

$DIST_{jt}$ = Distance between capital of India and capital of trading partners 'j' in period 't' (kms)

$COContig_{jt}$ = Common continent dummy; 1: country 'j' and India are in some contig in period 't', 0: otherwise

$COCOLony_{jt}$ = Common colony dummy; 1: country 'j' and India are in some colony in period 't', 0: otherwise

COL_{jt} = Common language dummy; 1: country 'j' and India having the same language in period 't', 0: otherwise

$WTOmem_{jt}$ = World Trade Organization (WTO) membership dummy; 1: country 'j' is a WTO-member in period 't', 0: otherwise

LL_{jt} = Landlocked dummy; 1: country 'j' is landlocked with India in period 't', 0: otherwise

The term ε_{ij} represents the stochastic error term (residual), capturing unobserved factors affecting trade flows such as policy differences, measurement errors and omitted variables.

The "Zeros" trade problem, arises when using the logarithmic form of the gravity equation, is due to the undefined

logarithm of '0', especially when some country pairs don't trade during certain time periods. To tackle this issue, the PPML method widely used in the gravity model, handle "Zeros" in trade values (23). This method may provide the most robust analysis, with the PPML method modelling trade intensities.

Results and Discussion

India is one of the largest importers of palm oil in the world and its imports play a crucial role in meeting the country's edible oil demand (24). Palm oil is a versatile and widely used vegetable oil, known for its high productivity and relatively low cost compared to other vegetable oils (25). India primarily imports palm oil from several countries, including Indonesia, Malaysia, Nepal, Singapore and Bangladesh.

The data on palm oil imports to India from 2019–23 revealed several significant insights into the country's sourcing patterns and preferences. Firstly, Indonesia emerged as the dominant supplier (62.51 %) of palm oil to India, consistently exporting larger volumes compared to Malaysia (29.58 %). This trend is consistent across the five years, with Indonesia's export volumes surpassing Malaysia by a substantial margin. For instance, in 2022, Indonesia exported a staggering 1928404 tonnes of palm oil to India, while Malaysia's exports stood at 415331 tonnes. This indicated that Indonesia holds a significant market share in India's palm oil imports, likely due to factors such as competitive pricing, proximity and possibly trade agreements that favour Indonesian exports. While Indonesia maintains its position as the primary supplier, Malaysia remained as a key player in India's palm oil market, consistently exporting significant volumes over the years. Despite the fluctuation in export volumes, Malaysia consistently delivering a substantial amount of palm oil to India, indicating a stable trade relationship between the two countries in this sector.

On the other hand, other countries such as Nepal, Singapore, Papua New Guinea, Bangladesh, Argentina, China, Saudi Arabia and the United States of America showed minimal to no exports of palm oil to India. This highlighted the concentrated nature of India's palm oil imports, with Indonesia and Malaysia accounting for the bulk of the supply. The

negligible imports from these other countries suggested that they do not play a significant role in India's palm oil market, possibly due to factors such as higher prices, lower production capacity or lack of trade agreements.

Fig. 2 reflects some fluctuations in import volumes over the years. Despite these fluctuations, the overall trend points towards a growing reliance on Indonesia and Malaysia for palm oil imports, indicating the importance of these countries in India's palm oil supply chain. Table 2 provides a summary of logarithmically transformed variables, including the mean, standard deviation (SD), minimum and maximum values.

Gravity model

Gravity model is one which is widely used techniques for finding the factors affecting the international trade. This model is having the assumption of no cross dependency in the data. For checking this, various tests are available. Out of those, three tests, viz., Paseran's, Friedman's and Free's test were selected, followed by comparing the results obtained from them.

In Table 3, the results of the panel cross-sectional dependence (CD) tests, which provide strong evidence of cross-sectional dependence among residuals (H_0 : no CD among residuals). The Pesaran CD test reports a statistic of 23.522 with a p -value of 0.00, indicating highly significant dependence across panel units. Similarly, Friedman's test yields a statistic of 328.134 with a p -value of 0.00, further confirming the presence of cross-sectional dependence among the selected countries. In addition, the Frees test statistic of 8.545 exceeds the critical threshold, supporting the existence of cross-sectional dependence in the panel data.

Collectively, these results indicate that the null hypothesis of cross-sectional independence (H_0 : No CD among residuals) is rejected at conventional significance levels. This implies that the residuals of the model are correlated across countries, likely reflecting common global shocks, trade linkages, or shared market conditions. The presence of such dependence underscores the importance of employing robust estimation techniques, such as the PPML estimator, which ensure reliable and consistent results in the presence of interdependencies within panel data.

Table 2. Descriptive statistics of India's palm oil imports

Variable	Mean	S. Dev	Minimum	Maximum
Palm oil imports (tonnes)	40925.98	175259.10	0.05	957280.57
India GDP (US \$)	1702277.50	845652.37	490658.80	3201470.94
Partner countries GDP (US \$)	1216678.09	3112300.05	476.40	21380976.00
India PCI (US \$)	1303.93	WTO: World Trade Organization; 563.08	449.91	2238.13
Partner countries PCI (US \$)	20836.19	23670.28	221.29	103553.84
Oil palm production (tonnes)	852.31	667.83	128.87	2389.42
Exchange rate	55.20	11.23	41.35	74.10
India population (million)	1253.38	102.89	1078.97	1407.56
Partner countries population (million)	96.05	226.36	0.60	1412.36
Distance (km)	5582.20	3503.95	683.36	15817.92

US: United States; PCI: product complexity index.

Table 3. Results of panel cross dependency tests

Sl. No	CD test	Statistic	p value/ table value	Cross dependency
		Palm oil imports		
1	Pesaran's test	23.522***	0.00	Present
2	Friedman's test	328.134***	0.00	Present
3	Frees' test	8.545**	0.16	Present

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

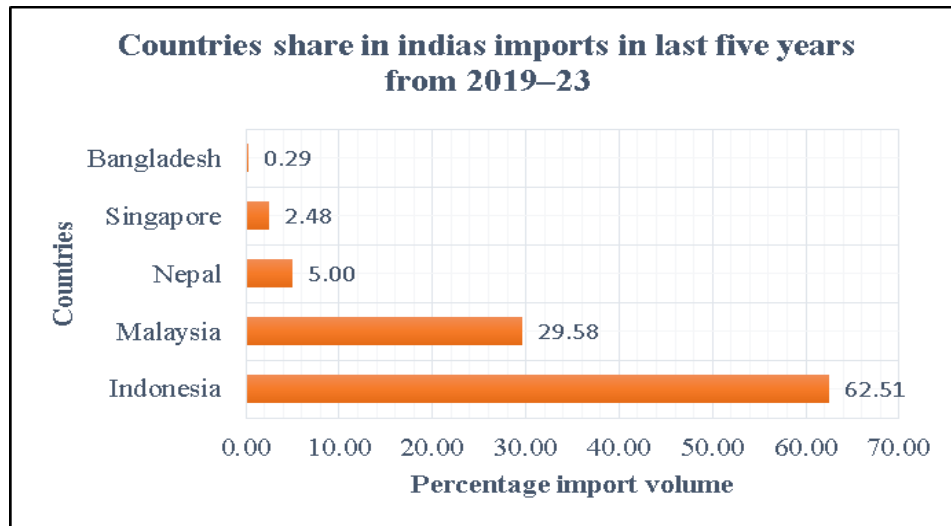


Fig. 2. Countries share in India's palm oil imports in last five years from 2019–23.

Now, the PPML estimation procedure is applied to the panel data of palm oil imports to determine the influence of different factors on India's palm oil imports. Table 4 presents a comprehensive analysis of the determinants influencing the import quantity of palm oil in India, utilising the PPML model coefficients. The product of GDPs for both the countries emerged as a crucial factor influencing import quantities, with coefficient of 3.31 that means 1 % increase in the income of exporting country leads to 3.31 % increase in exporting efficiency of palm oil. This implies that as the GDP of trading partners increases, there is a positive impact on the import quantity of palm oil into India (26).

On the contrary, the log of the product of both nations' per capita income (PCI_{it}, PCI_{jt}) shows a noteworthy negative impact on palm oil imports, with a coefficient of -10.17. This indicates that variations in the per capita income have a substantial inverse relationship with the import quantity of palm oil. Furthermore, population of importing and exporting countries has no significant effect on import quantity of palm oil. Exchange rate volatility exhibited a negative and significant influence on palm oil import efficiency (6, 27). It shows that 1 % increase in foreign exchange rate causes a 5.33 % decline in the palm oil import quantity. In other words, when the Indian rupee is relatively weak, it causes import costs to become costlier, which leads to decrease in palm oil import.

Geographic factors such as distance shows a negative relationship with the palm oil imports efficiency. A 1 % increase in distance reduces the palm oil import by 1.06 %. This finding is satisfying the hypothesis of gravity model, which is that India's palm oil imports is inversely proportional to the distance between trading partners (28). And factors such as common contiguity and common colonial history also play a role, with varying impacts on import quantity for palm oil. The WTO membership emerges as a substantial positive influencer, indicating that increased global trade openness corresponds to higher import quantity of palm oil in India.

The status of landlocked, measured by LL_{it} , showed negative impact on the import quantity of palm oil, highlighting the role of transportation in driving edible oil imports. The coefficient of -1.32 suggested that partner country being landlocked with India has a statistically significant negative effect on the trade of palm oil. This emphasises that being landlocked is associated with a greater reduction in the trade of palm oil.

The pseudo log-likelihood value of -40825504 suggested a satisfactory fit for the model, while the R -squared value of 0.31 indicated that approximately 31 % of the variance in the import quantity of palm oil in India is explained by the included determinants. These findings collectively provide valuable insights into the multifaceted factors shaping India's imports of palm oil.

Table 4. Determinants for quantity of palm oil trade in India

Variables	PPML model coefficient	Std. error.	95 % Conf. Interval	95 % Conf. Interval
GDP_{it}, GDP_{jt}	3.31**	5.84	-8.13	14.76
PCI_{it}, PCI_{jt}	-10.17*	6.28	-22.48	2.14
Production of CPO	4.61	4.08	-3.40	12.62
Exchange rate	-5.33*	4.73	-14.61	0.94
Population of importing country	11.43	43.94	-74.70	97.56
Population of trading partner	-0.71	6.12	-12.69	11.28
Distance	-1.06*	0.63	-2.29	0.16
Common continent	-6.17***	0.67	-7.48	-4.86
Common colony	-1.63	1.74	-5.03	1.78
Common language	-4.15**	1.60	-7.29	-1.00
WTO membership	4.21***	0.77	2.70	5.72
Land lockedness	-1.32*	1.06	-2.12	4.02
Constant	-90.67	372.01	-819.80	638.45
Pseudo log-likelihood	-40825504	-40825504	-40825504	-40825504
R -squared	0.31	0.31	0.31	0.31

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$; GDP: gross domestic product; PCI: product complexity index; WTO: World Trade Organization; CPO: crude palm oil; PPML: pseudo maximum likelihood.

Finally, PPML model highlighted the undeniable impact of globalisation. The WTO membership significantly boosts trade for palm oil, showcasing the organisation's role in promoting liberalisation and smoothing trade flows. This underscores the importance of international cooperation in ensuring a stable and efficient flow of essential commodities like oil.

Conclusion

This study combines a theoretically consistent gravity framework with panel data on India's palm oil imports from 35 trading partner countries over the period 2001–23, estimated using the Poisson Pseudo Maximum Likelihood (PPML) approach, to measure the effect of the various factors influencing the direction and volume of trade. The findings reveal that economic size, represented by the gross domestic product (GDP) of trading partners, has a positive and significant influence on India's palm oil imports, indicating that larger economies facilitate greater trade flows. In contrast, exchange rate fluctuations exhibit a negative and significant effect, suggesting that depreciation of the Indian rupee increases import costs and reduces import demand. Furthermore, trade costs such as distance negatively affect imports, while institutional factors like World Trade Organization (WTO) membership positively influence trade flows, highlighting the importance of trade openness. The results also indicate a high dependence on a few major exporting countries, raising concerns regarding supply vulnerability. Overall, the study underscores the need for policymakers and stakeholders to focus on strengthening domestic oilseed production, reducing import dependency and managing exchange rate risks to ensure stability in edible oil supply.

Acknowledgements

The authors want to acknowledge the Acharya N G Ranga Agriculture University (ANGRAU) and ICAR-Indian Institute of Oilseed Research (IIOR) for providing basic requirements and for providing financial assistance for conducting this research work.

Authors' contributions

KNL carried out the research work and statistical analysis, participated in the sequence alignment and drafted the manuscript. VSR participated in design of the study and analytical support. CS participated in the sequence alignment and provided the data required for the analysis. AAR provided guidance for selecting the research problem. KNS participated in its design and coordination. BMUR contributed to enhancing the quality of the document and supported the data collection process. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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