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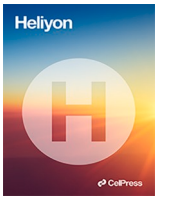

Research article

Tree nuts demand analysis using the LA-AIDS model: A case of the Indian economy paradox

David Forgenie [a,1], Karambir Singh Dhayal [b,1], Satesh Sookhai [c], Nikmatul Khoiriyah [d,*], Celine Suchit [e], Gabrielle Simbhoo [f], Wendy-Ann P. Isaac [e]

[a] Department of Agricultural Economics and Extension, Faculty of Food and Agriculture, The University of the West Indies, St. Augustine Campus, Trinidad and Tobago
[b] Department of Economics and Finance, Birla Institute of Technology & Science (BITS), Pilani Campus, Rajasthan, India
[c] Department of Management Studies, Faculty of Social Sciences, The University of the West Indies, St. Augustine Campus, Trinidad and Tobago
[d] Department of Agribusiness, Faculty of Agriculture, University of Islam Malang, Malang, Indonesia
[e] Department of Food Production, Faculty of Food and Agriculture, The University of the West Indies, St. Augustine Campus, Trinidad and Tobago
[f] Institute of International Relations, Faculty of Social Sciences, The University of the West Indies, St. Augustine Campus, Trinidad and Tobago

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ABSTRACT

India is one of the world's largest producers of tree nuts, yet it paradoxically remains a net importer of these commodities. This study aims to analyze the demand for imported tree nuts in India, motivated by the need to understand the factors contributing to this imbalance. The primary objective is to calculate income elasticities and own- and cross-price elasticities for five categories of imported tree nuts using the linear approximate almost ideal demand system model. Data is sourced from monthly import records from the United Nations Comtrade database covering 2014 to 2022. The tree nuts considered are almonds, cashews, pistachios, walnuts, and hazelnuts. Key findings reveal all imported tree nuts are normal goods. Cashews exhibit income elasticity (1.2), indicating a significant demand increase with rising incomes, while other nuts show income inelasticity. Cashews are price-elastic (−1.3), while other nuts are price-inelastic. Compensated cross-price elasticities indicate notable substitution effects, particularly between almonds and cashews. The study recommends enhancing domestic cashew production to meet growing demand and developing targeted marketing strategies to address competitive dynamics within the tree nut market. These strategies aim to reduce India's dependency on imports and promote a balanced, sustainable domestic market.

1. Introduction

In the contemporary era, the importance of tree nuts cannot be overlooked or underestimated. Tree nuts have become an integral part of different aspects of human life, ranging from nutritional intake and dietary preferences [1–4], health [5–8], livelihood and economic prosperity [9–11], and environmental sustainability [12–14]. Nuts are rich in fats, low in carbohydrates, and serve as excellent source of various nutrients such as vitamin E, magnesium, and selenium [4,15–18]. Nuts also contain protein, dietary fiber, unsaturated fatty acids, amino acids, flavonoids, phytochemicals, phytonutrients, and minerals [1,2,19–21]. Thus, due to their

* Corresponding author.
E-mail addresses: anthonyforgenie@gmail.com (D. Forgenie), nikmatul@unisma.ac.id (N. Khoiriyah).
[1] These authors have contributed equally to this work, hence, they are designated as co-first authors.

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extensive contribution to economic livelihood, the environment, nutrition, and health, tree nuts are regarded as significant and valuable resources in many countries.

Tree nuts encompass a very diverse range of edible seeds enclosed in a hard shell such as cashew, almond, pistachio, walnut, hazelnut, etc. Recently, tree nuts have gained substantial importance within the global agricultural trade landscape due to increased demand [22]. In 2021, the global consumption of tree nuts was approximately 5.15 million metric tonnes [23]. Almonds stood out as the predominant tree nut in global consumption, accounting for a substantial 31 %, equivalent to 1.57 million metric tonnes of the total worldwide consumption. Following closely were walnuts and cashews, collectively representing 19 % of the global nut consumption. Pistachio and hazelnut accounted for 15 % and 11 % of total global consumption in 2021, respectively. Furthermore, in 2021, the consumption of major tree nuts was estimated to be approximately 519.39 thousand metric tonnes. Cashews accounted for approximately 33.4 % of total tree nut consumption in India in 2021, followed by almond (10.3 %), walnut (2.3 %), and pistachio (1.7 %), respectively [23].

India finds itself part of this growing trade regime due to its agricultural diversity and economic dynamism, followed by the rising population pressure, which demands a different set of dietary preferences. Tree nuts have started becoming an integral part of the diet not just because of their nutrient-rich profile but also due to their role in the prevention of various chronic diseases [5,24]. This increased health awareness, coupled with a shift in consumer preference behavior of healthier food options, increased disposable income, and a rapidly growing urban population, has fueled tree nuts demand, thus making them an essential part of the diet in India. Furthermore, they are becoming widely popular in salads and sweets, which further adds to their popularity and increased demand.

In 2022, India imported approximately 1.11 million metric tonnes of tree nuts valued at US$ 2.38 billion [25]. Compared to 2014, Indian tree nuts import volume increased by 12.4 % in 2022. In terms of import volume, imported almond and cashew were the most popular tree nut groups. Import demand for cashews by India reached its peak in 2018, when approximately 0.99 million metric tonnes were imported (Fig. 1). However, the import demand for almond has seen a consistent increase in import volume between 2014 and 2022 (Fig. 1). Imported walnut, have seen drastic increases in import volume between 2014 and 2022 (Fig. 2). Walnut imports increased from 0.002 million metric tonnes in 2014 to 0.05 million metric tonnes in 2022. Imported pistachio, like walnut, have also seen a major increase in import volume between 2014 and 2022. However, despite being a major producer, India faces economic losses due to its significant import dependence on cashew nuts. The country's substantial import volume of cashews translates into a considerable financial outflow, which could otherwise have been channeled into domestic agricultural development and welfare programs, benefiting the populace.

The import expenditure share for almond and cashew constituted 42.9 % and 48.7 % of total tree nuts imports in 2022 (Fig. 3), corresponding to US$ 1.02 billion and US$ 1.16 billion, respectively. In contrast, imported hazelnut only accounted for less than 1 % of total tree nuts imports in India during the same period (Fig. 3). India is the second largest producer of cashew, producing approximately 15 % of the global total production or 670 thousand metric tonnes in 2021 [23]. However, of the 1.4 million tonnes of cashew nuts that were exported in 2021, India imported approximately 879.67 thousand metric tonnes, mainly from West Africa [23]. It is projected that tree nuts import demand will continue to increase in the future in India due to having significant importance in India [26,27].

The body of empirical literature abounds with studies that analyze demand using the Almost Ideal Demand System Model (AIDS) developed by Deaton and Muellbauer [28]. This approach is exemplified in various research works, including those by Refs. [29–39]. However, studies that explicitly take a demand analysis approach to study tree nuts import demand are few, see Refs. [22,40,41]. In demand analysis research, the Rotterdam model [42,43] and the AIDS model are particularly common. Both models are rooted in consumer theory and are used to impose or test theoretical restrictions derived from that theory [44–46]. However, as noted by Barnett

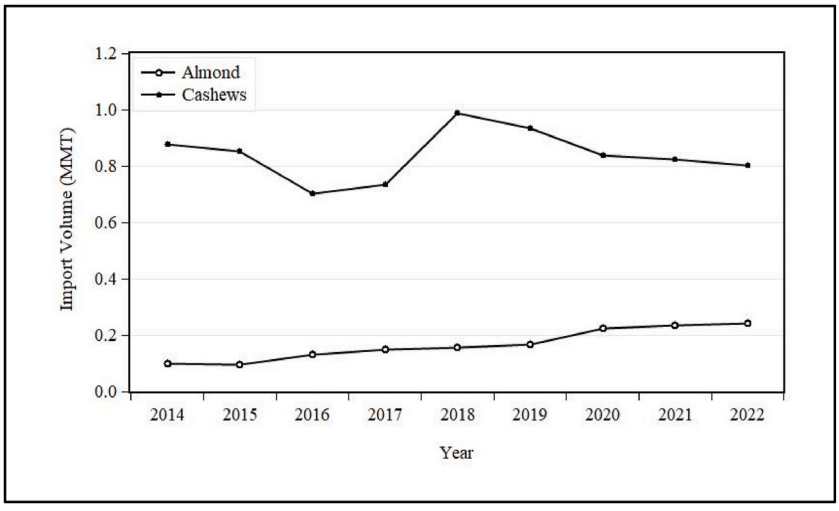

Fig. 1. Import demand of almonds and cashews by India for the period 2014–2022. **Note:** MMT – millions of metric tonnes.

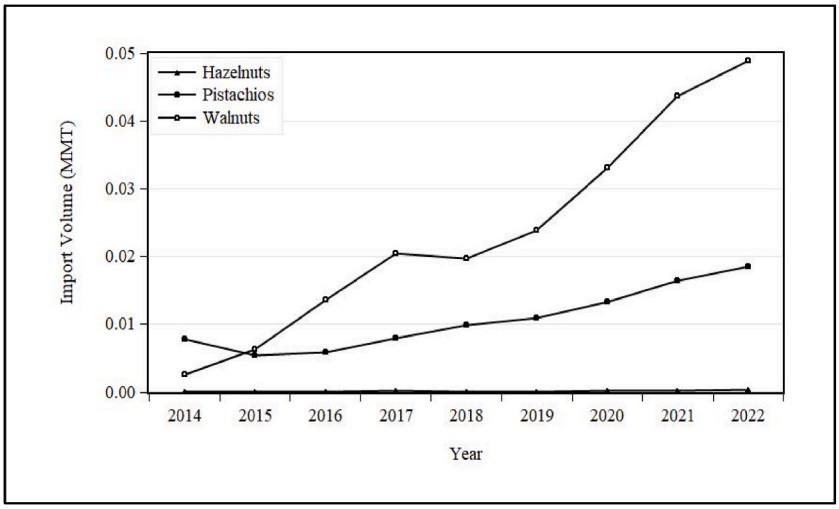

Fig. 2. Import demand of hazelnuts, pistachios, and walnuts by India for the period 2014–2022. **Note:** MMT – millions of metric tonnes.

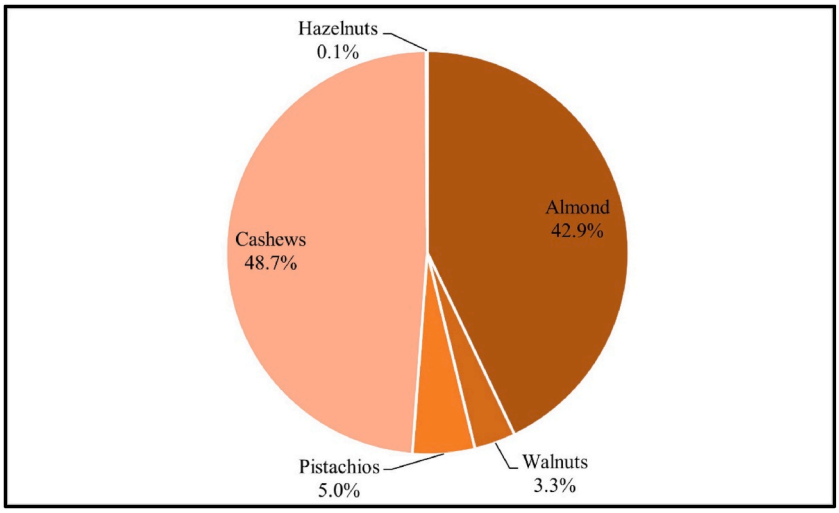

Fig. 3. Import share of various tree nuts by India in 2022.

and Seck [45], there is no clear a priori criterion from economic theory or statistical analysis to choose between these models. Consequently, determining which model better fits a specific dataset becomes an empirical question. However, comparative studies by Jung and Koo [47], Taljaard et al. [48], Muzayyanah and Maharjan [49], and Andjamba [50] have shown that the AIDS model outperforms the Rotterdam model in accurately recovering the true elasticities of consumer demand.

Import elasticities play a crucial role in shaping policy decisions, providing insights into the extent of changes in quantity demanded and overall demand in response to alterations in key determinants like price or income. Import elasticities are essential for formulating policies that enhance consumer welfare by offering a deeper understanding of consumption patterns [37]. Singh et al. [51] and Lokuge and Edirisinghe [52] highlighted the significance of reliable price and income elasticities in devising impactful campaigns and marketing strategies. Furthermore, studies focusing on estimating import demand not only benefit the importing nation but also provide valuable insights for trading partners, fostering a comprehensive understanding of how factors such as prices and income influence demand. To the best of our knowledge, no study that examines the dynamics of tree nuts import demand for India and derives price and income elasticities which reinforces the timeliness and novelty of this study. In addition, demand analysis across different varieties of tree nuts is crucial to understand their economic implications. Each type of nut faces unique challenges and economic losses related to import dependency. For instance, while cashews are a major product of India, the high import volume of cashews results in substantial economic loss, redirecting potential funds from domestic agricultural development and welfare programs. Policy challenges arise in supporting domestic nut production, including infrastructure development, market access, and sustainability practices. These challenges affect demand dynamics, influencing import trends and consumer preferences.

Despite the India's global position of being a major tree nuts producer economy it still remains to be a 'net importer' of these

agricultural commodities. This paradoxical situation makes it imperative for the present study to explore this research gap with a focus on the imported tree nuts demand. Moreover, the increased import bill due to the tree nut demand adds to the economic loss which can otherwise be used to support the agricultural development through multiple job creation and income enhancement of the local farmers. It should also be noted that India's tree nut demand should also be understood along with various underlying factors like agro-economic environmental conditions, farmer's level of education and their access to credit, population dynamics etc. These factors influence not just the domestic production but do play a contributing role in shaping the overall consumer behavior and market dynamics which creates import dependency. Thus, the present study also gives useful insights to understand the interplay of these factors for better policy implications.

Therefore, this study sought to study tree nuts import demand in India using the linear approximate almost ideal demand system (LA-AIDS) model for the period 2014 to 2022 using monthly data. It will help to unravel the intricate trade complexities and foster discussions amongst academics for more such empirical investigations to foster sustainable growth of tree nuts in India. In addition, the study calculates policy-relevant price and income elasticities for various imported tree nuts which are not currently available in India. The study gains importance from the recent development in India, where various types of tree nuts have emerged as highly coveted agricultural commodities. This trend underscores a shift in dietary preferences, economic dynamics, and the complexities of global trade.

2. The curious case of the Indian tree nuts paradox

Recently overtaking China in terms of population growth, India has become a central hub for research, influenced by a diverse range of factors. The shift from a predominantly agrarian economy to one marked by rising per capita income has fueled an increased demand for healthier food options, making tree nuts a staple in the diets of many Indian households. Despite favorable climatic conditions and being a leading global exporter of cashews [13,53,54], India finds itself in the paradoxical position of being a net importer of tree nuts. This contradiction has not only caught the attention of researchers but also underscores the complexities surrounding the production, distribution, and consumption of tree nuts within the Indian economy.

The paradox deepens when considering that India while making commendable strides in increasing domestic production of tree nuts, grapples with an increase in demand driven by a population increase and various market inefficiencies such as production inefficiencies [55]. The nutritional richness of tree nuts and their versatile applications in culinary practices have contributed to their significance in the changing food habits of a health-conscious population with rising disposable incomes. This shift presents a unique economic opportunity for farmers to transition from traditional crops to commercially cultivating tree nuts. However, the paradox persists, demanding a closer empirical examination to unravel the intricacies and provide actionable insights for policymakers and stakeholders.

Despite India's progress in the nuts cultivation sector, issues such as inadequate post-harvest infrastructure, fragmented agricultural market practices, and market inefficiencies hinder the country's ability to meet the growing demand domestically [53,56,57]. An empirical study focusing on the demand dynamics of tree nuts in the Indian context becomes crucial, not only for understanding the complexities but also for addressing broader socio-economic and nutritional challenges. By exploring the research gap in the paradoxical situation of being a top global exporter yet a net importer of tree nuts, this study aims to contribute to the existing body of knowledge, aligning aspirations with sustainable development goals and paving the way for informed decision-making in the Indian tree nuts sector.

3. Linkage of tree nuts to sustainable development

This study aims to investigate the import demand for tree nuts in India, with a primary focus on deriving income and price elasticities of import demand. The significance of analyzing tree nut demand in India extends beyond mere economic considerations, aligning with the broader framework of the sustainable development goals (SDGs). This research serves as a multifaceted lens through which the interconnected dimensions of nutrition, economic growth, and environmental sustainability can be comprehensively addressed. In India, tree nuts stand as highly prized crops, creating unique employment opportunities, particularly in rural areas where tree nut farming is prevalent. This contributes significantly to the achievement of SDG 8, fostering economic growth and positively impacting poverty reduction (SDG 1) and the reduction of inequalities (SDG 10). Furthermore, the promotion of sustainable farming practices aligns with responsible consumption and production (SDG 12), offering potential benefits for overall welfare.

The global trade presence of tree nuts also sparks innovation and entrepreneurial opportunities, aligning with SDG 9. By exploring the complexities of tree nut demand, this research strives to be a catalyst for transformative actions and well-informed policies. It seeks not only to meet current demands but also to guide India towards a resilient and sustainable future. Additionally, this study directly contributes to SDG 2 by ensuring food security[2] and promoting nutritional diversity, thereby aligning with the overarching goal of zero hunger. In essence, the research aims to pave the way for future initiatives that transcend current challenges, fostering a more sustainable and thriving trajectory for India.

[2] According to the World Food Summit (1996), food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

4. Materials and method

4.1. Model specification: the LA-AIDS model

The Almost Ideal Demand System (AIDS) model, proposed by Deaton and Muellbauer [28], is widely used in empirical research. Despite the existence of numerous alternative demand systems, the AIDS model remains a preferred choice in empirical studies due to its several desirable attributes. These include perfect aggregation over consumers, a functional form consistent with observed data, adherence to the axiom of choice, ease of estimation, and the ability to impose and test theoretical restrictions such as adding-up, homogeneity, and symmetry on model parameters [28,45,58]. Following the specification provided by Deaton and Muellbauer [28], the AIDS model which was used to study tree nuts import demand for India is specified as follows:

$$S_i = \alpha_i + \beta_i \ln\left(\frac{X}{P}\right) + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \varepsilon_i \tag{1}$$

The budget share (S_i) for the ith imported tree nuts group is determined by dividing the import expenditure of the ith imported tree nuts group by the total import expenditure on tree nuts. The import price of the jth imported tree nut group is represented by p_j, while X denotes the overall import expenditure of tree nuts. The white noise error term is denoted by epsilon (ε_i). The parameters to be estimated α_i, β_i, and γ_{ij}. Additionally, an aggregate price index (P) is defined in the AIDS model as follows:

$$\ln P = \alpha_0 + \sum_{i=1} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1} \sum_{j=1} \gamma_{ij} \ln p_i \ln p_j \tag{2}$$

To align the AIDS model with economic theory, three specific parametric constraints are imposed upon the model parameters. These constraints are known as adding-up, homogeneity, and symmetry are highlighted by equations (3)–(5).

$$\text{Adding} - \text{Up}: \quad \sum \alpha_i = 1; \sum \beta_i = 0; \sum_{i=1}^{n} \gamma_{ij} = 0 \tag{3}$$

$$\text{Homogeneity}: \quad \sum_{j=1}^{n} \gamma_{ij} = 0 \tag{4}$$

$$\text{Symmetry}: \quad \gamma_{ij} = \gamma_{ji} \tag{5}$$

The adding-up constraint is inherent in the model as the budget shares must collectively equal unity. Consequently, during the estimation process, one of the share equations is omitted, and the parameters of the excluded share equation are determined by applying the adding-up restriction. The constraints of homogeneity and symmetry are imposed during estimation.

The utilization of the price index outlined in equation (2) presents empirical challenges, particularly when employing aggregate annual time-series data, as in the present study. Taljaard et al. [59] and Rathnayaka et al. [60] highlighted that the specified price index in equation (2) introduces non-linearity to the demand system, thereby complicating the estimation process. To address this non-linearity issue, Deaton and Muellbauer [28] propose using the Stone geometric price index to linearize the model. The Stone geometric price index is expressed as follows:

$$\ln P^s = \sum_{i=1} S_i \ln p_i \tag{6}$$

Substituting equation (6) into equation (1) yield a linear approximate almost ideal demand system (LA-AIDS) model. This model, The LA-AIDS model has been widely applied in demand analysis, see example Shibia et al. [31], Anindita et al. [33], Verbeke and Ward [61], Jabarin [62], Alboghdady and Alashry [63], Basarir [64], Zhou [65], Mufeeth et al. [66], da Silva Pinto et al. [67], Agwaya and Ochieng [68], Rahman et al. [69], Siddique et al. [70], Gido [71], Khan [72], Forgenie et al. [73]. In addition, a time trend variable is added to each of the import share equations. The inclusion of a time trend in the AIDS equations for studying monthly imports of tree nuts in India serves to capture evolving patterns and economic dynamics over time. The LA-AIDS model that is used to study tree nuts import demand in India is therefore specified as follows:

$$S_i = \alpha_i + \beta_i \ln\left(\frac{X}{P^s}\right) + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \theta trend + \varepsilon_i \tag{7}$$

where all variables are previously defined and α_i, β_i, γ_{ij}, and θ are parameters to be estimated. Equation (7) is estimated using the iterated seemingly unrelated regression (ISUR) technique [74] to account for cross-equation correlation.

4.2. Deriving elasticities

In studying tree nuts import demand in India, price and income elasticities play a crucial role in analyzing and understanding the factors influencing the quantity of tree nuts imported into the country. Price elasticity helps assess how sensitive the demand for tree

nuts is to changes in their price [75,76]. This information is essential for businesses and policymakers to make decisions regarding pricing strategies and trade policies [77,78]. Additionally, income elasticity provides insights into how variations in consumers' incomes impact their demand for tree nuts [75,76,79]. This knowledge is valuable for anticipating market trends and tailoring marketing strategies. By incorporating these elasticities into the analysis, the study can offer comprehensive insights into the dynamics of tree nuts import demand in India, contributing to more informed decision-making in the realm of international trade and commerce.

The estimated parameters from equation (7) are used to derive income or expenditure elasticities as follows:

$$\xi_i = \frac{\beta_i}{s_i} + 1, \mathrm{i} = 1, \ldots, \mathrm{n}.. \tag{8}$$

The study also derived uncompensated and compensated own- and cross-price elasticities using the formulas as follows:

$$\zeta_{ij}^{U} = -\delta_{ij} + \frac{\gamma_i}{s_i} - \frac{\beta_i s_j}{s_i}, \mathrm{i}, \mathrm{j} = 1, \ldots, \mathrm{n}. \tag{9}$$

$$\zeta_{ij}^{C} = \zeta_{ij}^{U} + \xi_i s_i \tag{10}$$

In the given context, ξ_i represents the income elasticity of import demand, while ζ_{ij}^{U} and ζ_{ij}^{C} represent the uncompensated and compensated price elasticities of import demand, respectively. The variable s_i denotes the mean budget share of the ith imported tree nuts group, and δ_{ij} is the Kronecker delta, taking a value of 1 for own-price elasticity and 0 otherwise.

4.3. Data and source

This study utilized monthly import quantities and expenditure data for the period 2014–2022 obtained from the United Nations Comtrade (UN Comtrade) database. All quantities are given in metric tonnes and expenditure and prices are given in US dollars. The study encompassed five groups of imported tree nuts, namely almonds, walnuts, pistachios, cashews, and hazelnuts, chosen due to the availability of data. Since specific import prices for certain imported tree nuts were unavailable, import unit values were approximated. This was done by dividing the total import expenditure for each tree nut group by its import quantity. Additionally, the budget share for each imported tree nut group was determined by dividing the import expenditure of that particular group by the total expenditure on tree nuts imports. All empirical estimation is completed using STATA 18.

5. Results and discussion

5.1. Summary statistics

Table 1 outlines the descriptive statistics for the five imported nut groups for India for the period 2014–2022. In examining India's nut import data monthly, distinct patterns emerge across various nut groups. Almond hold a substantial market share, representing 41.4 % of the mean import expenditure, showcasing a notable consumer preference. Walnut, with a modest 2.6 % share, demonstrate consistent albeit comparatively smaller demand. Pistachio contribute moderately to the market, accounting for 3.9 % of the mean import expenditure. Cashew dominate the landscape, comprising 52.1 % of the mean import expenditure and indicating a significant demand for this nut variety. Conversely, hazelnut accounts for the smallest import share, making up just 0.1 % of the average import expenditure, indicative of a comparatively lower demand. The study reveals that in the landscape of Indian nut imports, cashew is notably prominent, almond maintains a substantial share, and other tree nuts contribute to different degrees, highlighting the diverse preferences in India's nut import market throughout the period of study. Table 1 also presents the mean import prices per metric tonne in US dollars for various nuts. It was found that hazelnut commands the highest mean import price at US$7839.39 per metric tonne, indicating a relatively premium pricing for this nut variety. Almond follow with a substantial mean import price of US$5357.46 per metric tonne, highlighting a notable cost associated with this popular nut. Pistachio exhibits a relatively high mean import price of US $7662.97 per metric tonne, suggesting a premium positioning in the market. In contrast, Cashew and Walnut have lower mean import prices of US$1520.64 and US$2722.02 per metric tonne, respectively, reflecting comparatively more affordable pricing for these nut types.

5.2. Parameters of the LA-AIDS model

Table 2 presents the parameter estimates of the LA-AIDS model for imported tree nuts estimated using ISUR technique with the theoretical restrictions of homogeneity and symmetry imposed. Interpretation of the estimated parameters are not straight-forward, however, they are useful in calculating price and income elasticities [22,80]. However, all of the own-price parameter estimates reveal that price increase of a specific imported tree nut group leads to an increase in expenditure share. In addition, the time trend parameter (θ) was found to be statistically significant and positive in all of the import share eqautions except imported cashews. The positive time trend parameter suggest that as time progress, India is expected to increase import expenditure on these groups except cashews which is expected to decrease.

Table 1
Summary statistics for imported tree nuts (2014–2022).

Tree Nut	Variable	Obs.	Mean	Std. Dev.
Budget Share				
Almond	s_1	108	0.414	0.165
Walnut	s_2	108	0.026	0.019
Pistachio	s_3	108	0.039	0.021
Cashew	s_4	108	0.521	0.180
Hazelnut	s_5	108	0.001	0.001
Unit Price (US$ per Metric Tonne)				
Almond	p_1	108	5357.46	1165.90
Walnut	p_2	108	2722.02	820.02
Pistachio	p_3	108	7662.97	1120.39
Cashew	p_4	108	1520.64	396.66
Hazelnut	p_5	108	7839.39	2479.95

Source: Own calculation based on data from UN Comtrade.

Table 2
Estimated parameters for India tree nut imports.

Parameter	Tree Nuts Import Share Equation				
	Almond	Walnut	Pistachios	Cashew	Hazelnut
α	3.050 (0.171)	0.040 (0.032)	0.138 (0.033)	−2.232 (0.169)	0.004 (0.001)
γ_1	0.037 (0.037)	0.012 (0.008)	0.004 (0.009)	−0.051 (0.035)	−0.000 (0.004)
γ_2	0.012 (0.008)	0.003 (0.006)	−0.002 (0.006)	−0.013 (0.007)	0.000 (0.000)
γ_3	0.004 (0.009)	−0.002 (0.006)	0.018 (0.010)	−0.020 (0.007)	−0.000 (0.000)
γ_4	−0.051 (0.035)	−0.013 (0.007)	−0.020 (0.007)	0.084 (0.035)	0.000 (0.000)
γ_5	−0.000 (0.004)	0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
β	−0.256 (0.016)	−0.004 (0.003)	−0.014 (0.003)	0.274 (0.016)	−0.000 (0.000)
θ	0.002 (0.000)	0.040 (0.060)	0.000 (0.000)	−0.003 (0.000)	0.000 (0.000)
R^2	0.744	0.359	0.443	0.791	–
RMSE	0.083	0.015	0.016	0.082	–
Chi^2	313.95	64.48	86.01	415.85	–

Note: Standard errors in parentheses. Source: Own calculation based on data from UN Comtrade.

5.3. Income elasticities and marginal shares

Table 3 presents the income elasticities for the five imported tree nut groups for India calculated using equation (8). Income elasticities in this context measures the percentage change in import quantity as a result of a percentage change in income. All estimated income elasticities are statistically significant at the 1 % level and range from 0.38 to 1.53. In addition, the income elasticities for all imported tree nuts were found to be positive, which suggests that they are normal[3] goods. However, imported cashew was found to be a luxury good since income elasticity is greater than unity or 1.53. This suggests that a 1 % increase in income is expected to bring about on average a 1.53 % increase in the import demand for cashew nuts on average monthly. However, import demand for imported cashews have been on the decline since 2019. This decline can maybe be attributed to changing consumer taste and preference and also the availability of close substitutes such as almonds and hazelnuts. All other imported tree nuts were found to be necessities since their income elasticities were less than unity. Imported almonds and hazelnuts were the least responsive to changes in income. For instance, a 1 % increase in Indian income is expected to bring about only a 0.38 % increase in the import demand for almonds and hazelnuts. Pistachios were found to have a moderate response to changes in income, or a 1 % increase in income is expected to bring about a 0.65 % increase in import demand on average.

Marginal[4] shares are also presented in Table 3. Marginal shares indicate how an additional dollar spent on imported tree nuts would be allocated [81]. The analysis of the marginal shares suggests that cashew nuts import would take around US$0.80 of an additional dollar allocated to tree nut imports in India. In contrast, it was found that imported hazelnuts will take an extremely small percentage of an additional dollar allocated to tree nut imports in India. Marginal shares also show that imported almond is expected to take approximately US$0.16 of an additional dollar allocated to tree nut imports in India.

[3] Normal goods are goods for which demand increases as consumer incomes rise and decreases as consumer incomes fall. In other words, as individuals or households experience an increase in their income levels, they tend to purchase more of these goods. Normal goods exhibit a positive income elasticity of demand, indicating a proportional relationship between changes in income and the quantity demanded for these goods.

[4] Marginal share are calculated following [81] J. L. Seale, M. A. Marchant, and A. Basso, "Imports versus domestic production: A demand system analysis of the US red wine market," *Applied Economic Perspectives and Policy,* vol. 25, no. 1, pp. 187–202, 2003. as $\beta_i + s_j$, where β_i is the expenditure parameter from the LA-AIDS model and s_j is the average import share for nuts group *i*.

Table 3
Income elasticities and marginal shares for imported tree nuts.

Tree Nut	Income Elasticities	Marginal Shares
Almond	**0.383** (0.038)	**0.159** (0.016)
Walnuts	**0.829** (0.113)	**0.021** (0.003)
Pistachio	**0.646** (0.077)	**0.030** (0.003)
Cashews	**1.526** (0.030)	**0.795** (0.016)
Hazelnut	**0.380** (0.177)	**0.000** (0.000)

Note: Standard errors in parentheses. Source: Own calculation based on data from UN Comtrade.

5.4. Uncompensated and compensated price elasticities

Uncompensated price elasticity of demand measures the responsiveness of the quantity demanded of a good to a change in its price, holding constant the income of the consumer. In other words, it measures the percentage change in quantity demanded resulting from a 1 % change in price while keeping the consumer's income constant. It helps assess how sensitive consumers are to changes in price alone, without considering adjustments in their purchasing power. A higher absolute value of the uncompensated price elasticity indicates a more responsive demand to price changes, while a lower value suggests less sensitivity [82,83].

Table 4 presents uncompensated price elasticities of demand for the various imported tree nut groups for India derived using equation (9). These elasticities are calculated using the formula in equation (9). Own-price elasticities are shown on the diagonal and were all found to be statistically significant and negative as expected. Imported cashew nuts were found to be the most responsive to changes in prices since the estimated own-price elasticity was −1.11. This means that a 1 % increase in the import price of cashew nuts is expected to bring about on average a 1.11 % decrease in the quantity demanded, *ceteris paribus*. Imported cashew nuts was found to be import price elastic during the study period. Imported cashews might be relatively more import price elastic due to having close substitutes. Possible substitutes for cashews was found to be almonds and hazelnuts, which may offer competitive pricing or perceived health benefits which might explain relative price-elasticity.

In contrast, imported pistachios were found to be the least responsive to changes in import prices. It was discovered that a 1 % increase in the import price of pistachios is expected to bring about on average a 0.51 % decrease in import demand, *ceteris paribus*. Furthermore, since the own-price elasticities are all less than unity for imported almond, walnut, and pistachio, it can be concluded that these tree nut groups are relatively import price inelastic. Imported hazelnut were found to have an own-price elasticity very close to unity which means that a 1 % increase in imported prices is expected to bring about approximately a 1 % decrease in import demand, *ceteris paribus*. Therefore, it can be suggested that hazelnut are close to being unitary elastic.

Table 4 also presents uncompensated cross-price elasticities for imported tree nuts. Cross-price elasticity evaluates the relationship between two goods, discerning whether they are substitutes or complements [84]. It specifically examines how changes in the price of one good influence the demand for the other. A positive cross-price elasticity suggests substitutability, indicating that as the price of one good rises, there is a corresponding increase in the demand for the other [85]. This implies consumers shift their consumption from the more expensive to the relatively cheaper alternative. Conversely, a negative cross-price elasticity implies complementarity, indicating that two goods are typically consumed together. In this case, a price increase in one good results in a decrease in the demand for the related complement [85]. The study found various substitution and complementary relationships between pairs of imported tree nuts.

5.5. Compensated price elasticities

Compensated price elasticity of demand assesses how the quantity demanded of a product responds to price changes, with adjustments made to the consumer's real income to keep their level of satisfaction or utility constant. Compensated price elasticity, often referred to as the Hicksian elasticity, isolates the substitution effect by measuring how a change in price affects the quantity demanded while keeping the consumer's real income constant. This approach provides insights into consumer responses driven solely by changes in relative prices, offering a more specific understanding of the impact of price variations independent of income effects.

Compensated own- and cross-price elasticities are presented in Table 5 for imported tree nuts calculated using equation (10). All calculated compensated own-price elasticities are statistically significant and exhibit the anticipated negative sign, as expected.

Table 4
Uncompensated import price elasticities for imported tree nuts.

Tree Nut	Price Elasticities				
	Almond	Walnut	Pistachios	Cashew	Hazelnut
Almond	**−0.656** (0.094)	**0.521** (0.330)	**0.242** (0.240)	**−0.316** (0.070)	**0.256** (0.073)
Walnut	**0.044** (0.020)	**−0.894** (0.235)	**−0.036** (0.143)	**−0.038** (0.013)	**0.016** (0.005)
Pistachio	**0.033** (0.022)	**−0.062** (0.215)	**−0.511** (0.253)	**−0.313** (0.021)	**0.024** (0.001)
Cashew	**0.197** (0.082)	**−0.404** (0.249)	**−0.336** (0.185)	**−1.113** (0.065)	**0.323** (0.092)
Hazelnut	**−0.001** (0.001)	**0.010** (0.010)	**−0.001** (0.010)	**−0.000** (0.001)	**−0.999** (0.026)

Note: Standard errors in parentheses. Source: Own calculation based on data from UN Comtrade.

Interestingly, they are all smaller in magnitude than uncompensated own-price elasticities. Compensated own-price elasticities are typically smaller in magnitude than uncompensated ones due to the inclusion of the income effect in the latter [86,87]. The income effect tends to partially offset the substitution effect, resulting in a more muted overall response to price changes in the compensated elasticity. All imported tree nut categories were found to be price inelastic since the own-price elasticities were less than unity. Imported cashew were the least responsive to changes in prices based on compensated elasticity while imported hazelnut were the most responsive. For instance, a 1 % increase in the import price of cashew and hazelnut is expected to bring about on average a 0.32 % and 0.99 % decrease in import quantities, respectively.

Table 5 also presents compensated cross-price elasticities. Compensated cross-price elasticity measures the responsiveness of the quantity demanded for one good to a change in the price of another good while keeping the consumer's real income constant. This elasticity provides insights into how changes in the price of one commodity affect the demand for another, specifically capturing the substitution effect. It is often considered better to use compensated cross-price elasticities for assessing relationships between commodities than uncompensated ones. This is because the compensated elasticity isolates the substitution effect [86], allowing for a more accurate analysis of how consumers adjust their preferences and purchasing patterns in response to relative price changes. By holding real income constant, the compensated cross-price elasticity focuses solely on the substitution effect [86,88], providing a clearer picture of the direct impact of price changes between two goods without the confounding influence of income effects. A positive cross-price elasticity would mean the two commodities are substitutes while a negative value would mean that they are complements.

It was found that mostly substitution relationships existed among various pairs of imported tree nuts over the study period. Imported almond was found to be substituted with all other imported tree nuts when prices increased. For instance, a 1 % increase in the import price of almonds is expected to bring about a 0.86 %, 0.51 %, 0.32 %, and 0.41 % increase in the import demand of walnut, pistachio, cashew, and hazelnut, respectively. Imported cashew were also found to be substituted with other imported tree nuts when prices increased. It was found that a 1 % increase in the import price of cashew is expected to bring about a 0.40 % and 0.52 % increase in the import demand of almond and hazelnut, respectively. Imported walnut were also found to be substituted with almond and hazelnut when prices increased. A 1 % increase in the import price of almond is expected to bring about on average a 0.05 % and 0.03 % increase in the import demand for almonds and hazelnut, respectively.

5.6. Policy implications

This research examined the import demand for tree nuts in India, placing a central emphasis on determining the income and price elasticities associated with the import demand. The study found that imported cashews were highly responsive to changes in income, whereby a 10 % increase in income is expected to cause import demand to fall by 15.3 %. Since imported cashews are relatively income elastic, policymakers should consider measures to leverage this positive correlation between income and demand. Strategies may include targeted marketing campaigns to align cashews with rising incomes, promoting awareness of their nutritional benefits, and exploring trade agreements to ensure a stable and affordable supply. Additionally, investments in sustainable farming and processing practices domestically could enhance long-term resilience. For instance, given the popularity of cashew in India, policymakers might want to consider making cashew a strategic commodity where incentives and resources are provided to producers to facilitate increased domestic production. Given that per capita income is increasing in India, it is expected that demand for cashews will increase more than proportional to when compared to increase in income, hence, declaring cashew as a strategic commodity can help with sustainable livelihoods in rural areas where most of the production is done in the long-term.

Other imported tree nuts were found to be income inelastic which means that for imported almond, walnut, pistachio, and hazelnut a 10 % increase in income leads to a 3.8 %, 8.3 %, 6.5 %, and 3.8 % decrease in imports, respectively. Hence, policymakers should focus on measures to stabilize domestic prices and ensure consistent supply to prevent excessive imports in the long-term of these tree nut groups. This may involve negotiating favorable trade agreements, implementing storage and distribution infrastructure improvements to manage fluctuations effectively, and exploring domestic cultivation initiatives to reduce dependence on imports.

Based on import price elasticities, imported cashew were found to be highly responsive to changes in prices. A 10 % increase in prices is expected to cause import demand to fall by 11.1 % on average. This provides policymakers with a strategic window to implement impactful measures, including the introduction of production subsidies to incentivize local cashew producers, facilitating easy access to loans and credits for enhanced processing capabilities, and initiating educational programs to uplift domestic production standards. These integrated policy actions aim to not only bolster the competitiveness of local producers but also foster a resilient and self-sufficient cashew industry in alignment with broader economic and sustainable development goals in the long-term. Imported

Table 5
Compensated import price elasticities for imported tree nuts.

Commodity	Price Elasticities				
	Almond	Walnut	Pistachios	Cashew	Hazelnut
Almond	**−0.498** (0.090)	**0.864** (0.324)	**0.510** (0.236)	**0.316** (0.066)	**0.414** (0.004)
Walnut	**0.054** (0.020)	**−0.873** (0.235)	**−0.020** (0.143)	**0.001** (0.013)	**0.026** (0.000)
Pistachios	**0.048** (0.022)	**−0.030** (0.215)	**−0.486** (0.233)	**0.000** (0.014)	**0.038** (0.000)
Cashew	**0.397** (0.083)	**0.028** (0.254)	**0.001** (0.188)	**−0.318** (0.067)	**0.521** (0.000)
Hazelnut	**−0.000** (0.001)	**0.011** (0.010)	**−0.005** (0.010)	**0.001** (0.001)	**−0.992** (0.415)

Note: Standard errors in parentheses. Source: Own calculation based on data from UN Comtrade.

pistachio and almond were found to be moderately responsive to changes in imported prices. A 10 % increase in prices is expected to cause demand to fall by 5.1 % and 6.6 %, respectively. To address the anticipated decline in demand resulting from a 10 % price increase in imported pistachios and almonds, policymakers may consider measures such as targeted subsidies or financial incentives to mitigate the impact on consumers. Additionally, fostering domestic production and diversification strategies could help reduce reliance on imports, enhancing resilience against external price fluctuations in the long term.

The success of the Indian cashew industry highlights the imperative for concerted efforts across various tree nut categories, necessitating research and investment to address evolving demand-supply dynamics driven by changing dietary preferences and health concerns. As the import demand is poised to persist and potentially rise, policymakers must closely monitor consumer preferences to ensure a steady supply. Recognizing that domestic production may not fully align with demand, India, leveraging its position as a top cashew exporter, should engage in strategic trade deals based on comparative advantage, facilitating the exchange of cashew exports for the import of other tree nuts specialized by partner countries.

Effective policy formulation is crucial for addressing nutritional challenges and enhancing economic resilience, contributing significantly to food security. Future policies should encourage technological innovations and awareness programs to guide farmers in cultivating tree nuts suitable for specific agro-climatic conditions. Increased incentives and investments in research are vital to improving the yield, quality, quantity, and resilience of tree nuts, especially in the face of climate change. Significant investments in upgrading infrastructure, such as processing units, cold storage facilities, and efficient transportation, are essential to minimize losses and maintain product quality.

In light of India's status as a tree nut importer, a re-evaluation of trade policies and tariff structures is necessary to meet consumer demands effectively. Introducing policies that incentivize sustainable agricultural practices is crucial for environmental sustainability and should be complemented by capacity-building programs to empower farmers with technological advancements. Effective policy interventions encompassing agricultural support, economic inclusivity, research, and innovations are paramount for amplifying the positive impact of the tree nut sector on the Indian economy. This comprehensive approach not only fuels economic growth but also creates employment opportunities while promoting sustainable agricultural practices, positioning India as a global leader in the resilient, sustainable, and self-reliant future.

5.7. Discussion

Tree nuts have become significantly important agricultural commodities, thus making substantial contribution for the economies of the nations which are producing and importing it. The increased production and demand surge of the tree nuts at global level also underscore the need for effective trade policies in order to sustain the market equilibrium. The previous studies have predominantly been focused only on a particular aspects like market trend [22], production [89–91], and benefits [4,6,7,21,91]. However, this created a notable research gap in the Indian context to comprehensively study the demand analysis of the tree nuts to gain valuable insights into the consumer behavior and market dynamics. Thus, the present study makes a valuable contribution to the existing literature which will motivate the future researchers to look into this domain through different perspective. Previous studies have ignored and overlooked the different factors like change in the income, price level, and cross-price effects on demand for tree nuts which gave an incomplete overview of the tree nuts demand in India.

The LA-AIDS model used in the present study provides the policymakers with the robust framework to analyze the associated demand elasticities of the different tree nuts to get insights into how change in the income and price affects the market dynamics. The findings of the study reveal that cashews have high income elasticity and price elasticities unlike the other tree nuts, implying that any change in the consumer income or the prices can have significant change for the demand. On the other hand, the inelastic nature of the other tree nuts suggest that their demand is more stable and doesn't respond easily to the changing market dynamics. This differentiated response calls for a tailored policy formulation which is specific for every tree nut variety. These findings highlight the extreme sensitivity of the cashews towards the changing consumer income levels and global price fluctuations. These findings also align with the other existing studies Yousafzai et al. [92] and Kutty [93] which consider cashews to be more of a luxury goods whose consumption in developing nation's rises in disproportionate level as with the income level.

Unlike the traditional demand analysis methods, LA-AIDS model provides more comprehensive understanding of the different factors influencing the demand. The import dependency for the cashews can be reduced with effective strategies to promote and support the sustainable agricultural development practices for the domestic market [94,95]. Enhanced domestic production, particularly for the cashews, can help in rural development through providing employment opportunities which will foster the economic stability [96,97].

6. Concluding remarks

This study analyzed the import demand for imported tree nuts in India using the linear approximate almost ideal demand system model and monthly data for the period 2014 to 2022. The main goal was to analyze the impact of income and price on tree nuts import demand. It was found that income had a positive and significant impact on all imported tree nut groups over the study period. Furthermore, based on income elasticities, all imported tree nuts were found to be normal goods. Imported cashew were found to be relatively income elastic since the income elasticity was greater than unity. All other imported tree nuts were found to be income inelastic having income elasticities ranging from 0.38 to 0.83. Marginal shares revealed that imported cashew is expected to account for 80 % of an extra dollar allocated to tree nuts imports. The study also derived uncompensated and compensated own- and cross-price elasticities. All own-price elasticities were negative and statistically significant as expected. Based on uncompensated own-price

elasticities, all imported tree nuts were found to be import-price inelastic except for imported cashews which were found to be import-price elastic. Cross-price elasticities also highlight substitution and complementary relationships between various pairs of imported tree nuts over the study period.

Two major limitations of this study should be acknowledged. Firstly, the analysis is restricted to only five imported tree nut groups due to insufficient data for other varieties in India. This limitation highlight the need for comprehensive data collection and the inclusion of a more extensive range of imported tree nuts to enhance the study's generalizability. Secondly, the study does not account for additional factors that could influence import demand, such as population dynamics and domestic production, as monthly data for these variables was unavailable. However, despite these limitations, it is noteworthy that this study is the first of its kind for India, and the derived income and price elasticities carry significant policy implications, offering valuable insights for policymakers and stakeholders in the tree nut industry. Future research endeavors could explore household demand for imported tree nuts, shedding light on consumption patterns and providing a nuanced understanding of preferences. Additionally, a potential avenue for future investigations could involve examining the influence of broader economic indicators on import demand for tree nuts.

Ethical statement

The authors would like to declare that no humans or animals were subjected to study in this paper.

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CRediT authorship contribution statement

David Forgenie: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Karambir Singh Dhayal:** Writing – review & editing, Writing – original draft, Validation, Investigation, Conceptualization. **Satesh Sookhai:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Data curation. **Nikmatul Khoiriyah:** Writing – review & editing, Writing – original draft, Validation, Investigation, Conceptualization. **Celine Suchit:** Writing – review & editing, Writing – original draft. **Gabrielle Simbhoo:** Writing – review & editing, Writing – original draft. **Wendy-Ann P. Isaac:** Writing – review & editing, Writing – original draft, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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