Original Research Article

Identification of Mutation Point and Trend in Export of Indian Groundnut

ABSTRACT

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| --- |
| The study aimed to identify structural mutation points and analyze long-term trends in India’s groundnut exports from 2005 to 2024 using time series data on export quantity and value sourced from Trade Map. Pettitt’s test, Buishand’s range test, and the Standard Normal Homogeneity (SNH) test, were applied to detect mutation points, while trend significance and magnitude were assessed using the Mann-Kendall test and Sen’s slope estimator. All three tests consistently identified 2010 as a major mutation year for both export quantity and value. Sen’s slope analysis indicated the highest growth during the full study period, with export quantity increasing by 23.84 thousand tonnes/year and value by 35.24 million USD/year. Trend models revealed that the quadratic model best explained the variation in exports. The findings highlight a structural shift post 2010 and emphasize the importance of strengthening trade strategies and infrastructure to sustain and enhance India’s groundnut export performance in the global market.  |

*Keywords: Groundnut exports; Mutation point; Trend analysis; SNH test; Sen’s slope*

1. INTRODUCTION

“Groundnut (*Arachis hypogaea*) is a self-pollinating allotetraploid legume crop that belongs to the Fabaceae family. Groundnut, also known as peanut, is recognized as the third most significant oilseed crop globally, following soybean and rapeseed. It holds great significance due to its high-quality edible oil and protein content. Moreover, the crop’s byproducts, namely oilcake and haulms, play a crucial role as valuable animal feed, further enriching its economic value. China is the largest groundnut producer in the world, followed by India and Nigeria” (Sajindra et al.,2023). “The kernels of groundnut are a nutritional powerhouse, boasting a remarkable composition of protein (approximately 25 per cent), oil (about 50 per cent), antioxidants, essential minerals, and vitamins. Beyond being a staple food, groundnut is vital to the oil industry due to its high oil content and heart-healthy fats. Rich in antioxidants like resveratrol, it offers numerous health benefits, including reducing oxidative stress and inflammation. Additionally, groundnut supports sustainable agriculture by improving soil fertility through nitrogen fixation and promoting biodiversity, making it an ideal rotational crop” (ICRISAT, 2024). “India, accounts for 31 % of the total groundnut area in the world with 26.4 Mha with a total production of 37.1 million MT. The average productivity is 1400 kg/ha. The annual global export of groundnuts is of two million MT valued at 2,600 million US $” (Chowdary, K. R., 2021). India showcased its agricultural prowess in the fiscal year 2022–2023 by exporting oilseeds valued at Rs. 673,525.23 lakhs (US$ 831.6 million), with groundnut production being a major contributor to this accomplishment. India exports groundnuts to more than 132 nations worldwide through a broad network. Significantly, countries like the Philippines, Vietnam, Malaysia, and Indonesia (Vignesh and Selvakumar, 2024). In recent years, the export performance of Indian groundnut has exhibited significant fluctuations influenced by domestic production variability, global market dynamics, trade policies, and climatic factors. Identifying long-term trends and critical structural changes known as mutation points in the export pattern is essential to understand these shifts and respond strategically. Mutation points reflect key turning points in the time series that may result from policy changes, economic events, or external shocks, and their identification can provide valuable insights into the stability and direction of trade flows and Identifying export trends helps businesses anticipate global demand shifts and optimize production and marketing strategies. It also enables policymakers to strengthen trade policies and boost economic growth through targeted support (Maheta and Rank, 2017; Ghadiya and Maheta, 2018; Bharodia et al., 2025; Maheta et al., 2025). Analysing these patterns is vital for exporters, policymakers, and stakeholders to evaluate the effectiveness of existing strategies and to anticipate future challenges. Therefore, this study aims to investigate the trend and detect mutation points in India’s groundnut export data using statistical methods such as trend analysis and structural break tests, thereby contributing to evidence-based decision-making for sustained export growth.

2. methodology

**2.1 Data**

The present study deals with identification of mutation point and trend in export of groundnut. To fulfil the objectives of the study, a secondary data on export quantity and export value of groundnut from India for the period 2005 to 2024 have been obtained from Trade map. The time series data was analyzed using the XLSTAT trial version.

**2.2 Analytical Tools**

**2.2.1 Identification of mutation point**

The purpose of mutation point analysis, also known as change point analysis, is to detect significant structural shifts or turning points in the time series data of groundnut exports. Identifying these change points is essential for understanding the impact of external factors such as policy changes, trade agreements, climatic conditions, or market disruptions that may alter the export performance over time (Oganja *et al.,* 2024). Various researchers have employed different statistical techniques to identify such structural breaks in agricultural and trade-related time series data. In this study, appropriate statistical methods have been employed to detect mutation points in the groundnut export time series. This helps in identifying periods of significant change and understanding the underlying causes, thereby assisting policymakers and stakeholders in framing effective export strategies.

***2.2.1.1 Pettitt test***

Pettitt test method is a non parametric test method based on the rank to detect abrupt changes in the mean of the variables ([Verstraeten, 2006](https://researcherslinks.com/current-issues/Statistical-Assessment-of-Trend-Analysis-on-Production-of-Wheat-Crop-over-India/14/1/2722/html%22%20%5Cl%20%22Verstraeten--G.--J.-Poesen--G.-Demar-e-and-C.-Salles.-2006.); [Dhorde and Zarenistanak, 2013](https://researcherslinks.com/current-issues/Statistical-Assessment-of-Trend-Analysis-on-Production-of-Wheat-Crop-over-India/14/1/2722/html%22%20%5Cl%20%22Dhorde--A.G.-and-M.-Zarenistanak.-2013.)).This method is commonly applied to detect single change point in time series data.

$$U\_{t} =\sum\_{i=1}^{t}\sum\_{j=t+1}^{n}sign (x\_{t }- x\_{j})$$

$sign ( x\_{t }- x\_{j})$ **=** $\left[\begin{array}{c}1, if \left( x\_{i }- x\_{j}\right)>0\\0, if \left( x\_{i }- x\_{j}\right)=0\\-1, if \left( x\_{i }- x\_{j}\right)<0\end{array}\right]$

Test statistic K and the associated confidence level (ρ) for the sample length (n) may be described as $$ K=Max \left|U\_{t}\right|$$

$$ρ=exp \left(-\frac{K}{n^{2}- n^{3}}\right)$$

When ρ is smaller than the specific confidence level, the null hypothesis is rejected. The approximate significance probability (p) for a change-point is defined as given below:

$$p=1-ρ$$

It is obvious that where a significant change point exists, the series is segmented at the location of the change point into two subseries. The test statistic K can also be compared with standard values at different confidence level for detection of change point in a series (Pettitt, 1980).

***2.2.1.2 Buishand range test***

The adjusted partial sum (Sk), that is the cumulative deviation from mean for kth observation of a series x1, x2, x3 ….xk…. xn with mean $(\overbar{x)}$ can be computed using the following equation:

$$S\_{k}= \sum\_{i=1}^{k}(x\_{i}-\overbar{x)}$$

The significant breakpoint can be computed by the method of rescaled adjusted range (R) if the $S\_{k} $≅ 0, in this case, R is defined by

$R=\frac{Max \left(S\_{k}\right)-Min (S\_{k})}{√n}                                                      $$ $

Here, R denotes the change point value (Buishand, 1982).

***2.2.1.3. Standard Normal Homogeneity (SNH) test***

Test statistic ($T\_{k}$) is used to compare the mean of the first n observations with the mean of the remaining (n-k) observations with n data points

$$T\_{k}=kZ\_{1}^{2}+(n-k)Z\_{2}^{2}$$

Z1 and Z2 can be computed as:

$$Z\_{1}=\frac{1}{k}\sum\_{i=1}^{k}\frac{(x\_{i}-\overbar{x)}}{σx}$$

$$ Z\_{2}=\frac{1}{n-k}\sum\_{i=k+1}^{n}\frac{(x\_{i}-\overbar{x)}}{σx}$$

Where, $\overbar{x}$ and $σx$ are the mean and standard deviation of the series. The year k can be considered as change point and consist a break where the value of Tk attains the maximum value. To reject the null hypothesis, the test statistic should be greater than the critical value, which depends on the sample size (n) is given.

For confirmation of mutation point, the result of at least two tests of three tests should be same. That point will be considered as the true mutation point. The significance will be tested for 1 per cent and 5 per cent probability levels (Alexandersson, 1986).

**2.2.2 Trend analysis**

Generally, the magnitude of trend is measured in terms of ratio, this ratio can give an idea about trend i.e., either falling or rising or remaining relatively constant. With the help of ratio, it is possible to detect the poor or good signs of management (Polisetty and Paidipati. 2019)The presence of a significant trend in the time series was tested using the Mann-Kendall test, and its magnitude was subsequently estimated using Sen’s slope estimator.

***2.2.2.1 Mann-Kendall test***

The main task in trend analysis is to assess the monotonic fluctuations in long-period data sets, which can be well performed through a non-parametric linear trend test. The M-K test plays a vital role to find out the significant nature of monotonic trends for time series data ([Jaiswal *et al*., 2015](https://researcherslinks.com/current-issues/Statistical-Assessment-of-Trend-Analysis-on-Production-of-Wheat-Crop-over-India/14/1/2722/html#Jaiswal--R.K.--A.K.-Lohani-and-H.L.-Tiwari.-2015.); [Gavrilov *et al.*, 2016](https://researcherslinks.com/current-issues/Statistical-Assessment-of-Trend-Analysis-on-Production-of-Wheat-Crop-over-India/14/1/2722/html#Gavrilov--M.B.--T.-Ivana--B.M.-Slobodan--U.-Miroslava-and-P.-Predrag.-2016.)). The test statistic of the Mann-Kendall test (S) is expressed as

$$S=\sum\_{i=1}^{n}\sum\_{j=1}^{i=1}sign(x\_{i}- x\_{j}) $$

Where, n is the total length of data, xi and xj are two generic sequential data values, and function sign(xi–xj) assumes the following values

$$sign\left(x\_{i}- x\_{j}\right)=\left[\begin{array}{c}1, if \left(x\_{i}-x\_{j}\right)>0\\0, if \left(x\_{i}-x\_{j}\right)=0\\-1, if \left(x\_{i}-x\_{j}\right)<0\end{array}\right]$$

Under this test, the statistic S is approximately normally distributed with the mean E(S) and the variance Var(S) can be computed as follow:

$$E\left(S\right)=0$$

$$Var\left(S\right)=\frac{1}{18}\left[n\left(n-1\right)\left(2n+5\right)-\sum\_{t}^{}(t-1)(2t+5)\right]$$

Where, n is the length of time series, and t is the extent of any given tie and Σt denotes the summation over all tie number of values. The standardized statistics Z for this test can be computed by the following equation:

$$Z=\left[\begin{array}{c}\frac{S+1}{\sqrt{Var\left(S\right)}}, if S>0\\ O, if S=0\\-1, if S<0\end{array}\right]$$

Here, the detection of a trend depends on the value of Z. For example, if the Z value is zero, it means that the data does not follow any trend; if the value of Z is positive, it means that the trend is in an upward direction; and if the value of Z is negative, it means that the trend is in a downward direction (Mann 1945; Kendall 1975).

***2.2.2.2 Sen’s slope estimator***

Assuming that the time series data exhibits a significant trend, i.e., either a positive or a negative trend, then the Sen’s slope estimator can be estimated. It means the slope of the trend line or the average rate of change of the trend. Sen’s method calculates the slope as a change in measurement in consonance to the change in time (Singh *et al.,* 2022).The slope of the trend is estimated using the following test statistic:

**Ti =** $\frac{y\_{J- }y\_{K }}{J-K} $for i= 1,2,3… N

Here, yj and yk are the data values at time j and k (j > k), respectively. The median of these N values of Ti is the Sen’s slope estimator, which is defined as follows:

β$= \left\{ \begin{array}{c}T\_{\frac{N+1}{2}} N is odd,\\\frac{1}{2} \left(T\_{\frac{N}{2}}+T\_{\frac{N+2}{2}}\right) N is even \end{array}\right\}$

Here, if the value of β is positive, it means that the trend is in a rising pattern, and if the value of β is negative, it means that the trend is in a declining pattern (Sen, 1968).

**2.2.3 Statistical models for trend analysis**

In order to analyze the trend pattern in export of groundnut, the trend values will be computed by fitting linear, exponential and quadratic models (Arunachalam and Balakrishnan, 2012).

***2.2.3.1 Linear Model***

**yt = a + bt**

Where yt denotes the time series value at time 𝑡. The values of constants 𝑎 and 𝑏 are obtained by using the principle of least squares on solving the following normal equations:

$$∑y\_{t}=na+b∑t$$

$$∑ty\_{t}=a∑t+b∑t^{2}$$

Where, n represent the number of observed values.

***2.2.3.2 Exponential model***

**Yt= aebt**

Taking natural log on both sides of above equation, we have

 loge yt = loge a + bt logee

where,

 Yt = loge yt ,

 A=loge a, and logee = 1

The normal equations for estimating the values of 𝐴and 𝑏 are as follows:

 $∑y\_{t}=nA+b∑t$$ ∑ty\_{t}=A∑t+b∑t^{2}$

Finally, the value of 𝑎is obtained on using

 a = antilog (A)

***2.2.3.3 Quadratic model***

**Yt = b0 +b1t + b2t2**

 Where,

 Yt = the value of the data at time t

 b0 = A constant

 b1 and b2 = Coefficients for time

3. RESULT AND DISCUSSION

The data of groundnut exports from India procured from the Trade Map website covering the period from 2005 to 2024, was collected and summarized in Table 1. This table presents the descriptive statistics for two key export variables, quantity and value. The quantity of groundnuts exported, measured in tonnes, ranges from a minimum of 180,851 tonnes to a maximum of 760,764 tonnes, with an average export volume of 517,134.45 tonnes. The standard deviation of 181,845.63 tonnes reflects noticeable variability in the quantity exported each year, likely influenced by changes in domestic production, global demand, pricing, and policy interventions. The value of groundnut exports, measured in thousand USD, shows a wide range from a low of 109,447 thousand USD to a high of 941,047 thousand USD. The mean export value stands at 569,546.60 thousand USD, with a substantial standard deviation of 260,103.40 thousand USD, indicating significant annual fluctuations. These fluctuations may be attributed to variations in international market prices, currency exchange rates, and trade agreements. Overall, the data highlights considerable variability in both the quantity and value of groundnut exports from India over the years, pointing to the dynamic nature of the export market and its sensitivity to multiple external and internal factors.

**Table 1. Summary statistics of groundnut exports during 2005 to 2024 from India**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **Minimum** | **Maximum** | **Mean** | **Std. deviation** |
| **Quantity(tones)** | 180851 | 760764 | 517134.45 | 181846 |
|  **Value (thousand USD)** | 109447 | 941047 | 569546.6 | 260103 |
|  |

In the current study, The Pettitt’s, SNH and Buishand’s range tests have been applied to identify the mutation point for year wise export quantity and export value of groundnut from 2005 to 2024. From Table 2, the result exhibits for the export quantity variable, Pettitt’s test, Buishand range tests detected a significant change point around 2010, and SNH test showed 2009 as mutation point with all tests showing statistically significant result at the 1 per cent level. The year 2010 thus appears to mark a notable structural shift in the quantity of groundnut exported from India. This turning point could be attributed to a combination of factors such as favorable trade policies, increased international demand, or improvements in production and processing technology. Additionally, a significant depreciation of the Indian rupee around that period might have enhanced export competitiveness. Similarly, for export value, all three tests pointed to 2010 as a significant mutation year. Pettitt’s test revealed a significant change point at the 1% level (*P = .004*), whereas the Buishand and SNH tests both showed significance at the 1% level (*p = .001* and *P = .000* respectively). The concurrent surge in both the quantity and value of Indian groundnut exports around 2010 signals a significant transformation within the sector. This dual shift suggests that the changes were not isolated but rather rooted in broader, systemic developments that impacted the entire export framework. A key factor behind this structural break could be India’s strategic repositioning in the global groundnut trade, aimed at enhancing its competitiveness and market reach. Upgrades in post-harvest practices—such as improved grading, storage, and packaging—likely elevated the quality of Indian groundnuts, making them more appealing to international buyers. At the same time, India may have tapped into new export destinations, thereby reducing reliance on traditional markets and expanding its global footprint. Government policies also played a crucial role, with initiatives like export subsidies and a reinforced Minimum Support Price (MSP) mechanism offering financial incentives and stability to producers. These measures likely encouraged greater investment in production and processing infrastructure, fostering long-term growth. Furthermore, the depreciation of the Indian rupee during this period enhanced price competitiveness, making Indian groundnuts more attractive on the global stage. Collectively, these developments created a fertile environment for export expansion, positioning 2010 as a landmark year in the evolution of India’s groundnut trade.

**Table 2 Analysis of mutation point of groundnut exports during 2005 to 2024 from India**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Pettitt’s test** | **Buishand range test** | **SNH test** |
| Change point | *P*-value | Change point | *P*-value | Change point | *P*-value |
| Export quantity | 2010\*\*\* | .006 | 2010\*\*\* | <.0001 | 2009\*\*\* | .001 |
| Export value | 2010\*\*\* | .004 | 2010\*\*\* | .001 | 2010\*\*\* | .000 |

Note: *\*, \*\* and \*\*\* indicate significance at 10%, 5% and 1% level of significance respectively.*

Following the identification of the mutation year, the entire period from 2005 to 2024 was divided into three segments, as presented in Table 3: (i) the period before the mutation point (2005–2009), (ii) the period after the mutation point (2010–2024), and (iii) the overall time span (2005–2024). It observed from the table 3 that export quantity and value found statistically significant (p < .01) for MK-test and Sen’s slope during the overall time period highlighting long-term growth potential in groundnut exports from India. The highest significant increase in export quantity was found 23,837.53 tonnes/year, while export value increased at 35,235.98 thousand USD/year during the same period. However, the trends in the periods 2005–2009 and 2010–2024 were statistically non-significant (*P* > .05), indicating fluctuations and instability in the export pattern. The export value showed a relatively higher increasing trend as compared to export quantity during all three segments. This trend reflect improvements in export performance, global demand, and trade facilitation policies favoring India’s groundnut sector.

**Table 3 Mann-Kendall test and Sen’s slope estimators of groundnut exports during 2005-2024 from India**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Segmentation year** | **MK-test** | **Kendall’s Tau** | ***P*-value** | **Sen’s slope** |
| Export quantity (tonnes) | 2005-2009  | 4 | 0.4 | 0.462 | 17028.5 |
| 2010-2024  | 19 | 0.181 | 0.373 | 6205.714 |
| 2005-2024 | 98 | 0.516*\*\*\**  | 0.002 | 23837.53 |
| Export value (thousand USD) | 2005-2009  | 6 | 0.6 | 0.221 | 48026.5 |
| 2010-2024  | 23 | 0.219 | 0.276 | 16493.5 |
| 2005-2024 | 104 | 0.547*\*\*\**  | 0.001 | 35235.98 |

Note: *\*, \*\* and \*\*\* indicate significance at 10%, 5% and 1% level of significance respectively.*

Table 4 presents the coefficient of determination (R²) values for linear, exponential, and quadratic models fitted to the time series data on groundnut export quantity and export value. The R² values serve as indicators of the explanatory power of each model, showing how well the respective equations capture the variability in exports over time. For export quantity, the quadratic model provided the best fit, with an R² value of 0.660, indicating that approximately 66 per cent of the variation in export volume could be explained by this model. Similarly, for export value, the quadratic model again emerged superior, achieving an R² of 0.614 and accounting for about 61.4 per cent of the variation in export earnings. These results demonstrate that, compared to the linear and exponential models, the quadratic specification was more effective in capturing the non-linear growth patterns inherent in India’s groundnut export trends. Overall, the quadratic model consistently outperformed the other functional forms, making it the most reliable for explaining and projecting both export quantity and export value during the study period.

**Table 4 Model equations for linear, exponential and quadratic trends and value of R2 of export quantity and export value of groundnut from India**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Model name** | **Y** | **R2** |
| Export quantity (tonnes) | Linear model | y = 276631.8+22905.01t | 0.555 |
| Exponential model | y = 12.48·e0.4462t | 0.589 |
| Quadratic model | y = 127326.16 + 63624.73t− 1939.03t² | 0.660 |
| Export value(thousand USD) | Linear model | y = 232528.93+32096.92t | 0.533 |
| Exponential model | y = 12.25·e0.0812t | 0.594 |
| Quadratic model | y = 45063.81 + 83223.77t − 2434.61t² | 0.614 |

4. CONCLUSION

The study highlights significant variability and long-term growth trends in groundnut exports from India during 2005–2024. Using three different tests, a major structural shift was identified in 2010, likely influenced by trade policies, global demand, and currency movements. Trend analysis showed a statistically significant increase in both export quantity and value during the overall period. India’s groundnut exports have shown a notable annual growth with volumes increasing by 23.84 thousand tonnes and export value rising by $35.24 million. The quadratic model most effectively captures the dynamic nature of this upward trend. These findings highlight the urgent need to strengthen trade policies and upgrade export infrastructure to sustain and amplify India’s progress in the global groundnut market.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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