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CARDAMOM MARKET DYNAMICS: AN EMPIRICAL ANALYSIS

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ABSTRACT
The study undertakes an econometric investigation of small cardamom export price behaviour across the three major producing and exporting countries which are India, Guatemala and Indonesia. The study period is from January 2010 to December 2024 covering 180 monthly observations per market. The analysis was conducted using a structured methodological framework of Cuddy-Della Valle Instability Index (CDVI), Augmented Dickey Fuller test, Johansen cointegration, Vector Error Correction (VECM), Granger causality, and ARCH-GARCH. The study structurally characterizes the long-run equilibrium relationships, short-run price adjustment dynamics, price transmission, and volatility persistence in the global cardamom markets. The CDVI showed Indonesia as the most price-unstable market at 70.21%, followed by Guatemala at 41.96% and India at 22.97%. The ADF test confirms I(1) integration for all the three series. The Johansen cointegration identifies one significant cointegrating vector, establishing the existence of long-run price relationship. The VECM results showed that presence of short-run relationships, with Indonesia having the fastest correction at 17.86 % and India and Guatemala adjusting at 7.41 % and 6.14 % respectively. The Granger causality results indicate unidirectional price leadership from Guatemala to India, confirming the dominant role of Guatemala in global price discovery. ARCH-GARCH revealed high and persistent volatility in all the three markets across countries. These findings provide valuable insights for policymakers in developing price risk management frameworks, strengthening market infrastructure, and enhancing market stabilization policies in the global cardamom industry.

KEYWORDS: Cardamom, Granger causality, Instability, Market Integration, Price Transmission, Volatility.

INTRODUCTION
Cardamom (*Elettaria cardamomum*), famously known as the ‘Queen of Spices’, occupies an important position in global high-value spice trade, combining distinctive aromatic properties with diverse culinary, pharmaceutical, Ayurvedic and industrial applications that support strong demand in both traditional and emerging markets. The global cardamom economy is dominated by the three major producing and exporting nations i.e. India, Guatemala, and Indonesia, which collectively account for the overwhelming share of the world supply, and whose price dynamics, therefore largely determine international market conditions. Globally, cardamom is estimated at 1.3 lakh tonnes annually, with Guatemala contributing nearly 68% of world exports, followed by India at 18% and Indonesia at 9% *FAOSTAT (2024).*

REVIEW OF LITERATURE
Production and productivity fluctuations in cardamom have been found strongly and negatively correlated with prices *Lama et al. (2020). Rajanbabu et al. (2022), Nirmala et al. (2015)* reported price linkages between futures and spot cardamom markets in India through MCX.

The cardamom pricing are characterized by strong and persistent volatility arising from the interplay of supply side shocks, including erratic monsoon rainfall, pest and disease incidence, and irregular cropping cycles, with demand-side pressures from price-inelastic in Arab Gulf markets and growing international interest in specialty spices. *(Garg et al., 2023; Garg & Narwal, 2024)* reported volatility spillover running predominantly from spot to futures in Indian cardamom markets.

Despite the economic significance of cardamom, the research on its price dynamics remains limited, particularly at the level of multi-country analyses, *Maniselvan (2019)* examined the short-term relationship between cardamom spot and futures prices using VECM, *Vijayakumar (2021*) presented findings on e-auction prices as the primary vehicle of price discovery in the Indian cardamom market. *Garg and Narwal (2024)* presented findings that volatility spillover runs predominantly from spot to futures markets in Indian cardamom. Lama et al. (2020) demonstrated that GARCH-type models outperform ARIMA in forecasting volatile spice prices including cardamom *Paul et al. (2009)*. Studies have examined price trends in the Indian cardamom market using descriptive approaches, while a small number of studies have employed commodity futures data to examine price discovery in India, yet a systematic investigation of international price integration, transmission dynamics, causal price leadership, volatility structure across the three major dominant producing and exporting nations has not been undertaken in the available literature.

The present study was undertaken with the following objectives: (1) To analyse the price trends and instability across major producing and export cardamom markets, (2) To examine the long-term relationship among the selected markets. (3) To examine the price transmission among the selected cardamom markets, (4) To analyse the price volatility across the selected cardamom markets.

This study was conducted using secondary data from national and international databases. Monthly cardamom export unit value prices for India, Guatemala, Indonesia, expressed in USD per kilogram, were compiled from International Trade Centre (ITC) Trade Map and United Nations Comtrade (UN Comtrade) database for the time period of 2010 to 2024 180 monthly observations per. The three markets were selected based on their dominant share in global cardamom supply, their significance in international price discovery, and the availability of consistent time-series data across the full study period. India was selected as the main domestic market of interest, Guatemala as the world's largest exporter, and Indonesia as an important Southeast Asian producer and consumer with a growing influence on regional price dynamics.

MATERIALS AND METHODS

***Cuddy-Della Valle Instability Index (CDVI)**:* proposed by Cuddy and Della Valle (1978), is a widely used measure of instability in time-series data. Where CV represents the coefficient of variation expressed as percentage and R^2 is derived from a simple linear regression of the price series on time.

Coefficient of variation (CV): $\frac{\sigma}{\text{X}} \times 100$

CDVI: $\boldsymbol{CV \times \sqrt{1} - R^2}$

where σ = standard deviation of the price series; X, mean of the price series; R^2, Coefficient of determination from a simple linear trend regression of the price on time; $\sqrt{1} - \text{R}^2$, Correction factor that removes the influence of the underlying trend from total variability.

***Augmented Dickey-Fuller (ADF) test**:* To check presence of unit root for stationarity of data.

$$\boldsymbol{\Delta Y_t = \alpha + \beta_t +_{\gamma} Y_{t-1} + \sum \delta_i \, \Delta \, Y_{t-1} + \varepsilon_t}$$

where Δ, First difference operator; Y_t, Cardamom export price at time t; α, Constant intercept; β_t, Deterministic time trend; γ, Coefficient on lagged price level; null hypothesis H_0: $\gamma = 0$ implies unit root; $\delta_{i,}$ Coefficient on lagged first differences to eliminate serial correlation; p, Optimal lag length selected by AIC with maximum lag of 12; ε_t, White noise error term.

Johansen Cointegration: Johansen (1988) and Juselius (1990) the maximum likelihood procedure was applied to determine the number of long-run cointegrating relationships present among the price series.

$$\boldsymbol{\Delta Y_t = \prod Y_{t-1} + \sum_{i=1}^{p-1} r_i \, \Delta Y_{t-1} + \mu + \varepsilon_t}$$

where ΔY_t, Vector of first-differenced cardamom price series; $\prod$, Long-run impact matrix decomposed as $\prod = \alpha\beta'$; α, Adjustment coefficients; β, Cointegrating vectors; $\Gamma_{i,}$ Short-run coefficient matrices; μ, Deterministic constant; ε_i, Vector of white noise error terms.

When a group of non-stationary I(1) variables forms a stationary linear combination, they are considered cointegrated, indicating a stable long-run relationship among them. Two complementary test statistics are employed: the Trace Statistic and the Maximum Eigenvalue Statistic, both compared against MacKinnon-Haug-Michelis (1999) critical values.

Trace Statistic:

$$\boldsymbol{\lambda_{trace}(r) = -\text{T} \sum_{i=r+1}^{n} In(1 - \lambda_i)}$$

where T, Number of usable observations (178); r, Number of cointegrating vectors under null hypothesis; λ_i, i-th largest estimated eigenvalue; n, Total number of variables.

Maximum Eigenvalue Statistic:

$$\boldsymbol{\lambda_{max}(r, \lambda_{r+1}) = -\text{T}In\,(1 - \lambda_{r+1})}$$

where T, Number of observations; λ_{r+1}, $(r+1)$-th largest estimated eigenvalue; H_0: $exactly\, r$ cointegrating vectors against H_1: $r+1$ cointegrating vectors.

Granger Causality: Model used when two or more markets are cointegrated (presence of long run relationship).

$$\boldsymbol{Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, \text{Y}_{t-1} + \sum_{i=1}^{p} \beta_i \, X_{t-i} + u_t}$$

$$\boldsymbol{\text{X}_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, \text{X}_{t-1} + \sum_{i=1}^{p} \beta_i \, Y_{t-i} + u_t}$$

where Y_t, X_t, Cardamom export prices of the two markets being tested α_i, Coefficients on own lagged price values; β_i, Coefficients on lagged values of the other market; null hypothesis H_0: $\beta_i = 0$ for all i implies X does not Granger cause Y; p, Number of lags (6 lags: 174 observations); u_i, White noise error term.

Vector Error Correction Model (VECM): To determine the presence of short-term relationship.

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{i=1}^{p} \gamma_i \Delta X_{t-i} + \lambda \, ECT_{t-1} + \varepsilon_t$$

where ΔY_t, First difference of dependent cardamom price series; β_i, Coefficients capturing short-run effects of own lagged price changes; γ_i, Coefficients capturing short-run effects of other markets lagged price changes; λ, Error correction coefficient representing speed of adjustment toward long-run equilibrium; must be negative and significant to confirm mean reversion; ECT_{t-1}, Lagged error correction term; Lag length (5 lags); ε_t, White noise error term.

ARCH-GARCH: developed by Engle (1982) and Bollerslev (1986), models were employed to examine volatility behavior in cardamom prices. ARCH captures the impact of past shocks on current volatility, whereas GARCH accounts both the past shock and past volatility, by providing a more comprehensive framework for modeling volatility persistence in commodity prices.

Mean equation: $$P_t = C + \varepsilon_t$$

Variance equation: $$\sigma_t^2 = \omega + \alpha \cdot \varepsilon_{t-1}^2 + \beta \cdot \sigma_{t-1}^2$$

where P_t, Monthly cardamom export price (USD/kg) at time t; C, Mean constant; ε_t, Residual error term where $\varepsilon_t = \sigma_t z_t$ and $z_t \sim N(0,1)$; σ_t^2, Conditional variance at time t representing price volatility; ω, Variance intercept representing baseline volatility; $\omega > 0$; α, ARCH parameter measuring sensitivity to recent price shock ε_{t-1}^2; captures short-run shock effect; β, GARCH parameter measuring persistence; values exceeding unity indicate explosive persistence; required conditions: $\omega > 0, \alpha \geq 0, \beta \geq 0$.

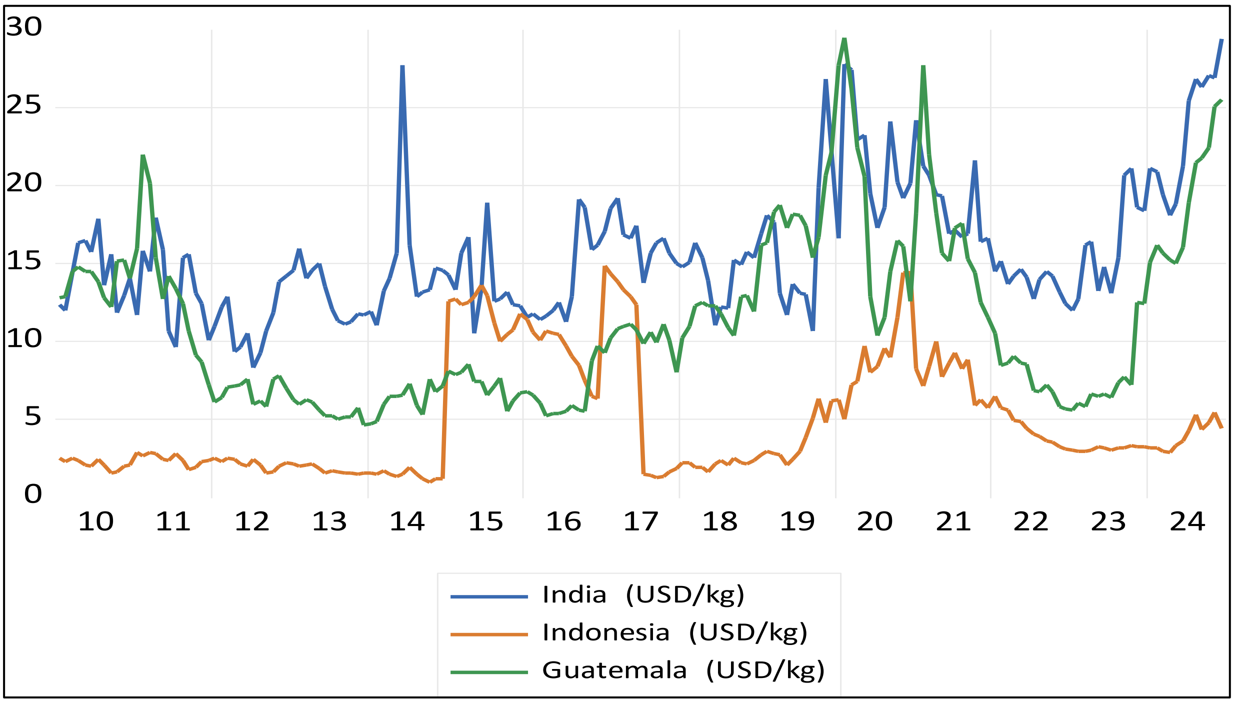

Fig. 1 Price Trends of cardamom in India, Guatemala, Indonesia (2010 to 2024)

Table 1 presents the descriptive statistics of the monthly cardamom export unit value for India, Guatemala and Indonesia over the study period of 2010 to 2024. Indian cardamom has the highest mean export price at USD 15.67 per kg over the study period, reflecting the globally recognized high quality of the Malabar and Mysore varieties. Guatemala recorded a mean price of USD 11.25 per kg, while Indonesia recorded a lower mean of USD 4.25 per kg, reflecting its unique product quality characteristics and strong focus on domestic market structure. The coefficient of variation of Indonesia was highest at 73.26 %, followed by Guatemala at 49.12% and India at 26.88%, indicating Indonesia's prices were the most volatile relative to mean, while India's prices exhibited the greatest relative stability over the study period. All the three series showed a general upward trend over time, interrupted by notable price spikes from 2021 and 2024 due to weather-related supply shortages and increased demand from Gulf markets. These findings are consistent with *Lama et al. (2020)* who reported high persistent price volatility in spice commodity markets including cardamom.

Table 1: Descriptive statistics of cardamom export prices (USD/kg)

Market	Mean	Median	Std. Dev.	Min.	Max.
India	15.67	14.20	4.21	8.27	29.39
Guatemala	11.25	9.83	5.53	4.61	29.43
Indonesia	4.25	3.19	3.11	0.92	14.39

Cuddy-Della Valle Instability Index (CDVI) test estimation: This index is considered as more appropriate measure of commodity price instability because it filters out the influence of any underlying long-term price trend before quantifying the variability. The CDVI results for all the three markets are given in (Table 2),

Table 2: Cuddy-Della Valle Instability Index for Cardamom Export Prices

Market	Mean (USD/kg)	CV (%)	R^2	CDVI (%)
India	15.67	26.88	0.2703	22.97
Guatemala	11.25	49.12	0.2703	41.96
Indonesia	4.25	73.26	0.0818	70.21

Note: CV = Coefficient of Variation; R^2= Coefficient of determination from simple linear trend regression; CDVI = CV $\times\sqrt{(1-R^2)}$; higher values indicate greater price instability.

The results reveal that all three markets experienced substantial price instability over the study period. Among them, Indonesia recorded the highest at 70.21%, reflecting the greatest degree of price variability after filtering out the effect of the underlying long-run trend. Followed by Guatemala CDVI of 41.96%, and India showed comparatively lower value of 22.97%. Notably, the coefficient of determination from linear trend regression are relatively modest, standing at 0.2703 for both India and Guatemala and 0.0818 for Indonesia, suggesting that the deterministic trend explains only a limited share of total price variation, and a substantial portion of the observed price movements across all the three markets is driven by irregular, non-trend factors that operate independently of any predictable directional path. Similar patterns were reported by *Rajanbabu et al. (2022); Guleria (2022); Thazhugal Govindan Nair (2021).* The elevated instability observed across all the three markets is caused by persistent supply-side vulnerabilities, Cardamom cultivation is concentrated in ecologically sensitive growing regions, where crop yields are highly sensitive to monsoon rainfall, temperature during the critical flowering period, and the incidence of pest and diseases. On the demand side, price dynamics in India and Guatemala are considerably influenced by seasonal religious demand peaks in Middle Eastern markets, while Indonesia's comparatively higher instability from its limited global export presence and increased exposure to exchange rate fluctuations affecting USD-denominated prices These findings underscore the critical importance of efficient market linkages and information flows, providing a strong empirical basis for the subsequent analysis of market integration and price transmission. Which is reflected in the mentioned literatures *Cariappa and Chandel (2020), Indhushree and Kuruvila (2021)*.

Augmented Dickey-Fuller (ADF) test estimation: The ADF test was applied to check the presence of unit root to verify properties of the monthly cardamom export price series for India, Guatemala, and Indonesia. Table 3 showed. India (p=0.2348), Guatemala (p=0.4464), and Indonesia (p=0.0960) all remained above the 5% critical value, indicating that the null hypothesis of a unit root could not be rejected in the three markets at their level form. However, when the ADF test was applied to the first difference of each series, India (P= 0.000), Guatemala (P= 0.000) and Indonesia (P= 0.000) the null hypothesis was rejected attaining stationarity upon first differencing. Similar stationarity results were reported by *Maniselvan (2019)* in examining cardamom spot and futures prices in India, where all the price series achieved stationarity at first difference. Similar stationarity at first difference observed in *Indhushree and Kuruvila (2021) and Thazhugal Govindan Nair (2021)*.

Table 3: Augmented Dickey-Fuller unit root test results

Price Series	ADF Stat. (Level)	p-value (Level)	ADF Stat. (1st Diff.)	p-value (1st Diff.)	Order
India (IND)	−2.1261	0.2348	−14.2165	0.0000	I(1)
Guatemala (GUT)	−1.6668	0.4464	−10.4808	0.0000	I(1)
Indonesia (IDN)	−2.5946	0.0960	−13.6435	0.0000	I(1)

Johansen Cointegration test estimation: It was applied to determine the number of long-run cointegration relationships present among the three-price series. Both the Trace and Maximum Eigenvalue statistics reject the null hypothesis of no cointegration and at most one cointegration equation, but fail to reject the null of at most two, consistently identifying exactly two cointegrating equations among the three-price series at the 5% level (Table 4). This confirms the existence of a strong long-run equilibrium relationship among the selected markets, providing justification for VECM.

Table 4. Johansen cointegration (Trace statistic and Maximum Eigenvalue statistic)

Null Hypothesis	Eigenvalue	Trace Stat.	5% Critical Value (Trace)	P-value (Trace)	Max-Eigen stat.	5% Critical Value (Max-Eigen)	p-value (Max-Eigen)
None	0.1253	32.50	29.80	0.0034	18.32	15.13	0.0056

At most 1	0.0461	17.90	15.49	0.0176	16.14	8.53	0.0253
At most 2	0.0001	0.01	3.84	0.9151	0.01	3.84	0.9151

Granger causality test estimation: The results presented in (Table 6) reveal an asymmetric price leadership structure in the global cardamom market. Guatemala emerged as the dominate price leader, Granger- causing both Indonesia (F=2.0352, p=0.0253) and the India (F=2.4323, p=0.0164). Indonesia (F= 1.0462, p=0.5103) showed any significant reverse influence on Guatemala. This confirms Guatemala's unidirectional influence over both the markets, consistent with its position as the world's largest cardamom exporter.

India, In turn, was found to Granger-cause the Indonesia (F=1.9863, p=0.0352), though the reverse relationship was insignificant (F=0.0763, P=0.7143), indicating a unidirectional relationship from India to Indonesia, and further from the India to Indonesia, positioning Guatemala as the primary driver of price discovery and among which Indonesia was most price following market in the global cardamom trade. These findings align with *Nirmala et al. (2015)* who reported directional price relationships in Indian cardamom futures markets and *Chopra and Bessler (2005)* . Similar slow adjustment speeds were reported by *Singh et al. (2022).*

Table 6: Pairwise Granger causality test results

Null Hypothesis	**observations**	**F-statistic**	**PROB.**
IND does not Granger cause GUT	180	1.0512	0.6372
GUT does not Granger cause IDN	180	2.0352	0.0253
IND does not Granger cause GUT	180	1.0462	0.5103
GUT does not Granger cause IND	180	2.4323	0.0164
IND does not Granger cause IDN	180	1.9863	0.0352
IDN does not Granger cause IND	180	0.0763	0.7143

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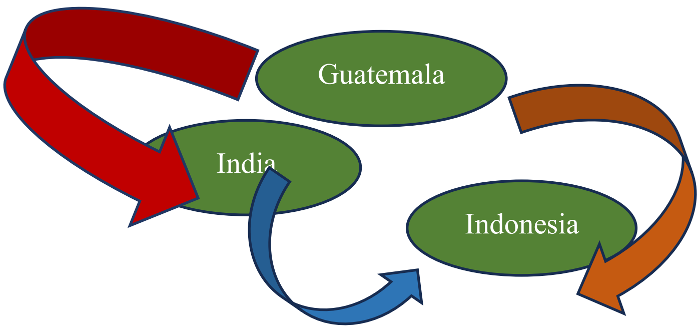

Fig.2 Direction of price transmission among major cardamom markets

Vector Error Correction Model (VECM) test estimation: The test estimates for the cardamom price markets are presented in Table 5. The error correction coefficients for all the three markets were negative and significant, confirming convergence toward long-run equilibrium and validating the cointegration relationship. Indonesia showed the fastest adjustment speed (2.1%), followed by India (1.8%) and Guatemala (1.5%), indicating Guatemala's relatively dominant, price-leading role.

In the short run, the lagged prices change in Guatemala significantly influenced both its own and India's prices, indicating quick transmission of shocks from Guatemala to India. India showed significant negative own-lag effects, reflecting short-run corrective adjustment, while Indonesia's lagged prices significantly affected Guatemala, pointing to bidirectional short-run linkages between the two. Overall, Guatemala emerges as the most influential market in the short-run price transmission.

Table 7: Vector Error Correction Model – Error Correction Term and Model Summary

Error Correction	**D(Guatemala)**	**D(Indonesia)**	**D(India)**
CointEq	-0.015 [-2.131]	- 0.021 [-2.653]	-0.018 [-2.705]
D (**Guatemala** (-1))	**0..2360 [2.8598]**	0.02308 [0.4190]	**0.2333 [1.9742]**

D (**Guatemala** (-2))	**-0.2020 [-2.3662]**	0.0153 [0.2695]	0.1242 [1,0159]
D (**Guatemala** (-3))	0.0714 [0.8325]	**0.0135 [0.2363]**	0.0785 [0.6391]
D (**Guatemala** (-4))	-0.0896 [-1.1066]	-0.0674 [-1.2472]	0.0206 [0.1778]
D (**Guatemala** (-5))	0.0023 [0.0297]	0.0062 [0,1193]	-0.1580 [-1.4067]
D **(Indonesia (-1))**	-0.1221 [-0.9970]	-0.0352 [-0.4311]	0.1235 [0.7040]
D **(Indonesia (-2))**	0.2075 [1.7045]	-0.0393 [-0,4846]	0.2221 [1.2743]
D **(Indonesia (-3))**	**0.2455 [2.0164]**	-0.0437 [-0.5381]	0.1777 [1.0190]
D **(Indonesia (-4))**	-0.0333 [-0.5223]	-0.0776 [-1.8202]	-0.0876 [0.9571]
D **(Indonesia (-5))**	0.0183 [0.1497]	-0.007 [-0.0925]	0.0367 [0.2094]
D (**India** (-1))	-0.0290 [-0.3926]	0.0190 [0.3843]	**-0,2224 [-2.0973]**
D (**India** (-2))	0.0175 [0.2416]	0.0323 [0.6680]	**-0.3639 [-3.5067]**
D (**India** (-3))	-0.0014 [-0.0198]	0.0235 [0.4907]	-0.1398 [-1.3576]
D (**India** (-4))	-0.0333 [-0.5223]	-0.0776 [-1.8202]	-0.0876 [0.9571]
D (**India** (-5))	0.0276 [0.4664]	-0.0321 [-0.8114]	-0.0010 [-0.0120]
R-squared	0.1984	0.08620	0.2414
F-statistic	2.4288	0.9256	3.1231
SIC	4.4147	3.6066	5.1327

ARCH-GARCH test estimation: The GARCH (1,1) estimates reveal high volatility persistence across all the three cardamom export price markets, with the sum of ARCH (α) AND GARCH (β) coefficients close to or exceeding the unity in each case. This indicates that price shocks in these markets are highly persistent and decay slowly over time, approaching near-integrated volatility behaviour. Indonesia exhibits the highest degree of persistence, followed by Guatemala and Inda, suggesting that volatility shocks in the Indonesian market take the longest to disperse. The negative beta coefficient for Indonesia further implies that past conditional variance has a marginal dampening effect on current volatility, unlike Guatemala and India where both past socks and past variance jointly reinforce volatility clustering. *Mahesha* (2011) who reported high and persistent price volatility in Indian spice exports *Paul et al. (2009).* Further confirmed by *Murugan et al. (2024).*

Table 8: ARCH-GARCH analysis for selected cardamom markets

Markets	**Alpha (α)**	**Beta (β)**	**Sum (α+β)**
Guatemala	1.0805	0.1020	1.1824
Indonesia	1.4039	-0.0085	1.3954
India	0.8508	0.1514	1.0022

This study has undertaken a comprehensive econometric analysis of cardamom export price dynamics across India, Guatemala, and Indonesia from January 2010 to December 2024.The CDVI establishes Indonesia as the most price-unstable market (70.21%), followed by Guatemala (41.96%) and India (22.97%). The ADF unit root test establishes that all three-price series are integrated of order one, satisfying the prerequisite for the cointegration analysis. The Johansen framework identifies two cointegration equations, confirming that the Indian, Guatemalan and Indonesian cardamom markets share a common long-run price equilibrium and are therefore, economically integrated. The VECM estimates reveal that all three markets participate in restoring long-run equilibrium following disequilibrium shocks, but the adjustment is slow Indonesia adjusts most rapidly at 2.1% per month, while Guatemala adjusts most slowly at 1.5% per month followed by India at 1.8% per month. The Granger causality analysis confirms unidirectional price leadership running from Guatemala to India, consistent with Guatemala's commanding share of global export volumes, and a further unidirectional relationship

from India to Indonesia. India does not significantly Granger cause Guatemala, confirming a one-directional price transmission structure between the two major exporters. The ARCH-GARCH analysis reveals uniformly high and persistent price volatility across all the three markets, with persistence measures close to exceeding unity in all the cases. Guatemala and Indonesia exhibit shock-driven volatility structures, while India displays a mixed volatility structure combining both ARCH and GARCH effects, reflecting the more institutionally integrated and informationally complex nature of Indian cardamom market.
The Policy Implications of these findings are significant. The slow VECM adjustment speeds observed across all the three markets suggest that short-term reactive interventions alone are not enough; what is needed are deeper structural reforms, including better storage infrastructure, strong price discovery institutions, and practical risk management tools such as futures contracts and weather-indexed insurance *Ward et al. (2020)*, to cushion farmers and traders from the prolonged income losses that arise during periods of price disequilibrium. The confirmation of Guatemala as the dominant price leader is a particularly important finding for Indian stakeholders, as it signals that Guatemalan supply conditions and export volumes should be closely monitored as early warning indicators of where international cardamom prices are headed. The uniformly high volatility persistence across all the three markets, with persistence measures close to or exceeding unity, further reinforces the case for commodity-specific price stabilization funds and expanding access to cardamom futures markets for smallholder producers in both India and Guatemala. Given Indonesia's exceptionally high price instability of 70.21%, regional cooperation mechanisms among the three major producing nations, including coordinated export policies, shared market intelligence, and joint supply management frameworks, could play a constructive role in reducing price volatility across the global cardamom markets. Looking ahead, future research could build meaningfully on this work by exploring asymmetric price transmission through threshold VECM models *s*, or by zooming into intra-national price linkages across individual auction centres within India, where much of the real price discovery for Indian cardamom actually takes place. This finding is consistent with Maniselvan (2019) who reported cointegration between cardamom spot and futures prices in India.

SUMMARY

The study examined price instability, price volatility, market integration, and transmission dynamics of cardamom export markets across India, Guatemala, and Indonesia using 180 monthly observations from January 2010 to December 2024. The Cuddy-Della Valle Instability Index reveals that Indonesia recorded the highest trend adjusted price instability at 70.21%, followed by Guatemala (41.96%) and India (22.97%). The ADF test confirms I(1) integration for all the three series, satisfying the necessary precondition for cointegration analysis. The Johansen cointegration test identifies two significant long-run equilibrium relationship, confirming that the three markets are economically integrated and move together over the long run. The VECM reveals slow mean reversion, with Indonesia adjusting fastest at 2.1% per month, Guatemala most gradually at 1.5% per month and India at 1.8% per month. The Granger causality analysis confirms unidirectional price leadership from Guatemala to India, establishing Guatemala as the dominant force in global cardamom discovery. The ARCH-GARCH estimation reveals uniformly high volatility persistence across all the three markets, with Guatemala and Indonesia exhibiting shock-driven structure and India displaying a mixed ARCH-GARCH structure reflecting its more institutionally integrated market environment. These findings collectively underscore the urgent need for structural market interventions, including real-time price monitoring systems, stronger futures market infrastructure, and coordinated supply management policies among the three major nations in the international cardamom markets.

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