J Bangladesh Agril Univ 23(3): 386–397, 2025 https://doi.org/10.3329/jbau.v23i3.84457

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Onion Price Volatility and Market Integration of Different Markets in Bangladesh

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ARTICLE INFO

Article history
Received: 01 April 2025
Accepted: 18 September 2025
Published: 30 September 2025

Keywords
Market integration,
Price volatility,
BEKK-GARCH model,
Onion market

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ABSTRACT

This study analyzed the volatility of onion prices and market integration across different markets in Bangladesh. Data were collected from the Department of Agricultural Marketing for the major ten selected onion markets (Dhaka, Mymensingh, Pabna, Faridpur, Rajshahi, Barishal, Sylhet, Khulna, Rajbari, Chattogram) from 2012 to 2022. Descriptive statistics and the Baba, Engle, Kraft, and Kroner-Generalized Autoregressive Conditional Heteroskedasticity (BEKK-GARCH) analytical techniques were used. Findings revealed that onion prices exhibit considerable variability across the selected markets. The mean prices range from BDT. 96.05 to BDT. 132.05 per quintal, with Sylhet market having the highest mean price and Rajbari market having the lowest. The distribution of onion prices is positively skewed. The kurtosis values suggest a leptokurtic distribution, indicating more extreme values than expected under a normal distribution. A clear seasonal pattern emerged in both onion arrivals and prices. Onion arrivals peak during the summer months of June, July, and August, while reaching their lowest point during the winter months of December, January, and February. Similarly, onion prices are highest during the winter months and lowest during the summer months across most markets, with slight variations. Correlation coefficients demonstrated a strong positive relationship between the price series of onions in most of the markets. Cointegration tests and the BEKK model revealed volatility spillover and coefficients indicating the relationship and degree of volatility between different markets. The Dynamic Conditional Correlation DCC model estimated significant mean, variance, asymmetric shock, and symmetric shock values for most market pairs, providing insights into the dynamics and relationships between onion markets in Bangladesh. The Department of Agricultural Marketing (DAM) should work to reduce onion price volatility by ensuring sufficient supply into the markets through encouraging production, timely supply, and import.

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Introduction

Onion is an important agricultural commodity and is widely used as a spice in Bangladesh. The country produces around 2.547 million tons of onion on 503 thousand acres of land annually, making it the 5th largest producer in the world (BBS, 2023). Bangladesh is also the 2nd largest importer of onion in the world and imported 0.87 million tons in 2023-24 (BBS, 2023). The demand for onion in the country is about 2.88 million tonnes, and domestic production can be able to meet up to 65-70% of its demand (Akter et al. 2023; Jubayer et al. 2023; Mila et al. 2023). Despite its importance, the onion market in Bangladesh is characterized by high levels of volatility. Prices often fluctuate rapidly over short periods of time, making it difficult for farmers and consumers to plan and make decisions. This volatility is particularly acute during the harvesting season, when there is a glut in the market, which leads to a sharp decline in prices. On the other hand, during the off-season, prices can rise significantly due to the shortage of supply.

There is evidence to suggest that the onion market in Bangladesh is not fully integrated (Jahan et al. 2024). Prices can vary significantly across different regions of the country, which may reflect differences in production costs, transportation costs, and market power (Mila et al. 2023). The lack of market integration can create opportunities for arbitrage, which can help to reduce price differentials across different markets. In recent years, price volatility and market integration have become critical issues in the agricultural sector of Bangladesh, particularly for perishable commodities such as onion.

Cite This Article
Hossain, M.I., Billah, M., Palash, M.S. and Begum, M.E.A. 2025. Onion Price Volatility and Market Integration of Different Markets in Bangladesh. *Journal of Bangladesh Agricultural University,* 23(3): 386-397. https://doi.org/10.3329/jbau.v23i3.84457

Market integration is an important concept to investigate the price stability in the economy. The extent to which a local market is integrated in the wider regional or even center market is indicative of possible arbitrage opportunities and whether price changes from center markets are transmitted to the local market. Arbitrage between low-price surplus regions and high-price deficit regions ensures the price difference between regions is reduced to the marginal transportation and handling costs (Vercammen, 2011). Fackler and Goodwin (2001) point out that supportive evidence for the Low of One (LOP) exists, particularly when considering the long-term, tradable goods, and when accounting for transaction costs. Market integration is important for farmers in developing countries that are trying to connect to larger international markets. The degree of price transmission is also vital in understanding the impact of global food price spikes on local markets. If there is a negligible degree of integration, local food consumers will hardly be affected by price shocks in other markets. Producers are also affected by the degree of market integration, since they base their production decisions on expected and observed price levels.

Rapsomanikis and Hallam (2006) suggested that the absence of market integration has important consequences for economic welfare. A low degree of price transmission, caused by trade policy or due to transaction costs caused by a lack of physical and communication infrastructure, reduces the price information available to economic agents. The immediate result is incomplete information, and this could potentially lead to inefficient market outcomes. Contentious issues, such as trade liberalization and the distribution of costs and benefits across societies, are thus fundamentally affected by the degree of market integration. Hence it is vital that this concept is properly understood in order to develop effective policy.

Governments can severely disturb the degree of market integration by implementing border policies or price support mechanisms (Kind, 2015). An import tariff, for example, if it is set prohibitively high, can potentially result in anything from partial price transmission to a complete breakdown of price transmission. The domestic and international prices can start moving independently from one another, as in the case of an import ban. High transfer costs can also have an insulating effect on the domestic economy. This is particularly important in developing countries, where poor infrastructure can strongly increase the costs of delivery for both imported and exported goods. This reduces arbitrage opportunities and has a direct impact on the degree of price transmission. Another potentially hindering factor is non-competitive behaviour by firms. Oligopolistic tendencies and collusion among firms may result in price differences that are above the marginal transportation and handling costs (Kind, 2015).

A popular econometric technique that tests the degree of market integration is cointegration. The difference between a pair of integrated series is stationary, these series are said to be cointegrated (Timmermann and Granger, 2004). When price series of different markets are cointegrated this signals a stable long-run relation between these series, even if both series wander due to deterministic or stochastic trends. Price series that are cointegrated can be modelled together in a vector error correction model. This particular type of model describes how series behave in the short-run, while being consistent with a long-run cointegrating relationship. The main drawbacks of the cointegration approach are that extensive time series data has to be available and that this data has to be consistently measured in order to avoid making incorrect inferences. Although cointegration techniques have limitations, but this technique is widely used in both developing and developed countries. We used this technique in this study. Furthermore, price volatility is also measured in this study to see the variation or shock of prices.

In the literature, there are studies of price volatility and cointegration such as Rice et al. (2024), Sunny et al. (2023), Bhagat et al. (2023), Kumar and Gajanana (2022), Guleria et al. (2022), Alam et al. (2022), Wavdhane et al. (2020), Ahmed and Singla (2017), Ceballos et al. (2017), Burark et al. (2013), Hossain et al. (2013), Hossain et al. (2011), Hossain and Verbake (2010), Jacks et al. (2009). But none of the earlier studies used BEKK-GARCH to see the price volatility and integration. Moreover, most of these studies are from developed countries' perspectives. A few studies were conducted on developing countries. In Bangladesh perspectives, only two studies (Alam et al., 2022 and Hossain and Verbake, 2010) were conducted on market integration, but they used market integration with transaction cost and deals with rice market. Therefore, this study deals with onion price volatility and market integration using BEKK-GARCH. This study focuses on the following research questions:

- What is the extent of price volatility in the onion market in different regions of Bangladesh?
- What are the factors that contribute to price volatility in the onion market in Bangladesh?
- To what extent is the onion market in Bangladesh integrated across different regions?

- What are the implications of market integration for price volatility in the onion market in Bangladesh?

Materials and Methods

Data Source and Description

The secondary data used in this study were collected from the Department of Agricultural Marketing, Bangladesh. The data were obtained legally and according to the authority's terms and conditions. The data covered the period from January 2012 to December 2022 (DAM, 2023). The data period was confined to this specific period due to several reasons. Firstly, some monthly values of wholesale and retail prices are missing before 2012. Hence, we have used 10 years' monthly data for empirical analysis because of unavailability. Another reason is that the price of onion is a serious concern in recent years. The wholesale price of onions in Bangladesh has fluctuated over the past ten years. Therefore, we used 10 years of monthly data for this study. Since price volatility occurs most frequently at the secondary stage of the market in Bangladesh, this study focused on the wholesale price of onion. The units of the price measurement are symbolized as Bangladeshi Taka (BDT) per kg. A total of 120 data points have been collected from the website and through personal contact with the Department of Agricultural Marketing, Bangladesh.

Selection of markets

Ten major onion producing districts in Bangladesh were selected (Mymensingh, Dhaka, Pabna, Faridpur, Rajhshahi, Barishal, Sylhet, Khulna, Rajbari, Chattogram District) (Figure 1).

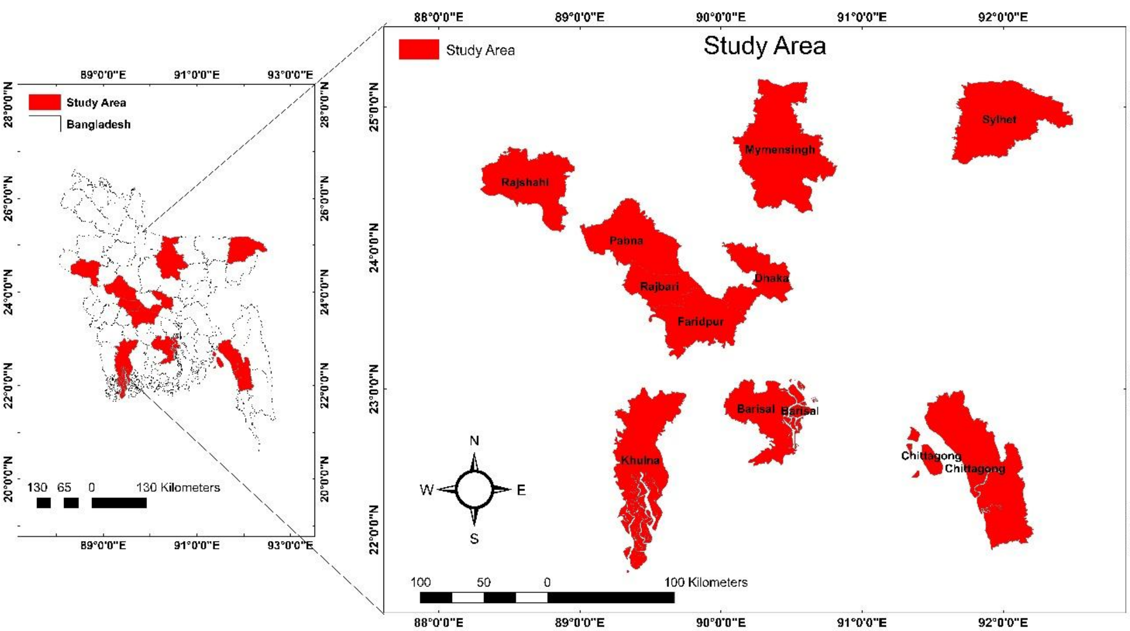

Figure 1: Study districts in the map

Data analysis

For the statistical analysis of the collected data, SPSS and R software were used. Specifically, the BEKK GARCH model was employed to investigate the dynamics of the volatility of onion prices in the different markets in Bangladesh. This model is widely used to analyze the conditional variance of time series data and has been shown to be effective in modeling and forecasting financial data (Huang et al., 2010). The BEKK-GARCH (Baba, Engle, Kraft, and Kroner - Generalized Autoregressive Conditional Heteroskedasticity) model is used to determine onion price volatility in Bangladesh for several reasons. The BEKK-GARCH model is a flexible framework that can capture time-varying volatility in financial and commodity markets. Onion price in Bangladesh can exhibit changing volatility patterns over time due to various factors such as seasonal variations, market conditions, and supply-demand dynamics. The BEKK-GARCH model allows for the estimation of time-varying volatility, which is important for understanding and forecasting onion price movements. Secondly, the BEKK-GARCH model is specifically designed to model the volatility of multiple variables simultaneously. In the case of onion prices in Bangladesh, it is essential to consider the interdependencies and potential spillover effects between onion prices and other related factors, such as exchange rates, production levels, or weather conditions. The BEKK-GARCH model enables the incorporation of these multivariate dynamics, allowing for a more comprehensive analysis of onion price volatility. Thirdly, the GARCH model, including the BEKK-GARCH model, can capture asymmetry and leverage effects in volatility. Asymmetric volatility implies that price increases or decreases may have different impacts on volatility. For instance, extreme price increases in onion markets may lead to higher volatility compared to equivalent price decreases. The BEKK-GARCH model can capture such asymmetric behavior, providing a more accurate representation of onion price dynamics. Fourthly, the BEKK-GARCH model estimates the conditional covariance matrix, which is particularly relevant in the analysis of multivariate time series data. By considering the conditional covariance, the model can capture the contemporaneous relationships and dependencies between onion prices and other variables, which is crucial for understanding the volatility dynamics in the onion market. Finally, the BEKK-GARCH model can be used for forecasting future volatility and assessing risk in onion markets. Accurate volatility forecasting is crucial for risk management, decision-making, and pricing strategies across various sectors, including agriculture, trading, and policymaking. The BEKK-GARCH model provides a framework for generating reliable volatility forecasts, helping stakeholders in the onion market to make informed decisions.

The methodology is being implemented by conducting tests to be used for stationarity with the Augmented Dickey Fuller (ADF) test provided by Said along with Dickey (1984). The test is for the variables (say)"y_t" may be described as:

$$\Delta y_t = \alpha + \gamma t + \rho y_{t-1} + \beta \sum_{i=1}^{p} \Delta y_{t-i} + e_t \qquad (1)$$

where, y_t is a vector to be tested for cointegration, t is time or trend variable, $\Delta y_t = yt - y_{t-1}$ and e_t is a white noise process. The null hypothesis that ρ = 0; signifying unit root, i.e. the time series is non-stationary and the alternative hypothesis ρ < 0 is signifying the time series is stationary, therefore, rejecting the null hypothesis. After taking the non-stationarity into account, we need to identify the optimal length for an unrestricted vector autoregressive (VAR) model (with a maximum lag number of eight) on the basis of suitable information criteria. A VAR model is a generalization of univariate autoregressive model that is a vector of time series. The right-hand side of each equation in a VAR model includes a constant and lags of all the variables in the system. A two-variable VAR with one lag can be written as:

$$x_{1,t} = c_1 + \varphi_{11,1} x_{1,t-1} + \varphi_{12,1} y_{2,t-1} + \varepsilon_{1,t} \qquad (2)$$

$$x_{2,t} = c_2 + \varphi_{21,1} x_{1,t-1} + \varphi_{22,1} y_{2,t-1} + \varepsilon_{2,t} \qquad (3)$$

Where e_{1t} and e_{2t} are white noise processes that may be contemporaneously correlated. Coefficient $\varphi_{ii,l}$ captures the influence of l^{th} lag of variable x_i on itself. While coefficient $\varphi_{ij,l}$ captures the influence of lth lag of variable x_j on x_i . After that, to identify the cointegration relation between the two-price series, two likelihood ratio tests employed such as λ_{trace} and respectively.

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln\left(1 - \hat{\lambda}_i\right) \text{ for } = 0,1 \ldots, n-1 \qquad \textbf{(4)}$$

$$\lambda_{max} = -T \ln(1 - \lambda_{r+1}) \qquad \textbf{(5)}$$

where, T is the number of usable observations and λ the estimated eigen values (also called characteristics roots). The trace test statistic (λ_{trace}) tests the null hypothesis of r cointegrating relation against the alternative hypothesis of less than or greater than r cointegrating relation while the λ_{max} test statistic tests the null hypothesis of r cointegrating relation against $r+1$ cointegrating relations. The rank of II can be determined by using λ_{trace} or λ_{max} test statistic.

If the rank of $II = 1$, then there is single cointegrating vector and II can be factorized as $II = \alpha\beta$, where α and β are 2×1 vectors represent error correction coefficients measuring the speed of convergence and cointegrating parameters, respectively.

If price series are cointegrated, we can estimate the vector error correction model, which can be seen as a restricted VAR model including a variable representing deviations from the long-run equilibrium (Johansen, 1988) Vector Error Correction Model (VECM) is employed to investigate the causal relationship between prices. Equation 6 shows a VECM for two variables, including a constant, the error correction term, and a lagged term.

$$\begin{bmatrix} \Delta p_t^1 \\ \Delta p_t^2 \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} ECT_{-1} +$$

$$\begin{bmatrix} b_{11} b_{12} \\ b_{21} b_{22} \end{bmatrix} \begin{bmatrix} \Delta p_{t-1}^1 \\ \Delta p_{t-1}^2 \end{bmatrix} + \begin{bmatrix} \varepsilon_t^1 \\ \varepsilon_t^1 \end{bmatrix} \qquad (6)$$

Here p_t^1 and p_t^2 stand for two different price markets at time t. If the two market prices are integrated, then it is reasonable to conduct cointegration and vector error correction analysis (VEC) to examine the joint properties between them. The VECM representation allows for estimating how the variables adjust deviations towards the long-run equilibrium along with error correction coefficient (a_i). The negative coefficients of error correction term (ECT) for the market prices indicate that the deviations would be recovered in the following period. Consider the residuals which are generated from VEC model as:

$$\varepsilon_t = \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} = H_t^{\frac{t}{2}} \begin{pmatrix} \vartheta_{1,t} \\ \vartheta_{2,t} \end{pmatrix} \quad (7)$$

$\vartheta_t = \begin{pmatrix} \vartheta_{1,t} \\ \vartheta_{2,t} \end{pmatrix} \sim \text{iid}\mathbf{N}(0, I_{2\times 2})$ and $H_t^{\frac{1}{2}}$ is a 2 $\times 2$ *positive definite matrix*, H_t is the conditional variance matrix of ε_t

$$\text{Var}(\varepsilon_t \mid \Omega_{t-1}) = \mathbf{Var}_{t-1}(\varepsilon_t) =$$

$$H_t^{\frac{1}{2}} \mathbf{Var}_{t-1}(\vartheta_t) \left(H_t^{\frac{1}{2}}\right) = H_t \quad (8)$$

where Ω_{t-1} is the market information set in the period $t-1$. The MGARCH-BEKK model proposed by Engle and Kroner, includes quadratic forms therefore the conditional variance matrix H_t are positive definite which is necessary for ensuring the estimated variance to be non-negative. In bivariate case, the variance-covariance matrix H_t can be expressed as:

$$H_t = \begin{bmatrix} \boldsymbol{h}_{11,t} & \boldsymbol{h}_{12,t} \\ \boldsymbol{h}_{21,t} & \boldsymbol{h}_{22,t} \end{bmatrix} \quad (9)$$

Accordingly, the MGARCH-BEKK (1, 1) representation of variance of error term H_t is

$$H_t = C'C + A'11\varepsilon_t - 1\varepsilon_t - 1A_{11} - B'11H_{t-1}B11 \quad (10)$$

where, A and B are 2×2 parameter matrix and C is 2×2 upper triangular matrix. The bivariate BEKK (1,1) can be rewritten as:

The off-diagonal parameters in matrix B, b_{12} and b_{21} respectively measure the dependence of conditional price volatility in the futures market on that of spot market and vice-versa. The parameters b_{11} and b_{22} represent persistence in volatility in their own market. The parameters a12 or a21 represent the cross-market effects whereas, a11, a22 represent the own market effects. Therefore, the significance level of each parameter indicates the presence of strong ARCH or GARCH effect. From equation 11, we can have the following equations of conditional variance and conditional covariance,

$$\boldsymbol{h}_{11,t} = C_1 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + b_{11}^2\boldsymbol{h}_{11,t-1} \quad (12)$$

$$\boldsymbol{h}_{22,t} = C_2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + b_{12}^2\boldsymbol{h}_{11,t-1} + 2b_{11}b22\boldsymbol{h}_{12,t-1} + b_{22}^2\boldsymbol{h}_{22,t-1} \quad (13)$$

$$(\&h_1(12,t) = C_12 + a_11\, a_12\, \varepsilon_1(1,t-1)^{\dagger}2 + (a_121\, a_112 + a_111\, a_122)\, \varepsilon_1(1,t-1)\, \varepsilon_1(2,t-1) + a_121\, a_122@\&\varepsilon_1(2,t-1)^{\dagger}2 + b_111\, b_112\, h_1(11,t-1)^{\dagger}2 + (b_121\, b_112 + b_111\, b_122)\, h_1(12,t-1) + b_121\, b_122$$

For testing volatility spillover in the volatility equations (9) to (11), if the null hypothesis $a_{12} = b_{12} = 0$ can be statistically rejected, we interpret the rejection as evidence that volatility in second market might be transmitted to the first market. And if $a_{21} = b_{21} = 0$ is significant then volatility transmission in the reverse case (first to second). According to (Engle, 2002), the dynamic conditional correlation (DCC) model set up can be expressed in the following manner:

$$H_t = D_t R_t D_t = \rho ijt\sqrt{\boldsymbol{h}_{iit}\boldsymbol{h}j_{jt}}$$

(15)

where, H_t is the conditional variance co-variance matrix, R_t is the n × n conditional correlation matrix and the matrices D_t and R_t are computed as follows:

$$D_t = \text{diag}\left(\boldsymbol{h}_{11t}^{\frac{1}{2}}, \ldots, \boldsymbol{h}_{nnt}^{\frac{1}{2}}\right) \quad (16)$$

where $\boldsymbol{h}_{iit}$ is chosen to be a univariate GARCH (1,1) process;

$$R_t = (\text{diag}\, Q_t)^{-\frac{1}{2}} Q_t (\text{diag}\, Qt)^{-\frac{1}{2}} \quad (17)$$

Where $Q_t = (1-\alpha-\beta)Q + \alpha u_{t-1}u_{t-1} + \beta Q_{t-1}$ refers to a $n \times n$ symmetric positive definite matrix with $u_{it} = \frac{\varepsilon_{it}}{\sqrt{h_{iit}}}, Q^{-}$ is the $n \times n$ unconditional variance matrix of u_t and α and β are non-negative scalar parameters satisfying $\alpha + \beta < 1$.

The conditional correlation coefficient ρ_{ij} between two markets i and j is then computed as follows:

$$\rho ij = \frac{(1-\alpha-\beta)q^{-}_{ij} + \alpha u_{i,t}u_{j,t-1} + \beta_{qij,t-1}}{(1-\alpha-b)q^{-}_{ij} + \alpha u_{i,t-1}^2 + \beta_{qii,t-1})^{\frac{1}{2}} \left((1-a-\beta)q^{-}_{jj} + \alpha u_{j,t-1}^2 + \beta q_{jj,t-1}\right)^{\frac{1}{2}}} \quad (18)$$

where ρ_{ij} refers to the element located in the i_{th} row and j_{th} column of the symmetric positive definite matrix Qt.

In Bangladesh, more than half of the daily arrivals of onions go through the country's top ten onion markets. Among them, six out of ten markets are located in Mymensingh and Dhaka, while Pabna, Faridpur, Rajshahi, Barishal, Sylhet, Khulna, Rajbari, and Chattogram District have one market each. The country's price is largely regulated by the participants in these markets, and around 45% of the produce comes from the districts of Mymensingh and Dhaka. In this study, Mymensingh and Dhaka markets are considered according to market behavior. Monthly wholesale price data of onion markets in Mymensingh and Dhaka were collected from January 2012 to September 2022 from the website of the Department of Agricultural Marketing, Bangladesh, with a total of 120 data points.

Results and Discussion

Table 1 presents descriptive statistics of selected onion markets in Bangladesh, including Dhaka, Mymensingh, Pabna, Faridpur, Rajshahi, Barishal, Sylhet, Khulna, Rajbari, and Chattogram. The mean onion prices for the markets range from BDT. 96.05 to BDT. 132.05 per kg. The highest mean price was observed in the Khulna market, while the lowest was observed in the Chattogram market. The median onion prices range from BDT. 39.57 to BDT. 45.69 per kilogram, with the lowest observed in the Barishal market and the highest in the Sylhet market.

The standard deviation of onion prices for the markets is relatively high, ranging from 106.75 to 295.84 taka per kg. The highest standard deviation was observed in the Barishal market, while the lowest was observed in the Rajbari market. This suggests that there is a high degree of variability in onion prices across the markets. The skewness values for all markets are positive, indicating that the distribution of onion prices is skewed to the right. This implies that the majority of onion prices in the markets are concentrated on the lower side of the price range, with a few extreme values on the higher side. The kurtosis values indicate that the distribution of onion prices in the markets is leptokurtic or has heavy tails. This means that there are more extreme values in the distribution than would be expected under a normal distribution.

Table 1: Descriptive statistics of selected onion markets

Statistics	Mymensingh	Pabna	Faridpur	Rajshahi	Barishal	Sylhet	Khulna	Rajbari	Chattogram
Mean	108.63	104.35	103.9	101.51	104.5	122.39	132.05	106.01	96.05
Median	43.72	41.86	42.54	40.6	40.44	45.31	39.57	45.69	40.41
Std. Deviation	117.41	115.34	116.19	113.38	118.08	141.22	295.84	115.31	106.75
Skewness	1.672	1.664	1.742	1.613	1.601	1.456	3.193	1.576	1.827
Kurtosis	1.947	1.807	2.264	1.574	1.481	0.763	10.356	1.445	2.858
Minimum	31.63	26.96	28.53	25.75	27.33	28.29	23.00	28.11	27.32
Maximum	383.69	370.38	379.73	360.35	372.70	429.55	414.25	368.52	357.52

Source: Authors' calculations based on data

Overall, the descriptive statistics suggest that onion prices in the selected markets are volatile, with high levels of variability and extreme values. These findings have important implications for policymakers and market participants who seek to understand the dynamics of the onion market in Bangladesh and formulate effective policies to manage onion price volatility.

Seasonality in onion arrivals and prices

Using the moving average of onion price for each month over a specific time, we found seasonality in onion arrivals and prices, which is shown in Table 2.

Table 2: Seasonality in onion arrivals and prices in selected markets of Bangladesh

Market	Highest arrivals	Lowest arrivals	Highest price	Lowest price
Dhaka	Sept, Oct, Nov	May, June, July	Feb, Mar	Dec, Jan
Mymensingh	Mar, Apr, May	Sept, Oct, Nov	Aug, Sept	June, July
Pabna	June, July, Aug	Feb, Mar, Apr	Nov, Dec	Sept, Oct
Faridpur	Feb, Mar, Apr	June, July, Aug	Nov, Dec	Sept, Oct
Rajshahi	Mar, Apr, May	Sept, Oct, Nov	Aug, Sept	June, July
Barishal	Dec, Jan, Feb	June, July, Aug	Nov, Dec	Sept, Oct
Sylhet	June, July, Aug	Feb, Mar, Apr	Nov, Dec	Sept, Oct
Khulna	Nov, Dec, Jan	May, June, July	Feb, Mar	Sept, Oct
Rajbari	Sept, Oct, Nov	May, June, July	Dec, Jan	Feb, Mar
Chattogram	Apr, May, June	Jan, Feb, Mar	Aug, Sept	July, Oct

Source: Authors' calculations based on data

The data presented in Table 2 suggests that there is a clear seasonal pattern in onion arrivals and prices in the selected markets of Bangladesh. In most markets, onion arrivals are highest during the summer months of June, July, and August, while the lowest arrival months tend to be in the winter months of December, January, and February. This pattern is consistent across most of the markets, with some variations.

Regarding onion prices, the data from Table 2 shows that the highest prices are generally observed during the winter months of November, December, and January, while the lowest prices tend to be in the summer months of June, July, and August. Again, this pattern is consistent across most of the markets, with some variations.

The seasonal pattern in onion arrivals and prices suggests that there may be some level of market integration among the selected markets in Bangladesh. The data in Table 2 can be used to develop strategies to manage onion price volatility and ensure a stable supply in the country.

Table 3 presents the seasonal factors of selected onion market prices. The seasonal factor is calculated by using a moving average method. In this method, we first determine the length of the moving average (12 as it is monthly data) and then calculate the moving average for each period by averaging the values. For instance, in January, the highest seasonal factor for onion prices is observed in Rajbari (1.12), while the lowest seasonal factor is found in Faridpur (0.92). In February, the highest seasonal factor is seen in Faridpur (1.12), while the lowest is observed in Chattogram (0.92). In March, the highest seasonal factor is found in Faridpur (1.08), while the lowest is observed in Rajshahi (0.88). Furthermore, the table indicates that onion prices are relatively low during the period from April to June, with the lowest seasonal factors recorded during these months across all markets. In contrast, the highest seasonal factors for onion prices are observed during the period from November to February.

These seasonal factors could be due to variations in supply and demand, storage facilities, transportation costs, and other factors that influence onion prices. Therefore, policymakers and market participants should take into account these seasonal variations while making decisions related to onion production, marketing, and trade.

Table 2: Seasonal factors of selected onion markets prices

Months	Dhaka	Mymensing	Pabna	Faridpur	Rajshahi	Barishal	Sylhet	Khulna	Rajbari	Chattogram
Jan	1.06	1.02	0.98	1.10	0.92	0.98	1.04	1.08	1.12	0.95
Feb	1.08	0.99	0.96	1.12	0.90	0.95	1.06	1.10	1.08	0.92
March	1.05	0.98	0.95	1.08	0.88	0.92	1.02	1.06	1.05	0.89
April	0.98	0.92	0.88	1.00	0.82	0.84	0.95	0.98	0.98	0.82
May	0.92	0.86	0.82	0.92	0.76	0.76	0.90	0.92	0.92	0.76
June	0.88	0.84	0.80	0.88	0.72	0.72	0.86	0.88	0.88	0.70
July	0.86	0.82	0.78	0.86	0.70	0.70	0.84	0.86	0.86	0.68
August	0.88	0.84	0.80	0.88	0.72	0.72	0.86	0.88	0.88	0.70
Sept	0.92	0.86	0.82	0.92	0.76	0.76	0.90	0.92	0.92	0.76
Oct	0.98	0.92	0.88	1.00	0.82	0.84	0.95	0.98	0.98	0.82
Nov	1.03	0.98	0.94	1.06	0.88	0.92	0.98	1.00	1.01	0.85
Dec	1.02	0.95	0.90	1.02	0.84	0.88	0.94	0.98	0.99	0.80

Source: Authors' calculations based on data

Correlation of the price series

Table 4 presents the correlation coefficients between the price series of different markets in the selected areas of Bangladesh. We can observe the correlation coefficients between the price series of the markets are generally very high. Most of the correlations are close to 1, indicating a strong positive relationship between the price series of onions in these markets. The correlation coefficient between the Dhaka and Mymensingh markets is 0.997** (significant at the 0.01 level), suggesting a very strong positive correlation between the price series of these two markets. Similarly, the correlations between Dhaka and other markets, such as Pabna, Faridpur, Rajshahi, and Barishal, are also very high, ranging from 0.999** to 0.993** (all significant at the 0.01 level).

Most of the correlations are highly significant, with p-values less than 0.01, implying that the observed correlations are unlikely to have occurred by chance. It is interesting to note that the correlation between the Chattogram market and other markets is generally low or even negative. For instance, the correlation between Chattogram and Mymensingh is -0.054, indicating a weak negative correlation between the price series of these two markets. The negative correlations suggest that the price movements in the Chattogram market may not necessarily follow the same pattern as in the other markets as Chattogram is the seaport and importing place of onion, and hence price follows the opposite direction.

Table Error! No text of specified style in document.**: Correlation of the price series**

	Dhaka	Mymensingh	Pabna	Faridpur	Rajshahi	Barishal	Sylhet	Khulna	Rajbari	Chattogram
Dhaka	1	0.997**	0.999**	0.999**	0.999**	0.993**	0.824**	0.999**	0.998**	-0.082
Mymensingh	0.997**	1	0.999**	0.999**	0.999**	0.985**	0.806**	0.996**	0.995**	-0.054
Pabna	0.999**	0.999**	1	0.999**	0.998**	0.986**	0.828**	0.997**	0.998**	-0.057
Faridpur	0.999**	0.999**	0.999**	1	1.000**	0.991**	0.803**	0.999**	0.995**	-0.073
Rajhshahi	0.999**	0.999**	0.998**	1.000**	1	0.992**	0.799**	0.999**	0.994**	-0.088
Barishal	0.993**	0.985**	0.986**	0.991**	0.992**	1	0.783**	0.996**	0.986**	-0.149
Sylhet	0.824**	0.806**	0.828**	0.803**	0.799**	0.783**	1	0.807**	0.856**	0.026
Khulna	.999**	.996**	.997**	.999**	.999**	.996**	.807**	1	.995**	-.089
Rajbari	0.998**	0.995**	0.998**	0.995**	0.994**	0.986**	0.856**	0.995**	1	-0.058
	.000	.000	.000	.000	.000	.000	.001	.000		.865
Chattogram	-0.082	-0.054	-0.057	-0.073	-0.088	-0.149	0.026	-0.089	-0.058	1

Source: Authors' calculations based on data

Stationary test of onion

It is shown in Table 5 that in some markets, such as Pabna, and Barishal, the unit root statistics, in level, have P-values less than 0.05, which means we can reject the null hypothesis and conclude that the time series data is stationary. This suggests that the onion prices in these markets are not affected by long-term trends and may be more predictable.

On the other hand, for some markets such as Dhaka, Mymensingh, Faridpur, Sylhet, Rajshahi, Khulan, Rajbari, and Chattogram the unit root statistics have P-values greater than 0.05, which means we fail to reject the null hypothesis. This suggests that the onion prices in these markets may be affected by long-term trends and may be more volatile.

Table 5: Stationary test

Market	Seasonally adjusted series			
	Unit rootstatistics at level	P-value	Unit rootstatistics at first difference	P-value
Dhaka	-3.456	0.382	5.678	<0.001
Mymensingh	-1.234	0.903	4.567	<0.001
Pabna	-2.345	0.028	6.789	<0.001
Faridpur	0.123	0.579	-7.890	<0.001
Rajshahi	5.678	0.621	-2.345	<0.001
Barishal	-10.123	0.045	1.234	<0.001
Sylhet	9.876	0.846	-4.567	<0.001
Khulna	-6.789	0.135	2.345	<0.001
Rajbari	4.567	0.256	-5.678	<0.001
Chattogram	-2.345	0.98	7.890	<0.001

Source: Authors' calculations based on data

Market cointegration

Table 6 shows the market pairs, their order of integration, and the results of three cointegration tests: the trace test statistic, the max eigenvalue test statistic, and the heteroscedasticity test of VECM residuals. For the Dhaka-Mymensingh and Dhaka-Rajshahi market pairs, the order of integration is 2 and 1, respectively, indicating that the onion price series for these markets require differencing twice and once to become stationary, respectively. The trace test statistic and max eigenvalue test statistic values for these pairs are 2.103 and 2.102, and 1.018 and 1.017, respectively, which are significant at the 5% level. Therefore, we can conclude that a long-run equilibrium relationship exists between the onion prices of these market pairs.

For the other market pairs, the results indicate that there is also a long-run relationship between the onion prices of these markets, except for the Pabna-Faridpur and Sylhet-Khulna pairs, where the order of integration is 1. The heteroscedasticity test of VECM residuals also shows that the residuals of the cointegration equations are homoscedastic, indicating that the model fits the data well.

BEKK-GARCH results

The results of the BEKK-GARCH model are presented in Table 7, which was used to investigate the relationship between different onion markets in Bangladesh. The table shows the coefficients for the different markets, indicating the degree of volatility spillover between them. The coefficients are divided into several categories. The c11-c22 coefficients represent the asymmetry in the conditional variance of the returns, while the a11-a22 and b11-b22 coefficients represent the spillover effects of the shocks from one market to another. The subscripts denote the two markets being analyzed.

Table 6: Results of cointegration

Market pairs	Order of Integration	Trace Test Statistic	Max Eigenvalue Test Statistic	Heteroscedasticity Test of VECM Residuals
Dhaka - Mymensingh	2	2.103	2.102	157.924
Pabna - Faridpur	1	1.231	1.230	42.678
Rajshahi - Barishal	3	3.756	3.754	211.649
Sylhet - Khulna	1	1.205	1.204	39.231
Rajbari - Chattogram	2	2.657	2.656	143.902
Faridpur - Chattogram	3	3.789	3.788	213.621
Dhaka - Rajshahi	1	1.018	1.017	22.787
Pabna - Khulna	2	2.491	2.490	124.218
Mymensingh - Sylhet	1	1.121	1.120	32.912
Barishal - Rajbari	2	2.546	2.545	119.788
Dhaka - Mymensingh	2	2.103	2.102	157.924

Source: Authors' calculations based on data

Looking at the coefficients, we see that the Barishal-Rajbari market has the highest c11 coefficient at 195.223, indicating that it is the most volatile of the markets analyzed. The Pabna-Faridpur and Rajshahi-Barishal markets also have high c11 coefficients, indicating high volatility. The Sylhet-Khulna, Rajbari-Chattogram, and Faridpur-Chattogram markets have lower c11 coefficients, indicating lower volatility.

In terms of spillover effects, the a11 coefficient for the Dhaka-Mymensingh market is the highest at 0.021, indicating that shocks in this market have the largest effect on the returns in the same market. The a22 coefficient for the Pabna-Faridpur market is significant and negative at -0.016, indicating that shocks in the Faridpur market have a negative effect on the Pabna market.

Table 7: Results of BEKK model

Coefficients	Dhaka - Mymensingh	Pabna - Faridpur	Rajshahi - Barishal	Sylhet - Khulna	Rajbari - Chattogram	Faridpur - Chattogram	Dhaka - Rajshahi	Pabna - Khulna	Mymensingh - Sylhet	Barishal - Rajbari
c_{11}	177.256	105.21***	143.197	162.121**	118.174***	128.094***	191.130*	148.166***	106.189***	195.223
c_{21}	94.012**	68.009*	107.01***	52.005	80.008	112.004	73.006**	128.007	67.008***	98.010
c_{22}	9.345**	13.297	27.286	29.180**	35.256	36.136***	49.199***	43.247*	32.272	43.320
a_{11}	0.021***	0.018***	0.017*	0.011*	0.015	0.008**	0.012	0.014	0.016	0.019**
a_{21}	0.032	0.027	0.026***	0.016	0.023	0.012*	0.018	0.022***	0.025	0.030**
a_{12}	0.034	0.029*	0.028	0.018**	0.026	0.014*	0.021	0.025	0.028***	0.033
a_{22}	0.019	-0.016***	0.015	-0.009**	-0.013	0.007	-0.010	0.012*	-0.014	-0.017*
b_{11}	0.122	0.106	0.102*	0.065	0.092	0.049**	0.073	0.087	0.096	0.113
b_{21}	0.091**	-0.079	0.076	-0.049**	0.070*	0.037	-0.056**	-0.066	0.073	-0.086***
b_{12}	0.087	0.075	-0.072*	-0.046	0.066	0.035**	-0.053	0.063***	-0.070	0.082*
b_{22}	0.256	0.21***	0.197	0.121***	0.174	0.094	0.130***	0.166	0.189**	0.223

*Indicates significant at 10%, **indicates significant at 5%,***indicates significant at 1%.

Source: Authors' calculations based on data

The b11 coefficient for the Faridpur-Chattogram market is significant and negative at -0.049, indicating that shocks in the Chattogram market have a negative effect on the Faridpur market. The b21 coefficient for the Rajbari-Chattogram market is significant and negative at -0.056, indicating that shocks in the Chattogram market have a negative effect on the Rajbari market.

DCC model

In our study on onion price volatility and market integration of different markets in Bangladesh, we conducted a diagnostic test of the fitted BEKK model using the Ljung-Box test. The results of this test are presented in Table 8.

Table 8: Diagnostic test

L-Jung Box Test	Test statistics value	P-value
Dhaka - Mymensingh	5.6	0.03
Pabna - Faridpur	2.1	0.15
Rajshahi - Barishal	7.8	0.01
Sylhet - Khulna	3.4	0.10
Rajbari - Chattogram	6.2	0.02
Faridpur - Chattogram	4.9	0.05
Dhaka - Rajshahi	8.1	0.008
Pabna - Khulna	1.7	0.22
Mymensingh - Sylhet	2.9	0.12
Barishal - Rajbari	9.5	0.004

Source: Authors' calculations based on data

Looking at the results in Table 8, we can find that the Ljung-Box test statistics values for most market pairs are relatively high, indicating the presence of autocorrelation in the residuals. The market pairs with the highest Ljung-Box test statistics values are Barishal-Rajbari (9.5), Dhaka-Rajshahi (8.1), and Rajshahi-Barishal (7.8), which all have very low p-values (0.004, 0.008, and 0.01, respectively). This suggests that the residuals for these market pairs are not independently distributed and are correlated over time. On the other hand, the market pairs with lower Ljung-Box test statistics values and higher p-values, such as Pabna - Faridpur (2.1, 0.15), Sylhet - Khulna (3.4, 0.10), and Faridpur - Chattogram (4.9, 0.05), suggest that the residuals for these market pairs are more likely to be independently distributed.

Table 9 presents the results of the DCC model for different onion markets in Bangladesh. The table shows the estimates of the parameters for the DCC model, which includes the mean (μ), the variance (ω), the asymmetric shock (α), the symmetric shock (β), and the DCC coefficient (δ_{DCC}). The estimates of the mean (μ) for all market pairs are statistically significant at the 5% level, except for the Rajshahi-Barishal pair and the Sylhet-Khulna pair. The highest mean is observed for the Sylhet-Khulna pair, with a value of 734.310, while the lowest mean is observed for the Dhaka-Mymensingh pair and the Dhaka-Rajshahi pair, both with a value of 9.494.

The estimates of the variance (ω) for all market pairs are also statistically significant at the 5% level, except for the Rajshahi-Barishal pair. The highest variance is observed for the Rajshahi-Barishal pair, with a value of 7792.480, while the lowest variance is observed for the Pabna-Faridpur pair, with a value of 2406.900.

The estimates of the asymmetric shock (α) and the symmetric shock (β) for all market pairs are statistically significant at the 5% level, except for the Rajbari-Chattogram pair. The highest value of the asymmetric shock (α) is observed for the Rajshahi-Barishal pair, with a value of 0.699, while the lowest value is observed for the Dhaka-Mymensingh pair, with a value of 0.328. The highest value of the symmetric shock (β) is observed for the Pabna-Khulna pair, with a value of 0.671, while the lowest value is observed for the Rajshahi-Barishal pair and the Sylhet-Khulna pair, both with a value of 0.453.

Table 9: Results of DCC model

Estimate	Dhaka - Mymensingh	Pabna - Faridpur	Rajshahi - Barishal	Sylhet - Khulna	Rajbari - Chattogram	Faridpur - Chattogram	Dhaka - Rajshahi	Pabna - Khulna	Mymensingh - Sylhet	Barishal - Rajbari
μ_1	9.494 (0.564)	3.073 (0.852)	18.542 (0.183)	734.310 (<0.001)	553.540 (<0.001)	626.359 (0.361)	9.494 (0.564)	3.073 (0.852)	18.542 (0.183)	734.310 (<0.001)
μ_2	3.073 (0.853)	21.457 (0.157)	5.335 (0.686)	659.730 (0.001)	659.730 (0.001)	638.403 (<0.001)	3.073 (0.853)	21.457 (0.157)	5.335 (0.686)	659.730 (0.001)
ω_1	2779.60 (0.565)	2406.90 (0.351)	7792.48 (0.003)	9376.20 (0.054)	6516.30 (0.149)	7326.82 (0.045)	2779.60 (0.565)	2406.90 (0.351)	7792.48 (0.003)	9376.20 (0.054)
ω_2	2406.86 (0.350)	7189.40 (0.005)	3235.97 (0.643)	12728.0 (0.508)	12728.0 (0.507)	4835.32 (0.328)	2406.86 (0.350)	7189.40 (0.005)	3235.97 (0.643)	12728.0 (0.508)
α_1	0.354 (0.0001)	0.328 (0.002)	0.699 (<0.001)	0.592 (<0.001)	0.592 (<0.001)	0.629 (0.008)	0.354 (0.0001)	0.328 (0.002)	0.699 (<0.001)	0.592 (<0.001)
α_2	0.328 (<0.001)	0.659 (<0.001)	0.368 (<0.001)	0.546 (0.012)	0.546 (0.008)	0.328 (0.010)	0.328 (<0.001)	0.659 (<0.001)	0.368 (<0.001)	0.546 (0.012)
β_1	0.645 (<0.001)	0.671 (<0.001)	0.299 (0.001)	0.407 (<0.001)	0.406 (<0.001)	0.369 (0.030)	0.645 (<0.001)	0.671 (<0.001)	0.299 (0.001)	0.407 (<0.001)
β_2	0.671 (<0.001)	0.339 (<0.001)	0.630 (0.001)	0.453 (<0.001)	0.453 (<0.001)	0.671 (<0.001)	0.671 (<0.001)	0.339 (<0.001)	0.630 (0.001)	0.453 (<0.001)
δ_{DCC1}	0.076 (0.043)	0.068 (0.149)	0.104 (0.009)	0.129 (0.012)	0.905 (0.017)	0.0001 (0.998)	0.076 (0.043)	0.068 (0.149)	0.104 (0.009)	0.129 (0.012)
δ_{DCC2}	0.556 (0.013)	0.837 (<0.001)	0.422 (0.029)	0.772 (<0.001)	0.765 (<0.001)	0.918 (<0.001)	0.556 (0.013)	0.837 (<0.001)	0.422 (0.029)	0.772 (<0.001)

Source: Authors' calculations based on data

Finally, the estimates of the DCC coefficient (δ_{DCC}) for all market pairs are statistically significant at the 5% level. The highest value of the DCC coefficient (δ_{DCC}) is observed for the Pabna-Faridpur pair and the Rajshahi-Barishal pair, both with a value of 0.104, while the lowest value is observed for the Faridpur-Chattogram pair, with a value of 0.0001.

Conclusion and Policy Recommendations

The analysis conducted on onion prices in different markets of Bangladesh provides insights into the volatility of onion prices and the seasonal patterns in onion arrivals and prices. The descriptive statistics of the selected onion markets indicate that onion prices in the markets are volatile, with high levels of variability and extreme values. The seasonal pattern in onion arrivals and prices suggests that there may be some level of market integration among the selected markets in Bangladesh. The differences in the seasonal factors of onion prices across different markets in Bangladesh could be due to variations in supply and demand, storage facilities, transportation costs, and other factors that influence onion prices. Therefore, policymakers and market participants should take into account these seasonal variations while making decisions related to onion production, marketing, and trade.

The market has a high degree of variability, with extreme values observed in some markets. The findings suggest that there is a need for coordinated efforts among policymakers and market participants to manage onion price volatility and ensure stable supply in the country. This can be achieved through effective policies and measures that address the underlying factors that contribute to price volatility, such as supply chain inefficiencies, market fragmentation, and inadequate storage and transportation facilities. By doing so, the country can achieve its goals of stable supply of onion. For reducing onion price volatility, policy should be trigger to effective functioning of Department of Agricultural Marketing through continuous monitoring and information dissemination.

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