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Market Dynamics of Indian Apple: Assessing Integration with Global Importers

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ABSTRACT

The study was conducted at the Division of Agricultural Economics and Agri-business Management, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India during June, 2023 to study the market dynamics of Indian apples to assess the integration of prices with major importing countries at global level. Utilizing the data gathered from reliable secondary sources such as the United Nations Commodity Trade Statistics Database (UNComtrade) and the Agricultural and Processed Food Products Export Development Authority (APEDA) Agri-exchange, the research employed a cross-correlation formula to analyze the strength of price integration across markets. The findings revealed a significant degree of integration between Jammu and Kashmir apple market and that of Iran during peak harvesting periods indicating strong trade linkages and synchronized price movements. A considerable level of integration was also identified with the United Arab Emirates (UAE). In contrast, relatively weaker linkages were observed with Kuwait, Bangladesh and Nepal possibly attributed to lower trade intensity, logical constraints and temporal mismatch in demand and supply. At the aggregate level, Indian apple markets demonstrated strong integration with all major apple importing countries as the overall average apple prices in India exerted a substantial influence on the markets of these countries, indicating a robust and mutually beneficial relationship. The study concluded that strengthening market intelligence systems, improving supply chain efficiency and enhancing export quality standards would further augment India's competitiveness and position in global apple trade.

KEYWORDS: Apple, market integration, cross-correlation formula, price integration

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1. INTRODUCTION

Agricultural market integration plays a crucial role in enhancing economic efficiency, ensuring better price transmission and improving welfare outcomes for producers and consumers (Zafar et al., 2020; Baruah, 2022). It reflects the extent to which spatially dispersed markets are linked through the transmission of price signals, trade flows and information exchange. In an increasingly globalized agri-food system, understanding market integration has become essential for assessing the performance of agricultural markets and designing effective policy interventions (Borsellino etal., 2020). Price integration, a key dimension of market integration, indicates the degree and speed at which price changes in one market are transmitted to others. Often called price transmission, it captures whether and how quickly a price change in one market is reflected in another and is a standard proxy for market integration and efficiency (Cramon-Taubadel and Goodwin, 2021). Under the Law of One Price, perfectly integrated markets exhibit price differences no larger than transaction costs; shocks in one market are transmitted quickly and completely to others (Kidane, 2022). Efficiently integrated markets facilitate arbitrage, reduce regional price disparities and enhance resource allocation (Roman etal., 2024; Tomal and Gumieniak,2020). Researchers such as Ghosh (2010), Kar et al. (2004), Ahmad and Singla (2017), Yogisha (2010) and Reddy et al. (2012) have extensively explored agricultural market integration in India to understand the extent to which different agricultural markets are linked. In recent years, the scope of such research has extended to applying advanced econometric techniques such as cointegration and vector error correction models to examine spatial and vertical price linkages across agricultural markets (Paul and Karak, 2022; Ikhsan et al., 2024; Mishra etal., 2025; Jambagi etal., 2025). Horticultural commodities, particularly fruits, present unique challenges and opportunities in the context of market integration due to their perishability, seasonality and sensitivity to logistics and infrastructure. Among these, apples constitute a major high-value crop in India, especially in the Union Territory of Jammu and Kashmir, which contributes significantly to national production and rural livelihoods (Anonymous, 2022). The apple economy plays a pivotal role in income generation, employment and export earnings in the region, making it imperative to understand its market dynamics (Wani et al., 2021; Manzoor, 2017). Despite a growing body of literature on agricultural market integration, limited attention has been paid to the integration of Indian apple markets with global importing countries. The existing literature on apple market integration in India presents divergent findings. For instance, Deodhar et al. (2005) reported incomplete integration across wholesale apple markets, indicating the presence of price disparities arising from factors such as high transportation costs, regional demand–supply imbalances and structural inefficiencies. In contrast, Kar et al. (2004) observed strong integration among major metropolitan markets, suggesting efficient price transmission and inter-market linkages. Similarly, Beag and Singla (2014) identified significant integration across key wholesale markets highlighting improved market connectivity. These divergent findings indicate the lack of consensus regarding the extent of apple market integration in India and point to the need for a more comprehensive and updated analysis, particularly in the context of evolving market structures and increasing global trade linkages. Besides, no such study has been done for the UT of J&K, the region which is the highest contributor to apple production in the country. In this context, the present study extends its scope internationally to assess the degree of market integration between apple markets in J&K, India and its major importing countries to contribute to a deeper understanding of apple market dynamics and support evidence-based decision-making in the horticultural sector. Furthermore, such analysis can provide valuable insights for policymakers and stakeholders in improving market efficiency, strengthening export competitiveness and enhancing farmer incomes.

2. MATERIALS AND METHODS

The study was conducted during the month of June of the year 2023 to study the market dynamics of Indian apples to assess price integration with major importing countries at global level.

2.1. Data collection

To achieve the goals of this study, pertinent data was exclusively gathered from secondary sources including National Agriculture Market (e-NAM) and the United Nations Commodity Trade Statistics Database (UN Comtrade).The data of monthly apple prices, obtained for the market of J&K (from e-NAM) and major importers of apple from India (from UN Comtrade) was analysed for the period of 5 years i.e., from 2018 to 2022. Conversely, the monthly price data for the Indian markets with major import markets (both from UN Comtrade) of the world was scrutinized over a broader timeframe of 10 years, spanning from 2013 to 2022.

2.2. Research formulas

In conducting the study, the top 5 importers of apples from India in the year 2023 were integrated. These importers comprised Kuwait, Iran, Bangladesh, United Arab Emirates (UAE) and Nepal. Monthly average prices from the fruit markets in each of these countries, as well as the markets of Jammu and Kashmir and India, were compiled to assess the level of trade dependency on the markets of these countries.

The analysis employed the formula as under,

$$r_{x1}\, k_{x2}=\frac{\sum_{t=1}^{n}(X_{1t}-\overline{X}_1)\,(X_{2t-k}-\overline{X}_2)}{\sum_{t=1}^{n}\{(X_{1t}-X_1)^2\,(X_{2t-k}-\overline{X}^2)^2\}}$$

Where,

$$(\overline{X}_1)=\sum_{t=1}^{n}\frac{X_{1t}}{n} \text{ and } \overline{X}_2=\sum_{t=1}^{n}\frac{X_{2t}}{n}$$

n=Number of observations

K=Length of lag

X_1=Detrended price series of market 1, i.e. domestic prices

X_2=Detrended price series of market 2, i.e. prices of the comparative market

r_{x1x2}=Cross correlation between two series of prices of market 1 and market 2.

3. RESULTS AND DISCUSSION

3.1. Cross-correlation between J&K market and markets of major apple importers from India for the period of 2018-2022

The cross-correlation analysis between the Jammu and Kashmir market (i.e., Narwal Fruit and Vegetable Market, Jammu) and the markets of individual importing countries was presented in Table 1. The table encompassed the cross-correlation values for the market of each importing nation in relation to that of Jammu and Kashmir. The calculations were conducted for various lag orders, ranging from −14 to 14. Lag order zero signified the starting point of the analysis, corresponding to the month of January. It is important to note that negative and positive values in the lag orders denoted the months preceding and following the commencement month (i.e., January), respectively. Furthermore, both positive and negative values were observed in the cross-correlation. Positive values indicated a direct relationship between apple prices for a given month, suggesting that an increase (or decrease) in prices in one market was associated with a similar movement in the integrated market. In contrast, negative values indicated an inverse relationship, implying that a decrease in prices in one market corresponded to an opposite movement in the associated market.

3.1.1. Cross correlation: J&K and Kuwait

To comprehend the cross-correlation between the markets of Jammu and Kashmir and Kuwait, an autocorrelation test was executed across various lag orders, both backward and forward. The graphical representation of this analysis was illustrated in Figure 1. The absence of any values beyond the predefined bandwidth range of 0.25 to −0.25 suggested a lack of significant correlation between the two markets during the studied timeframe. The highest positive correlation values, lying close to the bandwidth limits, were observed at lag order zero (0.210) and lag order −11 (0.225). However, given the substantial 11-month time difference for examining price fluctuations, the closest and highest cross-correlation value was considered. Additionally, the minimal negative cross-correlation value was identified at lag order −9 (−0.001), a finding that was consistent with both Table 1 and Figure 1.

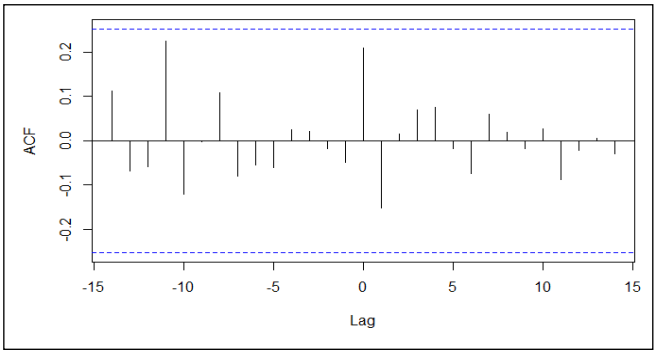

Figure 1: Cross-correlation between J&K and Kuwait

3.1.2. Cross correlation: J&K and Iran

On examining the market integration between Jammu and Kashmir and Iran through autocorrelation analysis, it was observed that the value lying outside the bandwidth range was identified at lag order −3, measuring 0.440, as depicted in Figure 2. A positive cross-correlation value of 0.440 at lag order −3 indicated a significant positive correlation, particularly in October, three months prior to January. Conversely, the least negative cross-correlation occurred at lag order −1, with a value of −0.005. The insights drawn from both Figure 2 and Table 1 suggested a substantial influence between the apple prices in these two markets, particularly during the month of October. The peak correlation value in October was attributed to the fact that this month witnessed the highest influx of apples into the Jammu and Kashmir market, consequently resulting in increased exports during this period.

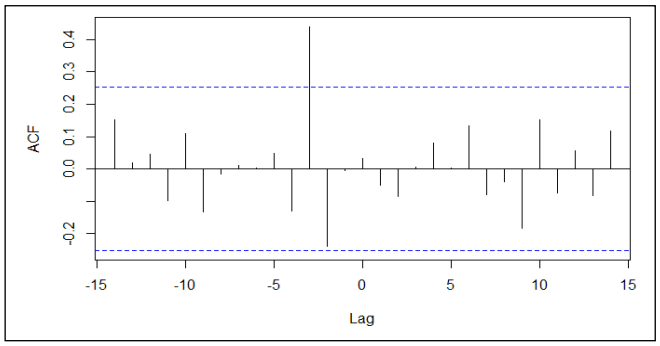

Figure 2: Cross-correlation between J&K and Iran

3.1.3. Cross correlation: J&K and Bangladesh

In assessing the correlation between the markets of Jammu and Kashmir and Bangladesh, results akin to those observed with Kuwait were identified. No value exceeded the established bandwidth range, indicating a lack of substantial

Table 1: Cross-correlation between the J&K market and the markets of major apple importers from India for the period of 2018–2022

Lag orders	Cross-correlation value				
	Kuwait	Iran	Bangladesh	UAE	Nepal
-14	0.112	0.153	-0.171	-0.449	-0.071
-13	-0.069	0.020	-0.038	0.266	0.112
-12	-0.059	0.045	-0.062	-0.135	0.011
-11	0.225	-0.098	0.126	-0.001	0.053
-10	-0.121	0.108	0.032	0.057	0.034
-9	-0.001	-0.132	0.020	-0.045	0.141
-8	0.108	-0.016	0.110	0.017	-0.053
-7	-0.079	0.011	-0.026	-0.024	-0.017
-6	-0.055	0.002	-0.019	0.153	-0.114
-5	-0.060	0.048	-0.026	-0.154	-0.063
-4	0.026	-0.130	-0.019	0.084	-0.191
-3	0.022	0.440	-0.054	-0.050	0.184
-2	-0.018	-0.240	-0.141	0.000	-0.117
-1	-0.049	-0.005	-0.037	-0.109	0.121
0	0.210	0.032	0.103	0.072	0.087
1	-0.151	-0.051	0.067	0.046	0.074
2	0.016	-0.085	0.034	-0.061	0.048
3	0.070	0.005	0.186	0.086	-0.184
4	0.075	0.081	0.047	-0.043	0.165
5	-0.017	0.003	-0.068	0.124	0.007
6	-0.075	0.134	0.017	-0.297	-0.012
7	0.060	-0.079	-0.080	0.303	-0.187
8	0.018	-0.039	-0.068	-0.162	0.127
9	-0.018	-0.184	-0.025	0.276	-0.085
10	0.028	0.152	-0.028	-0.269	-0.029
11	-0.087	-0.075	-0.015	0.195	0.096
12	-0.022	0.057	0.006	-0.164	-0.002
13	0.006	-0.081	0.015	0.026	-0.093
14	-0.029	0.117	0.111	-0.029	0.060

*For raw data, refer to Appendix 1

correlation, as illustrated in Figure 3. However, the highest positive cross-correlation value, closest to the bandwidth range, was noted at lag order 3, measuring 0.186. In contrast, the lowest value was recorded for lag order 11 at -0.015, a finding consistent with the information presented in Table 1.

3.1.4. Cross correlation: J&K and UAE

To measure the correlation between the market of Jammu and Kashmir and the UAE, an autocorrelation factor analysis was conducted, the corresponding plot of which was depicted in Figure 4. The values for various lag orders fell outside the predetermined bandwidth range. These included a value of 0.303 for lag order 7, 0.276 for lag order 9, -0.297 for lag order 6, -0.269 for lag order 10, 0.266 for lag order -13 and -0.449 for lag order -14. Analysis from both Table 1 and Figure 4 revealed that the highest positive cross-correlation occurred during the seventh month following January, i.e., in August. Additionally, the least negative

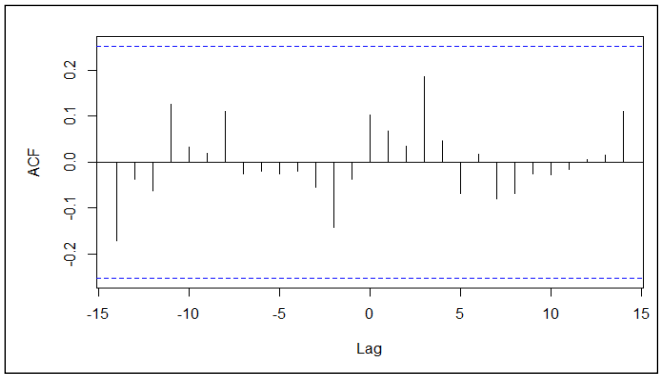

Figure 3: Cross-correlation between J&K and Bangladesh

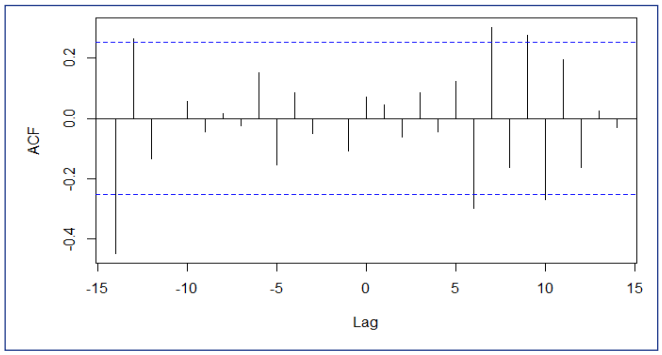

Figure 4: Cross-correlation between J&K and UAE

correlation value was observed for lag order -11, registering at -0.001. This could be a result of the fresh arrivals of apples in the Jammu and Kashmir market during August. Given that this was an off-season for apples in India which led to exports to countries like the UAE in accordance with the demand pattern.

3.1.5. Cross correlation: J&K and Nepal

In an effort to check the price relationship between the market of Jammu and Kashmir and Nepal, the autocorrelation factor was computed, and the results are presented in Table 1 and Figure 5. In this scenario, no value for any lag order exceeded the bandwidth range, indicating a lack of significant correlation between the two markets. Nevertheless, the highest positive cross-correlation value was identified at lag order -3, measuring 0.184, while the least negative cross-correlation value occurred at lag order 12, registering at -0.002.

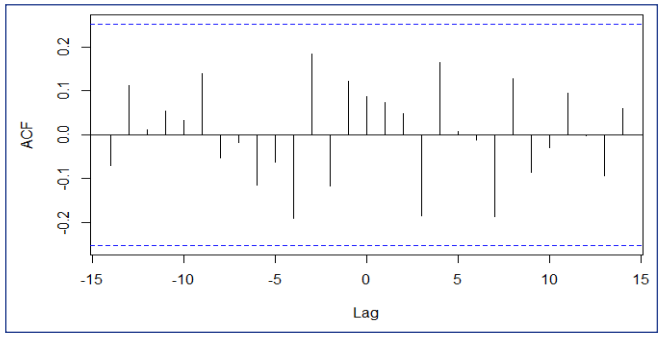

Figure 5: Cross-correlation between J&K and Nepal

3.2. Cross-correlation between Indian markets and markets of major apple importers from India for the period of 2013–2022

As the cross-correlation tests were performed for J&K and major import markets, similar pattern was followed to understand the price association between the Indian markets on the whole with the top countries importing apples from India. The cross-correlation values were tabulated in Table 2 along with the graphical representation of each one of them

3.2.1. Cross correlation: India and Kuwait

Upon conducting an autocorrelation factor test for various lag orders ranging from -14 to 14 between the Indian apple markets and Kuwait, the only value that fell within the predefined bandwidth range of -0.25 to 0.25 was for lag order -4, measuring 0.273, as depicted in Figure 6. The finding indicated a significant degree of cross-correlation between the markets of the two nations, particularly during the month of September, which was 4 months preceding lag order zero, i.e., the month of January. Thus, it could be inferred from Table 2 and Figure 6 that the highest positive cross-correlation value occurred at lag order -4, while the least negative value was observed for lag order -6, amounting to -0.012. This situation was attributed to the significant arrival of apples in the Indian markets during the month of September. As this period did not coincide with peak domestic demand, the surplus produce was exported to countries like Kuwait, where there was a demand for apples during this specific timeframe.

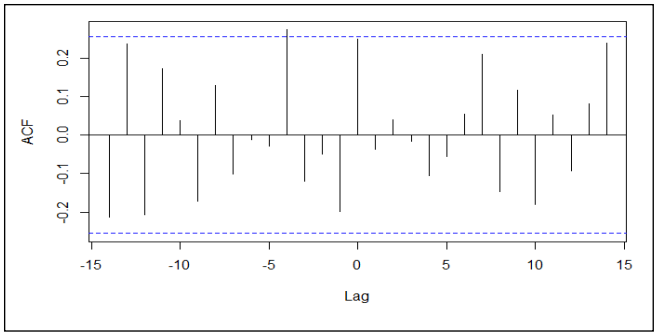

Figure 6: Cross-correlation between India and Kuwait

3.2.2. Cross correlation: India and Iran

The autocorrelation factor was used to assess the level of price dependency between the Indian market and that of Iran and the results were summarized in Figure 7 and Table 2, revealing two values, one for lag order zero and the other for lag order -11, exceeding the bandwidth range. Among these, the value for lag order zero, at 0.304, was deemed more relevant as it reflected instantaneous fluctuations in apple prices between the two markets without any time lag.

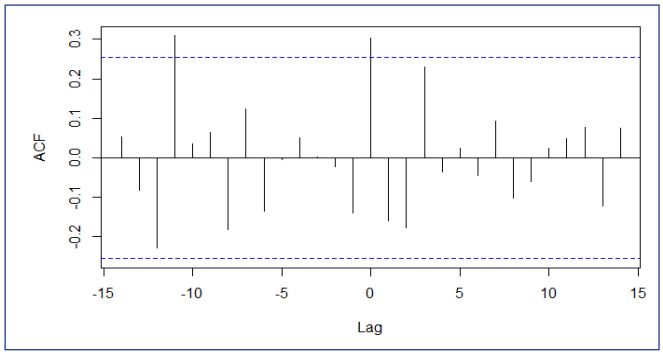

Figure 7: Cross-correlation between India and Iran

Additionally, the minimum amount of negative correlation was observed for lag order -5, with a value of -0.004.This might have resulted from the prompt export of apples to Iran as soon as they became available in the Indian markets, underscoring the evident popularity and demand for Indian apples in the region.

3.2.3. Cross correlation: India and Bangladesh

Regarding the cross-correlation values between India and Bangladesh after the autocorrelation test, the analysis in Table 2 and Figure 8 revealed that while three values, corresponding to lag orders -7, -12, and -13, exceed the bandwidth range, the value for lag order -7 (0.273), being the closest to lag order zero, was considered. This suggested that it took approximately seven months for price effects to manifest in the corresponding market, indicating better market integration in June, seven months before January. Additionally, the minimum cross-correlation value was observed for lag order 11 at -0.026, signifying minimal correlation during that particular month. The outcome of this correlation analysis indicated that our apples were exported to the markets of Bangladesh during the off-season period, specifically in the month of June.

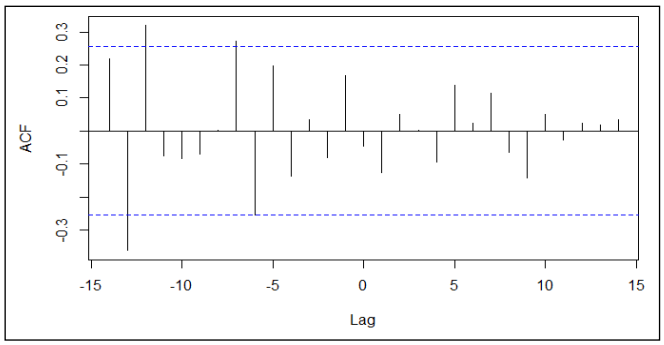

Figure 8: Cross-correlation between India and Bangladesh

3.2.4. Cross correlation: India and UAE

The cross-correlation formula was applied to the average monthly apple prices for the markets of India and the UAE during the studied time frame and the resulting autocorrelation factor plot was depicted in Figure 9. The

Table 2: Cross-correlation between Indian markets and markets of major apple importers from India for the period of 2013-2022

Lag orders	Cross-correlation value				
	Kuwait	Iran	Bangladesh	UAE	Nepal
-14	-0.213	0.053	0.219	-0.051	-0.095
-13	0.237	-0.082	-0.362	-0.109	0.093
-12	-0.206	-0.228	0.319	0.218	-0.297
-11	0.172	0.309	-0.074	-0.129	0.038
-10	0.037	0.036	-0.084	0.148	0.110
-9	-0.172	0.063	-0.070	-0.167	0.097
-8	0.128	-0.182	0.002	-0.039	-0.029
-7	-0.101	0.125	0.273	0.132	0.011
-6	-0.012	-0.135	-0.255	-0.042	-0.116
-5	-0.028	-0.004	0.197	0.078	-0.109
-4	0.273	0.051	-0.136	-0.036	0.035
-3	-0.119	0.003	0.034	0.014	0.268
-2	-0.049	-0.022	-0.080	-0.094	-0.024
-1	-0.198	-0.140	0.168	-0.145	-0.226
0	0.248	0.304	-0.045	0.300	0.044
1	-0.038	-0.159	-0.127	-0.095	-0.001
2	0.039	-0.176	0.049	0.027	0.022
3	-0.017	0.231	0.001	-0.110	0.117
4	-0.105	-0.035	-0.095	0.044	-0.005
5	-0.055	0.025	0.139	0.033	-0.034
6	0.054	-0.043	0.023	0.001	-0.174
7	0.209	0.094	0.114	0.008	0.064
8	-0.147	-0.101	-0.064	0.036	0.142
9	0.117	-0.059	-0.142	-0.056	-0.030
10	-0.180	0.025	0.050	-0.066	0.036
11	0.052	0.048	-0.026	0.130	-0.056
12	-0.093	0.077	0.025	-0.133	-0.011
13	0.082	-0.122	0.019	0.142	-0.170
14	0.238	0.076	0.034	-0.057	-0.005

*For raw data, refer to appendix 2

cross-correlation value beyond the bandwidth range was observed for lag order zero, measuring 0.300. This signified an immediate, strong and positive correlation between the markets of both nations. Conversely, the minimum cross-correlation value was noted for lag order -4, with a value of -0.036, as confirmed by Table 2. An instant, robust and positive correlation between the markets of both nations could potentially be because of the substantial demand for

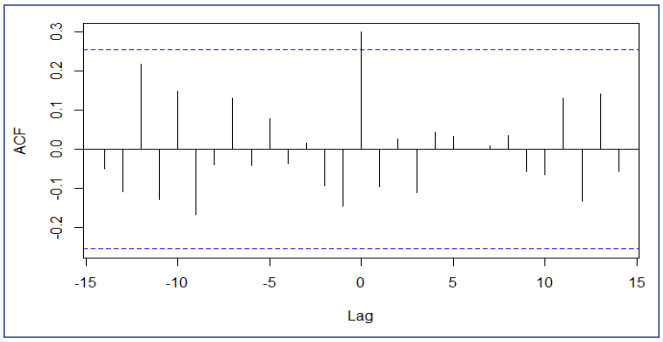

Figure 9: Cross-correlation between India and UAE

Indian apples in the UAE, where India served as a primary apple supplier.

3.2.5. Cross correlation: India and Nepal

The autocorrelation factor test, conducted to understand the extent of the price relationship between Indian markets and those of Nepal was illustrated in Figure 10 and summarized in Table 2. The findings revealed that the highest positive cross-correlation occurred in October, as the correlation value for lag order -3 exceeded the specified bandwidth range at 0.268. On the other hand, the lowest level of integration was observed for lag order 1, i.e., during February, with a value of -0.001. The highest correlation value observed in October could be a result of the substantial arrival of apples into the Indian market during this month, subsequently leading to increased exports within the same period.

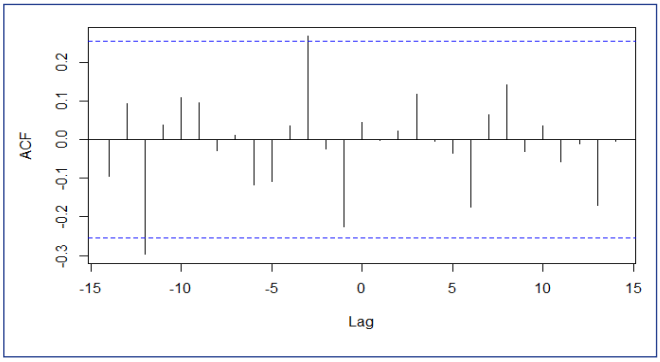

Figure 10: Cross-correlation between India and Nepal

The cross-correlation analysis between the Jammu and Kashmir apple market and the selected importing countries revealed varying degrees of market integration, which can be primarily attributed to differences in trade intensity, seasonal supply patterns and demand alignment. A relatively strong and significant positive correlation observed with Iran, particularly during the peak harvesting period (October), indicated that increased arrivals in the domestic market were closely associated with higher export flows and corresponding price movements in the importing market. The findings were consistent with the results of Bharodia et al. (2025), where strong interdependence between domestic and international fruit markets was found due to active trade linkages. Similarly, the results aligned with Sharma et al. (2021), who confirmed co-integration and interdependence among major apple markets.

In contrast, weak or insignificant correlations observed for countries such as Kuwait, Bangladesh and Nepal indicated limited price transmission, which may be attributed to lower trade volumes, logistical constraints and temporal mismatches in demand and supply. These results were in line with Wani et al. (2015), where despite overall integration, certain market pairs exhibited lack of co-integration. Further, the presence of lagged and weak correlations also finds support from the study by Elalaoui et al. (2018). The findings reinforced the argument that market integration is not always linear and may vary depending on transaction costs, market frictions and trade barriers. Such variations had been supported by Cramon-Taubadel (2017).

At the aggregate level, Indian apple markets exhibited relatively stronger integration with major importing countries, particularly with Iran and the UAE, where significant correlations at or near zero lag indicated near-instantaneous price transmission. This suggested the presence of efficient market linkages and well-established trade relationships. Similar patterns of strong interdependence and bidirectional price transmission between domestic and international markets have been documented in fruit export studies by Bharodia et al. (2025). However, the presence of lagged correlations in the case of Kuwait, Bangladesh and Nepal reflected delayed price adjustments, which could be attributed to factors such as transportation time, storage constraints and seasonal demand variations. The higher correlations observed during peak arrival months (September–October) further emphasized the role of seasonal surplus in driving export-oriented price linkages, as increased market arrivals facilitated greater participation in international trade. These findings were consistent with Sharma et al. (2021). It was therefore, found that the markets may be integrated in the long run but short-run deviations and lagged adjustments were common due to structural and operational inefficiencies. Overall, the results indicated that while Indian apple markets maintained strong linkages with key importing countries, the degree of integration varied across destinations depending on trade intensity, demand synchronization and supply chain efficiency.

4. CONCLUSION

Apple cultivation was regionally concentrated, whereas consumption was dispersed nationwide. The study revealed a strong price correlation between Jammu and Kashmir and Iran, significant integration with the United Arab Emirates and comparatively weaker associations

with Kuwait, Bangladesh and Nepal. Indian markets exhibited substantial integration with major importing countries, reflecting stable trade linkages. The findings suggested diversifying export markets, enhancing quality to meet international standards and strengthening market information systems to enable efficient pricing, marketing, and distribution decisions.

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