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RESEARCH PAPER

Comparative Analysis of Apple Price Trends and Arrivals in Bilaspur Market and National-level Production Dynamics: A Decadal Perspective

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ABSTRACT

This study investigates decadal trends (2013–2024) in apple prices and arrivals in the Bilaspur market of Himachal Pradesh and compares them with national-level production and yield patterns from 1982 to 2023. Apple remains a cornerstone of temperate fruit cultivation in India, contributing significantly to rural incomes and the horticultural economy. Using analytical tools like the Compound Annual Growth Rate (CAGR) and the Cuddy-Della Valle Instability Index (CDVI), the study finds that apple prices in Bilaspur grew at a moderate CAGR of 0.82 per cent, but with high instability (CDVI 44.81%) in the overall period. In contrast, national production and yield exhibited steadier growth at 1.41 per cent and 3.50 per cent, respectively. Forecasts show Bilaspur prices may rise sharply to over ₹ 10023.36 per quintal by Q4 (Sep- Dec) of 2027, highlighting increasing market stress and supply-side challenges. The findings emphasize the urgent need for robust cold-chain infrastructure, timely policy support, and climate-adaptive strategies to manage seasonal volatility. This research offers actionable insights for producers, traders, and policymakers navigating India's evolving apple market.

HIGHLIGHTS

- This study focuses on instability and forecast patterns of apple prices in Bilaspur, alongside national-level production and yield trends (1982–2023).
- The high price instability was observed (CDVI 44.81%) in the overall period, whereas the Q2 and Q3 quarter reveals CDVI of 32.82 per cent, and 38.23 per cent indicating heightened volatility during the monsoon harvest period.
- Price forecasts suggest a steep rise, with Bilaspur apple prices expected to exceed ₹ 10023.36 per quintal by the end of 2027.

Keywords: Apple Bilaspur Market, CAGR trend, CDVI Instability, Forecasting, Seasonal Fluctuation, Apple Price Volatility

Apple (*Malus domestica*), a high-value temperate fruit crop, plays a pivotal role in India's horticultural economy due to its nutritional significance, market value, and substantial contribution to total fruit exports. It ranks among the top five fruits in terms of global production volume, following banana, watermelon, grapes, and oranges (FAOSTAT, 2022). Globally, India is among the top ten apple-producing countries, with Jammu & Kashmir, Himachal Pradesh, and Uttarakhand accounting for more than 90 per cent of the country's production, owing to their ideal agro-climatic conditions for apple cultivation (Sharma *et al.* 2021; NHB,

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2022). According to the Food and Agriculture Organization (FAO), India produced nearly 2.59 million tonnes of apples in 2022, cultivated over an area of 315,000 hectares, with the majority of the supply concentrated in the northern Himalayan belt (NHB, 2022).

Bilaspur, located in the state of Himachal Pradesh, is emerging as a regional trade center for fruits and vegetables in Central India. Although the region is not a traditional apple-producing zone due to its subtropical climate, the Bilaspur fruit market has become a key hub for the distribution and retail of apples sourced from Himachal Pradesh, Jammu & Kashmir, and Uttarakhand, particularly during peak demand seasons (Kumar & Mukherjee, 2024).. Its strategic location along major transportation routes such as NH-130 and the South-East Central Railway has made Bilaspur an advantageous site for fruit traders to stock, sell, and redistribute apples to neighboring districts.

The selection of Bilaspur for this study was driven by the availability of consistent market commodity arrival over the past decade (2013–2023) and its growing importance as a non-producing yet high-volume trading center. Moreover, the limited existing research on price and arrival patterns in central Indian apple markets presents a valuable opportunity to offer fresh insights. Studying Bilaspur enables an examination of consumer-end market dynamics, revealing how price fluctuations, supply bottlenecks, and seasonal trends affect retail apple markets in non-traditional production zones.

While localized market studies provide useful insights into regional price dynamics, comparing local market behavior with national trends offers a broader perspective on supply-demand imbalances, policy implications, and logistical inefficiencies within India's apple trade system. This study investigates how fluctuations in national production volumes and yield patterns influence pricing and arrival trends in a secondary, consumption-heavy market like Bilaspur. The analysis incorporates price behavior, arrival instability, and forecasting using the Compound Annual Growth Rate (CAGR) and the Cuddy-Della Valle Instability Index (CDVI)—two well-established tools for assessing growth and volatility (Cuddy & Della Valle, 1978; More & Katkade, 2015). The study aims to uncover how micro-level market movements reflect or deviate from national trends, providing actionable insights for price policy formulation, supply chain resilience, and strategic planning in India's apple market.

OBJECTIVE

This study was conducted for the period 2013 to 2024 using purely secondary data collected from the Bilaspur market in Himachal Pradesh. The data was sourced from the official agricultural marketing website agmarknet.gov.in. To provide a comparative framework and evaluate broader market dynamics, the study also incorporates national-level data on apple production, area, and yield from 1982 to 2022. This macro-level dataset, obtained from FAOSTAT and national horticultural statistics, serves as a benchmark to understand how local market trends align with or diverge from national production patterns over time.

The primary focus of the study is on apple prices, with data analyzed on a quarterly basis: January–March (Q1), April–June (Q2), July–September (Q3), and October–December (Q4). The Bilaspur market was purposively selected based on its significance in apple trading within the region, being characterized by high prices and substantial arrivals. Bilaspur is recognized as one of the prominent markets in the major apple-producing state of Himachal Pradesh, India.

The research aims to achieve the following objectives:

1. **Examine Price Trends**: Analyze the area, production, yield, and price arrivals of apple to identify long-term growth patterns and seasonal fluctuations.
2. **Assess Market Instability**: Evaluate the volatility of area, production, yield, and prices using statistical tools such CV and CDVI to identify underlying causes.
3. **Forecast Future Prices**: Project future production and yield (2024–2030) and price arrivals (2025–2026) using a linear trend model, offering strategic insights for farmers, marketers, and policymakers.

MATERIALS AND METHODS

The compound annual growth model was used to examine the growth of area, production and yield of Apple also price arrival in the market Bilaspur. CAGR predicted the size of the change in the variable under investigation per unit of time, as well as the variable's tendency to rise, decrease, or stay the same over time.

Compound Annual Growth Rate

The compound growth rate was analyzed by using exponential growth function as given below

$$Y = ab^t \quad \ldots(1)$$

Where,

Y = Area / Production/Yield / Price arrivals of apple

t = Time variable

b = Regression coefficient

a = Intercept

Equation (1) will be converted into the natural logarithmic form in order to facilitate the use of linear regression. Taking logarithms on both sides we obtain,

$$Log\ Y = Log\ a + t\ Log\ b$$

The compound growth rates 'r' was computed by using the formula

$$CGR\ (r) = [Antilog\ (log\ b) - 1] * 100$$

Where, r = Compound growth rate

Instability Index

Instability in export is expected to hamper the process of economic development. The degree of instability in of area, production, yield and price arrivals was measured by using the coefficient of variation. The standard deviation as a percentage of mean is called the coefficient of variation.

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

Where,

σ = Standard deviation

$$\sigma = \sqrt{\frac{\Sigma\left(X - \underline{X}\right)^2}{n}}$$

$\overline{x}$ = Arithmetic mean

To examine the extent of variation and risk involved in prices, the instability index is calculated using the Cuddy-Della Valle approach.

$$CDVI = CV \times \sqrt{\left(1 - R^2\right)}$$

Where $CDVI$ is the Cuddy-Della Valle instability index in percent, CV is the coefficient of variation in percent and is the coefficient of determination from a time-trend regression. The estimating index value is a close approximation of the average variation in annual prices which is adjusted for trend.

Casual Model Approach – Linear Trends – Forecasting

The most widely used method of fitting trend lines to time series data is the method of least squares. The problem of fitting a least squares line $Y' = a + bx$ is essentially that of b for a given set of data and make $\Sigma\ (y - y')^2$ as small as possible and the problem either by solving the two equation.

$$\Sigma y = na + b\ (\Sigma x)$$

$$\Sigma xy = a(\Sigma x) + b(\Sigma x)^2$$

Y'= Predicted value of the dependent variable Y

x = Independent variable (typically time)

a = Intercept (value of Y when X = 0)

b = Slope of the trend line (rate of change in Y per unit change in X)

Alternatively, the values of a x and b can be determined by

$$a = \frac{(\Sigma y)\left(\Sigma x^2\right) - (\Sigma x)(\Sigma xy)}{n\left(\Sigma x^2\right) - (\Sigma x)^2}$$

$$b = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{n\left(\Sigma x^2\right) - (\Sigma x)^2}$$

In a time series, however the x's practically always refer to successive periods (usually years). In this case, the problem of fitting a trend line by the method of least squares can be simplified considerably by performing the following change of scale (coding).Letting x be the variable which measures time and taking the origin (the zero) of the new scale at the middle of series that is, at the middle of x's, we number of years (or other periods) so that in new scale $\sum x = 0$. If the series has an odd number of years,we assign $x = 0$ to the middle year and number of years ……, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ………………… If the series has an even number of years, there is no middle year, and we assign successive years the numbers …. -7, -6, -5, -4, -3, -2, -1, 1, 2, 3, 4, 5, 6, 7, ……., with -1 and 1 assigned to the two middle of years. This kind of coding makes $\sum x = 0$ and substituting this into the formula given earlier, the a and b can be estimated as given below;

$$a = \frac{\Sigma y}{n} \text{ and } b = \frac{\Sigma xy}{\Sigma x^2}.$$

RESULTS AND DISCUSSION

India's apple sector has undergone significant transformation, demonstrating consistent expansion in both cultivated area and overall production between 1982 and 2023. Analysis of FAOSTAT data reveals a Compound Annual Growth Rate (CAGR) of 0.86 per cent for harvested area, 1.41 per cent for production, and a notable 3.50 per cent for yield. These figures underscore a pivotal shift in the sector's growth drivers, with productivity gains increasingly outpacing area expansion (Table 1). This evolution is largely attributed to the successful implementation of orchard rejuvenation programs and the adoption of high-density planting techniques across India's temperate apple-growing regions (Bhat & Choure, 2014; APEDA, 2021; Ali & Kachroo, 2020).

Over the four-decade period, India's apple production surged from 936,980 tonnes to 2,876,000 tonnes, while the land under cultivation expanded from 153,750 hectares to 304,000 hectares. This substantial growth indicates a clear trajectory toward more commercialized apple farming. Concurrently, yield exhibited a robust positive trend, increasing from 60,291 kg/ha to 946,05 kg/ha. This improvement reflects the integration of advanced technologies, superior apple varieties, and enhanced orchard management practices. Nevertheless, regional agro-climatic challenges and inherent climate variability continue to pose limitations on fully realizing potential yields (Gayak, B *et al*. 2020). These findings resonate with observations by Chapai *et al*. (2024), who highlighted a shift towards yield-centric growth in recent times, despite persistent threats from hailstorms, pest infestations, and extreme weather events in key producing states like Himachal Pradesh and Kashmir.

The table 2 examines the apple price trajectories in the Bilaspur market from 2013 to 2024 reveals pronounced seasonal asymmetries and annual fluctuations. Quarterly CAGR analysis indicates a mixed trend. Specifically, the third quarter Q3 (July–September) registered the highest positive CAGR of 4.60 per cent respectively. This period coincides with the peak harvest season in hill states, characterized by compressed supply chains and limited cold storage capacity, which collectively intensify pricing pressures (Guleria, A. *et al*. 2020).

Conversely, the Q1 quarter (January–March) and Q2 quarter (April–June) experienced negative growth rates of –3.4 per cent and –0.39 per cent, respectively, reflecting sluggish pricing trends. These quarters represent the lean season and post-winter market phases, during which residual cold storage supplies or competition from imported apples tend to weaken domestic prices (Kumar & Mukherjee, 2024). The Q4 quarter (October–December) showed a moderate growth rate of 2.50 per cent, influenced by the influx of fresh produce and market adjustments to early winter demand.

These quarterly divergences underscore the Bilaspur market's acute sensitivity to seasonal arrivals, pre-monsoon heat stress, and underlying supply chain inefficiencies. Furthermore, the data indicate non-uniform price volatility throughout the year, with Q3 quarter exhibiting both strong growth and high variance. This suggests that climatic and logistical bottlenecks amplify price fluctuations (Tshikororo, M. 2023). Such patterns are consistent with international observations that high-value perishable commodities, like apples, are susceptible to significant intra-annual price swings due to inadequate post-harvest handling infrastructure (Sharma & Guleria, 2020).

When compared to national trends, where the CAGR for overall production and yield stood at 1.41 per cent and 3.50 per cent respectively, the Bilaspur market demonstrates a disproportionately sharper response to short-term disruptions. This disparity highlights localized infrastructural constraints and fragmented market integration. The inherent price elasticity of apples, being a seasonal and premium-priced fruit, further magnifies market responses to supply fluctuations, rendering retail hubs like Bilaspur more vulnerable than production-centric regions. This behavior mirrors trends observed in other temperate fruit markets, where issues such as post-harvest handling, supply chain inefficiencies, and climate sensitivity distort pricing mechanisms (Hassan *et al*. 2022).

The quarter-wise analysis not only contextualizes temporal price behavior but also offers actionable insights for targeted policy interventions. For example, enhancing cold-chain infrastructure and promoting timing-based procurement strategies during Q3 quarter could significantly mitigate market instability and reduce price distortions for both producers and consumers. While national-level data indicates steady gains in productivity and gradual price increases, the Bilaspur market exhibits a more pronounced reaction to short-term shocks, reflected in its higher coefficient of variation (CV) in prices. This point to heightened local market sensitivity to micro-climatic events and infrastructural limitations. These observations align with international studies emphasizing the disruption in price transmission from farm-gate to retail in decentralized fruit markets (Chauhan & Kumar, 2023). Moreover, the elasticity of consumer demand for apples a premium priced, seasonal fruit amplifies local-level price instability, rendering markets such as Bilaspur more susceptible compared to the aggregated national supply scenario (Bharti & Devi, 2023).

Table 1: Growth rate of apple area, production and yield (1982 - 2023)

Year	Area harvested (ha)	Production (tonnes).	Yield (g/ha)
1982	153750	936980	60291
1983	161710	966600	59774
1984	164940	985900	59773
1985	168230	1005560	59773
1986	165000	1258000	76242
1987	178305	861404	48311
1988	185083	995296	51250
1989	186660	1084557	53776
1990	187198	1093900	58080
1991	193638	1175005	58435
1992	194561	1147743	60680
1993	191256	1165842	58991
1994	200000	1300000	61083
1995	210000	1200000	65000
1996	217099	1211379	57143
1997	222700	1308390	55798
1998	227680	1320590	58751
1999	230000	1380000	58002
2000	240000	1050000	59740
2001	250000	1230000	45652
2002	201200	1160000	48333
2003	23700	1470000	58800
2004	226600	1521600	75626
2005	252000	1739000	75379
2006	264000	1814000	80853
2007	274000	1624000	64444
2008	282900	2001000	75795
2009	289100	1985000	72445
2010	321900	1777200	62821
2011	312000	2891000	100000
2012	313040	2203400	68450
2013	319000	1915000	61378
2014	277000	2497680	79788
2015	305000	2134000	66897
2016	301000	2521000	91011
2017	308000	2265000	74262
2018	310000	2327000	77309
2019	313000	2316000	75195
2020	311000	2814000	90774
2021	315800	2276000	72716
2022	315000	2589000	82190
2023	304000	2876000	94605
CAGR	0.86%*	1.41%*	3.50%**
R^2	0.412158	0.845641	0.194601

Note: * *indicate significant of 1 per cent and* ** *indicate significant of 5 per cent level, respectively (Source: https://www.fao.org).*

Table 2: Growth rate of apple price arrivals at Bilaspur market (2013-2024)

Year	Jan-Mar (Q1)	Apr- Jun (Q2)	July-Sep (Q3)	Oct – Dec (Q4)
2013	—	—	2535.71	4867.34
2014	7851.85	6488.75	2757.14	4718.75
2015	7725.58	11262.5	3071.73	5052.5
2016	6928.57	10375	4768.5	5823.8
2017	12000	14000	10746.66	5738

2018	6993.1	14044.44	5395.55	5327.11
2019	6342.85	11611.11	5748.71	5446.42
2020	9266.66	10860	7829.26	7633.33
2021	9660.71	19961.53	8969.38	7720
2022	10445.45	15166.66	6463.41	5386.79
2023	6357.14	16000	8684.21	7162.96
2024	5366.72	6212.93	4350.68	6543.84
CAGR	-3.40%***	-0.39%***	4.60%**	2.50%**
R^2	0.021146	0.091391	0.270085	0.479081
Growth rate of apple price arrivals over all period (2014 to 2023)				
CAGR	0.82%***		R^2	0.0474

Note: *** indicate significant of 5 per cent and **** indicate significant of 10 per cent level, respectively (**Source:** https://agmarknet.gov.in), (Price arrivals in Rs/Quintal)*

Instability Analysis of Area, Production, Yield, and Market Prices of Apple

Understanding the inherent instability in apple production and market prices is paramount for shaping effective agricultural policies and empowering farmers with informed decision-making tools. This study quantifies instability using two key metrics: the Coefficient of Variation (CV) and the Cuddy-Della Valle Instability Index (CDVI). Both measures effectively capture fluctuations within time-series data while accounting for underlying deterministic volatility.

Table 3: Instability analysis of area, production, yield of Apple (1982-2022)

Particulars	Area Harvested	Production	Yield
Mean	256198.6	1652048	72005.02
Standard Deviation	121115.4	612018.8	38613.65
Coefficient of Variation	42.27	37.04	53.62
CDVI	36.24	14.55	48.12
Range	High	Low	High

The table 3 illustrates the instability analysis of apple cultivation metrics across India over four decades. Apple production emerged as the most stable parameter, exhibiting CV and CDVI values of 37.04 per cent and 14.55 per cent respectively. This significant year-to-year low variability is primarily attributed to predictable weather patterns, notably untimely snowfall and hailstorms in major apple-producing states like Himachal Pradesh and Jammu & Kashmir, alongside market shocks and pest outbreaks (Bairwa *et al*. 2012). These findings align with previous research on temperate fruit crops that also reported significant production contribution induce the low variability due to the climate mitigation practice and post harvest management. (Sharma *et al*. 2021; Wani *et al*. 2017).

Area harvested showed moderate to high instability, with CV and CDVI values of 42.27 per cent and 36.24 per cent respectively. This likely reflects shifts in farmer preferences, the adoption of high-density planting schemes, and land-use changes influenced by urbanization or the cultivation of competing crops. Whereas the yield instability, at 53.62 per cent of CV and 48.12 per cent of CDVI, also remained high, suggesting that while technological and varietal advances are underway, the impact of seasonal stressors and uneven resource distribution remains a challenge.

These results highlight that while area expansion has progressed unsteadily, production instability remains a significant concern. This underscores the critical need for adopting climate-resilient agronomic practices and expanding crop insurance coverage. Furthermore, enhancing post-harvest infrastructure and cold chain systems is crucial for mitigating losses caused by unseasonal climatic events (Singh *et al*. 2016).

Table 4: Instability of Apple price arrivals overall period (2013-2024)

Particulars	Mean	Standard deviation (SD)	Coefficient of variation (CV)	CDVI	Range
Modal price	7992.68	3670.21	45.91	44.81	High

At the overall market level, the modal average price of apples in Himachal Pradesh's Bilaspur market displayed a high degree of volatility. As detailed in Table 4, price instability was considerable, with CV and CDVI values reaching 45.91 per cent and 44.81 per cent respectively, over the study period. This observation is consistent with findings by More and Katkade (2015) and Naqash *et al*. (2017), who emphasize that perishability, seasonal oversupply (gluts), and inefficient price realization mechanisms are major contributors to volatility in horticultural markets. Fluctuations in supply, driven by climate variability in apple-producing states and persistent logistical challenges, further intensify price volatility. Moreover, the presence of imported apples during peak off-seasons, particularly from countries like the USA and Chile, exerts external pressure on domestic prices, amplifying instability (Sethi, *et al*. 2020). This high price variation directly impacts both farmer incomes and consumer affordability, making price stabilization a critical policy priority.

The findings of the research strongly advocate for improved market intelligence systems, transparent procurement mechanisms, and greater integration with forward markets to effectively reduce price risks. Additionally, bolstering cold storage capacity and implementing staggered marketing strategies can help buffer farmers against seasonal price dips (Kumar *et al*. 2025).

The quarter-wise analysis offers deeper insights into intra-annual price fluctuations. As shown in table 5, the Q4 quarter (Oct–Dec) exhibited the lowest instability, with a CV of 17.76 per cent and CDVI of 12.82 per cent respectively. This erratic price behavior during the monsoon harvest season is likely attributable to supply pressures coinciding with limited storage availability (Kireeti & Sharma, 2017). In contrast, the Q3 quarter (Jul-Sep) displayed the highest CV at 44.75 per cent, though the CDVI remained high at 38.23 per cent, indicating continued post-harvest price adjustments and exposure to demand-side variables (Kashyap & Guleria, 2015).

The first and second quarters, Q1 (Jan–March) and Q2 (April–June), showed CVs of 25.01 per cent and 32.82 per cent whereas the CDVI of 24.74 per cent and 31.58 per cent respectively. These periods coincide with lean market supplies, where off-season import pressure and limited residual stocks often cause price imbalances (Ali *et al*. 2018). While national-level data demonstrates steady gains in productivity and gradual price increases, the Bilaspur market reacts more sharply to short-term shocks, as evidenced by its higher price CV. This results to heightened local market sensitivity to micro-climatic events and infrastructural limitations. These observations align with international studies that highlight disruptions in price transmission from farm-gate to retail in decentralized fruit markets (Kumar *et al*. 2014; Shilpa *et al*. 2021).

The study reveals the seasonal nature of apple markets, emphasizing that price volatility is not uniform throughout the year. Time-specific policy interventions, such as implementing a Minimum Support Price (MSP) during Q3 or establishing demand aggregation platforms during Q1 (January–March) and Q2 (April–June), could more effectively manage this instability.

Table 5: Instability of Apple price arrivals quarter wise - 2013-2024

Year	Jan-Mar (Q1)	Apr- Jun (Q2)	Jul-Sep (Q3)	Oct-Dec (Q4)
2013	—	—	2535.71	4867.34
2014	7851.85	6488.75	2757.14	4718.75
2015	7725.58	11262.5	3071.73	5052.5
2016	6928.57	10375	4768.5	5823.8
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2021	9660.71	19961.5	8969.38	7720
2022	10445.5	15166.7	6463.41	5386.79
2023	6357.14	16000	8684.21	7162.96
2024	5366.72	6212.93	4350.68	6543.84
Mean	8085.33	12362.08	5943.41	5951.73
SD	2022.39	4057.71	2660.02	1091.84
CV	25.01	32.82	44.75	17.76
R^2	0.021146	0.091391	0.270085	0.479081
CDVI	24.74	31.28	38.23	12.82
Range	Medium	High	High	Low

The comparative instability analysis between national-level apple area and yield metrics and Bilaspur market prices underscores a dual challenge: yield inconsistency coupled with market volatility. While yield instability can be addressed through agronomic and climate-resilient innovations, price instability necessitates broader institutional and market-based reforms (Amgai *et al*. 2015). These insights are consistent with findings from Sharma *et al*. (2021), who advocate for integrated strategies that combine productivity planning, post-harvest management, and real-time market linkages to stabilize India's apple sector. Furthermore, the elasticity of consumer demand for apples a premium priced, seasonal fruit amplifies local-level price instability, making markets like Bilaspur more vulnerable compared to the aggregated national supply scenario.

Forecast of production, yield, and price arrivals of apple

Forecasting is a critical tool for strategic planning in agriculture, especially for commodity markets prone to seasonal volatility and climatic uncertainties. This analysis uses time-series data from two distinct levels national production and yield data (1982–2023), and Bilaspur market price data (2013–2024) to offer a comparative look at India's apple market behavior, future growth prospects, and their implications for various stakeholders.

A regression-based forecasting model applied to the national dataset reveals a moderate yet consistent upward growth trajectory for both apple production and yield of the apple during 2024–2028. The apple production is projected to increase annually rising from about 26.28 lakh tonnes in 2024 to 28.06 lakh tonnes in 2028, while yield is expected to rise from 82,174 kg/ha to 84,926 kg/ha. These positive trends reflect the combined impact of several agronomic improvements. These include the adoption of high-density plantations, enhanced orchard management, better pest and disease control, and government

Table 6: Forecast analysis – Casual Model Approach (Equation Analysis for forecast of production and yield of Apple) :

Year	Production (Y_1)	Yield (Y_2)	X	X^2	XY_1	XY_2
1982	936980	60291	-21	441	-19676580	-1266111
1983	966600	59774	-20	400	-19332000	-1195480
1984	985900	59773	-19	361	-18732100	-1135687
1985	1005560	59773	-18	324	-18100080	-1075914
1986	1258000	76242	-17	289	-21386000	-1296114
1987	861404	48311	-16	256	-13782464	-772976
1988	995296	51250	-15	225	-14929440	-768750
1989	1084557	53776	-14	196	-15183798	-752864
1990	1093900	58080	-13	169	-14220700	-755040
1991	1175005	58435	-12	144	-14100060	-701220
1992	1147743	60680	-11	121	-12625173	-667480
1993	1165842	58991	-10	100	-11658420	-589910
1994	1300000	61083	-9	81	-11700000	-5497947
1995	1200000	65000	-8	64	-9600000	-520000
1996	1211379	57143	-7	49	-8479653	-400001
1997	1308390	55798	-6	36	-7850340	-334788
1998	1320590	58751	-5	25	-6602950	-293755
1999	1380000	58002	-4	16	-5520000	-232008
2000	1050000	59740	-3	9	-3150000	-179220
2001	1230000	45652	-2	4	-2460000	-91304
2002	1160000	48333	-1	1	-1160000	-48333
2003	1470000	58800	1	1	1470000	58800
2004	1521600	75626	2	4	3043200	151252
2005	1739000	75379	3	9	5217000	226137
2006	1814000	80853	4	16	7256000	3203412
2007	1624000	64444	5	25	8120000	3222220
2008	2001000	75795	6	36	12006000	454770
2009	1985000	72445	7	49	13895000	507115
2010	1777200	62821	8	64	14217600	502568
2011	2891000	100000	9	81	26019000	900000
2012	2203400	68450	10	100	22034000	684500
2013	1915000	61378	11	121	21065000	675158
2014	2497680	79788	12	144	29972160	957456

2015	2134000	66897	13	169	27742000	869661
2016	2521000	91011	14	196	35294000	1274154
2017	2265000	74262	15	225	33975000	1113930
2018	2327000	77309	16	256	37232000	1236944
2019	2316000	75195	17	289	39372000	1278315
2020	2814000	90774	18	324	50652000	1633932
2021	2276000	72716	19	361	43244000	1381604
2022	2589000	82190	20	400	51780000	1643800
2023	2876000	94605	21	441	60396000	19867050
	$\sum Y_1$	**$\sum Y_2$**	**$\sum X$**	**$\sum X^2$**	**$\sum XY_1$**	**$\sum XY_2$**
	69394026	2815616	0	6622	293752202	4555731
Production (Y_1)	a_1 = 1652238.7 b_1 = 44360.043 Y_1=1652238.7 + 44360.043X		Yield (Y_2)	a_2=67038.476 b_2 =687.969 Y_2= 67038.476 +687.969 X		

Table 7: Forecast analysis of apple production and yield from India upto year of 2024 - 2028

Year	Production (tonnes)	Yield (Kg/ha)
2024	2628159.65	82173.795
2025	2672519.69	82861.764
2026	2716879.74	83549.733
2027	2761239.78	84237.702
2028	2805599.82	84925.671

Table 8: Forecast analysis – Casual Model Approach (Equation Analysis for forecast of price arrivals of apple in Bilaspur market)

Year	Quarterly	Modal Price (Y) (₹/Qtl)	X	X²	XY
2013	Q3	2535.71	-23	529	-58321.3
	Q4	4867.34	-22	484	-107081
2014	Q1	7851.85	-21	441	-164889
	Q2	6488.75	-20	400	-129775
	Q3	2757.14	-19	361	-52385.7
	Q4	4718.75	-18	324	-84937.5
2015	Q1	7725.58	-17	289	-131335
	Q2	11262.5	-16	256	-180200
	Q3	3071.73	-15	225	-46076.1
	Q4	5052.5	-14	196	-70735
2016	Q1	6928.57	-13	169	-90071.4
	Q2	10375	-12	144	-124500
	Q3	4768.75	-11	121	-52456.3
	Q4	5823.81	-10	100	-58238.1
2017	Q1	12000	-9	81	-108000
	Q2	14000	-8	64	-112000
	Q3	10746.67	-7	49	-75226.7
	Q4	5738	-6	36	-34428
2018	Q1	6993.10	-5	25	-34965.5
	Q2	14044.44	-4	16	-56177.8
	Q3	5395.55	-3	9	-16186.7
	Q4	5327.11	-2	4	-10654.2

2019	Q1	6342.85	-1	1	-6342.86
	Q2	11611.11	1	1	11611.11
	Q3	5748.71	2	4	11497.44
	Q4	5446.42	3	9	16339.29
2020	Q1	9266.66	4	16	37066.67
	Q2	10860	5	25	54300
	Q3	7829.26	6	36	46975.61
	Q4	7633.33	7	49	53433.33
2021	Q1	9660.71	8	64	77285.71
	Q2	19961.54	9	81	179653.8
	Q3	8969.38	10	100	89693.88
	Q4	7720	11	121	84920
2022	Q1	10445.45	12	144	125345.5
	Q2	15166.67	13	169	197166.7
	Q3	6463.41	14	196	90487.8
	Q4	5386.79	15	225	80801.89
2023	Q1	6357.14	16	256	101714.3
	Q2	16000	17	289	272000
	Q3	8684.21	18	324	156315.8
	Q4	7162.96	19	361	136096.3
2024	Q1	5366.72	20	400	107334.4
	Q2	6212.93	21	441	130471.5
	Q3	4350.68	22	484	95714.96
	Q4	6543.84	23	529	150508.3
	∑Y = 367663.721		**∑X = 0**	**∑X²** = 8648	**∑XY**= 501750.93
	a = 7992.68 b = 58.019		Y= 7992.68+ b = 58.019 X		

Table 9: Forecast of Apple Price arrivals at Bilaspur market (2025-2027) (₹/Qtl)

Year	**Jan-Mar (Q1)**	**Apr- Jun (Q2)**	**Jul – Sep (Q3)**	**Oct-Dec (Q4)**
2025	9385.152	9443.172	9501.191	9559.210
2026	9617.230	9675.249	9733.268	9791.287
2027	9849.307	9907.326	9965.345	10023.365

subsidy schemes supporting inputs and cold-chain logistics (Hassan, *et al*. 2020).

From a policy standpoint, these projections underscore the effectiveness of ongoing initiatives. Programs like the Mission for Integrated Development of Horticulture (MIDH) and the National Horticulture Board's infrastructure development projects have played a significant role in boosting productivity in key apple-growing states such as Jammu & Kashmir, Himachal Pradesh, and Uttarakhand.

However, compared to many other temperate fruit crops, the projected rate of yield increase remains modest. This suggests that despite expanded cultivation areas and improved input accessibility, productivity gains still heavily depend on climate-sensitive factors. Consequently, sustained technological and institutional support will be essential to further enhance yields.

In stark contrast to the apple price forecast for the Bilaspur market presents a sharply divergent picture. A linear trend model, fitted to quarterly modal prices from 2013 to 2024, projects an exponential upward trend in future prices.

The forecast of apple prices are predicted to climb steadily every quarter at the Bilaspur market between 2025 and 2027, from ₹ 9,385/Qtl in Q1 (Jan - March) 2025 to ₹ 10,023/Qtl in Q4 (Oct - Dec) 2027. This upward trend across all quarters reflects increasing consumer demand, seasonal market fluctuations, and the impact of rising input and transportation costs, which collectively contribute to the gradual escalation of prices and significant supply-side and demand-side pressures within the regional market are reflected in the sharp price increase (Kireeti *et al*. 2014). These pressures are caused by seasonal arrival variations that result in off-season shortages, a lacklustre cold-chain infrastructure and weak price stabilisation mechanisms that increase market vulnerability, and climate variability, such as unpredictable rainfall and late frosts, which interfere with flowering, fruit setting, production, and supply chains (Sutradhar *et al*. 2024; Singh & Sekhon, 2017).

These quarters typically coincide with the early and mid-harvest seasons when supplies from hill regions begin to decline, and market arrivals become inconsistent. This scenario often leads to speculative pricing and increased volatility, further compounding the instability observed in consumer-end markets like Bilaspur (Chanda, K. 2018).

CONCLUSION

This study underscores the evolving dynamics and dual challenges facing India's apple economy steady national production growth on one hand, and volatile market behavior in consumer-driven hubs like Bilaspur on the other. Over the past decade (2014–2024), while apple prices in the Bilaspur market have grown modestly at a CAGR of 0.82 per cent, the exceptionally high instability index (CDVI- 44.81%) highlights the market's acute sensitivity to seasonal shocks, logistical disruptions, and climatic variability. In contrast, national-level production trends from 1982 to 2023 exhibit more consistent growth, with a CAGR of 1.41 per cent in production with low instability (CDVI-14.55%) and 3.50 per cent in yield growth rate with high range of instability (CDVI–48.12%) reflecting systemic improvements driven by agronomic advancements, policy interventions, and the adoption of high-density planting systems.

The quarter wise growth analysis prices peaked in Q3 (4.60%) due to harvest-driven supply pressures and limited storage facilities, while Q1and Q2 reflected weak trends influenced by lean-season supplies and import competition. Q4 showed moderate growth, driven by fresh arrivals and early winter demand adjustments. Overall, the findings underscore the strong seasonal sensitivity of apple prices, with Q3 emerging as the most volatile period and Q1–Q2 reflecting structural market weaknesses. Whereas the instability analysis reveals that apple prices of Q4 showed the lowest volatility (CDVI-12.82%), Q3 emerged as the most unstable due to post-harvest supply pressures and demand fluctuations. Q1 and Q2 also exhibited considerable instability, influenced by storage deficits and supply mismatches amplify price fluctuations.

The forecast analysis reveals the prices potentially exceeding ₹ 10023.36 per quintal by the end of 2027. This signals an urgent need for targeted interventions, including the development of cold-chain infrastructure, enhanced price discovery mechanisms, and climate-responsive planning tools. Integrated measures such as flexible MSP schemes, stronger market intelligence, and institutional support for value addition are essential to shield producers and consumers from price volatility. By linking local price behavior with national productivity trends, this study emphasizes the need for a resilient apple marketing system that supports climate-adaptive farming, data-driven trading, and affordable consumer access. Such strategies will strengthen supply chains while advancing sustainability, stability, and inclusive rural growth.

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