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Forecasting of wheat prices in the major markets of India

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Abstract
The entire world desperately requires a change of the global food system that will result in more nutritious food for everyone and a significant reduction in the environmental impact of agriculture. In the present study, effort was made to build the forecast model and forecasts were determined for the prices of wheat in different markets. Auto- Regressive Integrated Moving Average (ARIMA) method was adopted with the use of E-views software to forecast the prices of wheat for the next six months. Among six markets, the price forecast model for Vidisha market [(12, 1, 1) (0, 1, 0)] was found to be best model and predicted the good results. ARIMA forecasts indicated the prices of wheat would be maximum in December 2023 for all the selected wheat markets. The forecast prices using ARIMA showed an increasing trend, so farmers need to be advised to plan the production and sales accordingly to get a higher price with strengthened basic infrastructural facilities from APMCs.

Keywords: Compound annual growth rate, auto- regressive integrated moving average, agriculture produce market committee

1. Introduction
The entire world desperately requires a change of the global food system that will result in more nutritious food for everyone and a significant reduction in the environmental impact of agriculture. In recent years, India's agricultural sector has done brilliantly, rising at a compounded annual growth rate (CAGR) of 3.7 per cent per annum between 2017-18 and 2021-22. The predicted real agricultural gross value added (GVA) in 2021-22 was ₹ 21.1 lakh crore (US dollar 256.4 billion), accounting for 15.5 per cent of total GVA and 6.4 per cent higher than the pre-pandemic level. Even throughout the Covid-19 pandemic, agriculture GVA for all goods increased including food grains, cereals, pulses and oilseeds providing the country with much-needed food security. Total production of food grains in the country is projected to reach a record high of 314.6 million tonnes in 2021-22, an increase of 3.8 million tonnes over 2010-21. Cereals and pulses production raised at a CAGR of 2.0 per cent and 1.8 per cent respectively, from 2017-18 to 2021-22. Wheat is a primary source of nutrition for around 40 per cent of the world's population. Wheat production spans more than 220 million hectares (ha) worldwide, and its gross global trade exceeds that of all other crops combined. India accounts for around 12.40 per cent of global wheat area while accounting for 11.77 per cent of total global wheat production. Wheat production in India has increased at a CAGR of 2.59 per cent over the last ten years. Agricultural marketing is vital not only for encouraging production but also for hastening economic development. The analysis of price and market arrivals over time is critical for developing appropriate agricultural price policy. This study will also assist policymakers by projecting future demand for wheat and its products allowing them to adjust production and export towards policy reforms for the development of Indian agriculture in the years to come for smooth international trade in India's agricultural foreign trade.

2. Methodology
2.1 ARIMA Model: In statistics, Auto Regressive Moving Average (ARMA) models, sometimes called Box-Jenkins models are typically applied to time series data. In the current study, Auto- Regressive Integrated Moving Average (ARIMA) method was adopted with the use of E-views software to forecast the prices of wheat for the next six months.

In this model, the dependence of the present year value (X_t) on its past values and the error terms εt is assumed to be linear unless specified otherwise. If the dependence is nonlinear, the model is specifically called a Nonlinear Moving Average (NMA), Nonlinear Auto-Regressive (NAR), or Nonlinear Auto Regressive Moving Average (NARMA) model.
Several variations on the ARIMA model are commonly used. For example, if multiple time series are used then the 'X_t' can be thought of as vectors and a Vector ARIMA (VARIMA) model may be appropriate. Sometimes a seasonal effect is suspected in the model. In this case, it is often considered better to use a Seasonal ARIMA (SARIMA) model. If the time series is suspected to exhibit long-range dependence then the 'd' parameter may be replaced by certain non-integer values in a Fractional ARIMA (FARIMA also sometimes called ARFIMA) model.
ARIMA models are, in theory, the most general class of models for forecasting a time series which can be stationeries by transformations such as differencing and lagging. The present study deals with a seasonal ARIMA model, "SARIMA (P,D,Q) (p, d, q)" model,
where:

- P is the number of autoregressive terms,
- D is the number of non-seasonal differences
- Q is the number of lagged forecast errors in the prediction equation and
- p is number of autoregressive seasonal terms
- d is number of seasonal differences
- q is number of lagged seasonal error terms in prediction equation.

Given a time series of data X_t, the ARMA model is a tool for understanding and perhaps, predicting future values in this series. The model consists of two parts, an Auto- Regressive (AR) part and a Moving Average (MA) part. The model is usually then referred to as the ARMA (p,q) model where p is the order of the autoregressive part and q is the order of the moving average part, then an ARMA (p, q) model is given by

$$(1 - \sum_{i=1}^{p} \emptyset_i L^i) X_t = (\sum_{i=1}^{q} \theta_i L^i) \varepsilon_t$$

Where, L is the lag operator, the $'\emptyset_i'$ are the parameters of the autoregressive part of the model, the θ_i are the parameters of the moving average part, and the $'\varepsilon_t'$ are error terms. The error terms are generally assumed to be independent, identically distributed variables sampled from a normal distribution with zero mean.

An ARIMA (p, d, q) process is obtained by integrating an ARMA (p, q) process. That is,

$$(1 - \sum_{i=1}^{p} \emptyset_i L^i)(1 - L)^d = C + (1 - \sum_{i=1}^{q} \theta_i L^i) \varepsilon_t$$

Where, d is a positive integer that controls the level of differencing (or, if d = 0, this model is equivalent to an ARMA model). Conversely, applying term by term differencing d times to an ARIMA (p, d, q) process gives an ARMA (p, q) process. It should be noted that not all choices of parameters produce well-behaved models. In particular, if the model is required to be stationary, then conditions on these parameters must be met.
A series is said to be a stationary series if the precise point at which the series is examined does not affect the results. That means, mean and variance of the data are constant across time and thus the condition of stationary is rarely achieved. Many models used in time series analysis assume stationary (AR models, MA models, and combined ARMA models).

E-views methodology
In this software, by using 'Automatic ARIMA forecasting' option to choose the better model for accurate results.

Box-Jenkins (BJ) methodology
The Box-Jenkins methodology is used to identify the best ARIMA model. This method consists of four steps,

a. Identification
b. Estimation
c. Diagnostic checking
d. Forecasting

(a) Identification
To find out the appropriate values of p, d, and q, the chief tools of identification are the Auto Correlation Function (ACF), the Partial Auto Correlation Function (PACF), and the resulting correlograms, which are simply the plots of ACF and PACFs against the lag length. One way of accomplishing this is to consider the ACF and PACF and the associate's correlograms of a selected number of ARMA processes, such as AR(1), AR(2), MA(1), MA(2), ARMA (1, 1), ARMA (1, 2) and so on. Since each of these stochastic processes exhibits a typical pattern of ACF and PACF, if the time series under study fits one of these patterns, one can identify the time series with that process. Then apply diagnostic tests to find out if the chosen ARIMA model is reasonably accurate or not.

(b) Estimation
After identifying the appropriate values of p and q the next step is to estimate the parameters of the autoregressive and moving average terms included in the model. Sometimes this calculation can be done by simple least squares, but sometimes one will have to resort to the method of moments or method of maximum likelihood estimation.

(c) Diagnostic checking
In this step, one has to see whether the chosen model fits the data reasonably well or not. The two commonly used criteria are Akaike Information Criterion (AIC) and Mean Absolute Percentage Error (MAPE). Lower the AIC and MAPE values, better the fit of the selected ARIMA model.

(d) Forecasting
One of the reasons for the popularity of ARIMA modelling is its success in forecasting. To forecast the values of a time series, the basic Box-Jenkins strategy has to be followed. The steps involved in the computation are given below.
First, examine the stationarity. This step can be done by computing the ACF and PACF values.

a. If the time series is not stationary at level, then differencing is done one or more times to achieve stationarity.
b. The ACF and PACF of the stationary time series are then computed to find out if the series is purely autoregressive or purely of the moving average type or a mixture of the two.
c. The tentative model is then estimated.
d. The residuals from this model are examined to find out if they have white noise. If they have, the tentative model is probably a good approximation to the underlying stochastic process. If they have not, the process is started

all over again. Therefore, the Box-Jenkins method is an iterative process. The model finally selected based on lower values of MAPE can be used for forecasting.

3. Results

3.1 ARIMA Model

As Box-Jenkins model is preferred to the multiplicative time series model for forecasting purposes. Accordingly, this model was used for forecasting the wheat prices of major markets of India in the study. The best fit ARIMA model was established using E-views software as mentioned in the methodology. The best fit ARIMA models are presented in Table 1. The E-views software performed several iterations with respect to auto regression, differencing and moving average terms both at general [P, D, Q] and seasonal levels [p, d, q] and finalized the best fit as the output level model for each of the markets under study. The goodness of fit was decided on the basis of Akaike Information Criterion (AIC) and Mean Absolute Percentage Error (MAPE) which were decided by the software as the final output model.

Table 1: Best fit forecasting models for monthly prices of wheat in major markets of India (2008 January-2022 December)

State	Market	Model	AIC	MAPE
Uttar Pradesh	Lakhimpur	(7, 1, 4) (1, 1, 1)	10.91	6.67
	Agra	(2, 1, 2) (0, 1, 0)	11.28	8.18
Madhya Pradesh	Vidisha	(12, 1, 1) (0, 1, 0)	12.22	10.19
	Dewas	(3, 1, 3) (1, 1,1)	12.00	5.95
Rajasthan	Kota	(0, 1, 1) (1, 1, 1)	11.17	6.95
	Baran	(3, 1, 9) (1, 1, 1)	11.20	9.14

Note: AIC - Akaike Information Criterion, MAPE - Mean Absolute Percentage Error.

The best fit models as described in Table 1 for each of the selected wheat markets considered under the selected states were further utilized for forecasting the prices, Ex-post January 2022 to December 2023. The results of forecast analysis for the markets are presented state-wise in the Tables 2. The forecast were further tested for their validity by comparing them with the actual prices and the validity for the known actual prices in the respective markets up to May 2023 were established to know the efficacy of the model. Since, the prices of agricultural commodities are more volatile and are influenced by several of local factors, forecasts for the next six to seven months are more meaningful.

As shown in Table 2, the validation of prices was found to be more than 80 per cent in almost all the months of Lakhimpur market. The ARIMA model (7, 1, 4) (1, 1, 1) with MAPE value of 6.67 was found to be the best fit for Lakhimpur market for the forecast of wheat prices. The price of wheat would keep on increasing from June 2023 to December 2023, as per the forecast exercise. The price would be around ₹ 2460 by December 2023 in the market.

Table 2: Ex-post forecast of monthly prices of wheat in major markets of Uttar Pradesh state during 2022 January to 2023 December

Year and month	Lakhimpur			Agra		
	Actual price (₹ /q)	Forecast price (₹ /q)	Validity (%)	Actual price (₹ /q)	Forecast price (₹/q)	Validity (%)
2022 January	1911	2291	83	1979	2505	79
2022 February	1940	2298	84	2032	2515	80
2022 March	1963	2305	85	2083	2525	82
2022 April	2020	2313	87	2106	2536	83
2022 May	2034	2320	87	2159	2546	84
2022 June	2024	2327	86	2085	2556	81
2022 July	2064	2335	88	2112	2566	82
2022 August	2166	2342	92	2317	2576	89
2022 September	2187	2349	93	2332	2586	90
2022 October	2296	2357	97	2405	2596	92
2022 November	2279	2364	96	2565	2606	98
2022 December	2358	2372	99	2708	2616	96
2023 January	2702	2379	88	2781	2626	94
2023 February	2386	2386	100	2726	2636	96
2023 March	2095	2394	87	2350	2646	88
2023 April	2137	2401	89	2192	2656	82
2023 May	2174	2408	90	2199	2666	82
2023 June		2416			2676	
2023 July		2423			2686	
2023 August		2430			2696	
2023 September		2438			2706	
2023 October		2445			2716	
2023 November		2453			2726	
2023 December		2460			2736	

In the case of Agra market, the best fit found was (2, 1, 2) (0, 1, 0) model, with MAPE value of 8.18. For the best fit model, the validation worked out to be more than 80 per cent for almost all the months. The forecast price for upcoming seven months was found to be varying from ₹ 2676 per quintal to ₹ 2736 per quintal with the highest price in December 2023 (Table 2).

In case of Vidisha market, the best price forecast model was (12, 1, 1) (0, 1, 0) with MAPE value of 10.19. Validation of predicted prices from January 2022 to May 2023 were found to have more than 90 per cent accuracy. As shown in Table 3, the forecast price of wheat would reach as high as ₹ 2578 per quintal during December 2023.

Table 3: Ex-post forecast of monthly prices of wheat in major markets of Madhya Pradesh state during 2022 January to 2023 December

Year and month	Vidisha			Dewas		
	Actual price (₹ /q)	Forecast price (₹ /q)	Validity (%)	Actual price (₹ /q)	Forecast price (₹/q)	Validity (%)
2022 January	2290	2482	92	2069	2268	91
2022 February	2305	2486	92	2110	2273	92
2022 March	2515	2490	99	2145	2279	94
2022 April	2541	2495	98	2111	2285	92
2022 May	2761	2499	90	2106	2290	91
2022 June	2562	2503	97	2029	2296	88
2022 July	2533	2507	98	2055	2302	89
2022 August	2555	2511	98	2123	2308	91
2022 September	2579	2515	97	2095	2313	90
2022 October	2509	2520	99	2140	2319	92
2022 November	2325	2524	92	2325	2325	100
2022 December	2713	2528	93	2379	2330	97
2023 January	2808	2532	93	2515	2336	93
2023 February	2619	2536	97	2292	2342	98
2023 March	2428	2540	95	2133	2347	91
2023 April	2381	2545	93	2017	2353	85
2023 May	2384	2549	93	2035	2359	86
2023 June		2553			2365	
2023 July		2557			2370	
2023 August		2561			2376	
2023 September		2565			2382	
2023 October		2569			2387	
2023 November		2574			2393	
2023 December		2578			2399	

Table 4: Ex-post forecast of monthly prices of wheat in major markets of Rajasthan state during 2022 January to 2023 December

Year and month	Kota			Baran		
	Actual price (₹ /q)	Forecast price (₹ /q)	Validity (%)	Actual price (₹ /q)	Forecast price (₹ /q)	Validity (%)
2022 January	2028	2444	82	2073	2447	84
2022 February	2040	2461	82	2058	2455	83
2022 March	2209	2461	89	2243	2464	91
2022 April	2204	2477	88	2299	2472	93
2022 May	2175	2477	87	2281	2480	91
2022 June	2035	2493	81	2093	2488	84
2022 July	2108	2493	84	2166	2496	86
2022 August	2192	2509	87	2261	2505	90
2022 September	2191	2509	87	2237	2513	89
2022 October	2254	2525	89	2310	2521	91
2022 November	2439	2525	96	2506	2529	99
2022 December	2520	2541	99	2555	2538	99
2023 January	2651	2541	96	2630	2546	97
2023 February	2434	2558	95	2430	2554	95
2023 March	2169	2557	85	2419	2562	94
2023 April	2214	2574	86	2408	2570	94
2023 May	2185	2573	85	2260	2579	87
2023 June		2590			2587	
2023 July		2589			2595	
2023 August		2606			2603	
2023 September		2605			2611	
2023 October		2622			2620	
2023 November		2622			2628	
2023 December		2638			2636	

With respect to Dewas market, the best price forecast model was (3, 1, 3) (1, 1, 1) with MAPE value of 5.95. Validation of predicted price from January 2022 to May 2023 was found to have more than 88 per cent accuracy. As depicted in Table 3, the forecast price of wheat would be around ₹ 2399 per quintal during December 2023 in the market.

The analysis of monthly price data of wheat had given (0, 1, 1) (1, 1, 1) as the best fitted ARIMA model for Kota market. As shown in Table 4, the predicted prices had more than 80 per cent accuracy from January 2022 to May 2023. The forecast price of wheat would be ₹ 2638 per quintal during

December 2023 in the market, which would be the highest price for the commodity.

The price forecasting of wheat in Baran market has done up to December 2023, by using best fitted ARIMA model (3, 1, 9) (1, 1, 1) with MAPE value of 9.14. As shown in Table 4, the analysis of validation of predicted prices indicated an accuracy of more than 80 per cent in all the months for which actual prices are known. It was predicted that the future prices would have an increasing trend and would reach around ₹ 2636 per quintal by December 2023.

4. Discussion

4.1 Forecasting of wheat prices in the major markets of India

Monthly modal prices of wheat were used to fit an ARIMA model as outlined in the methodology. Price series of all the markets under study have clearly exhibited non-stationarity and there was slight seasonality in data. An examination of the Auto Correlation Function (ACF) and Partial Auto Correlation Function (PACF) revealed that there was seasonality, but not significant. As a result, the first difference price series was carried out in order to make price series stationary. Since the coefficients fell to zero after the second lag, it was determined that it was stationary after the first difference. In the present investigation, a large scale comparison was done by using automatic ARIMA forecasting feature in E-views software, in order to know the best model for forecasting of prices of wheat in the selected major markets of India. The parameters were estimated through an iterative process by the least square technique which gave the best model as presented in Table 1. The models were fitted based on the MAPE and AIC values which were considered to be least.

The results revealed that, the ARIMA models [(7, 1, 4) (1, 1, 1)], [(2, 1, 2) (0, 1, 0)], [(12, 1, 1) (0, 1, 0)], [(3, 1, 3) (1, 1, 1)], [(0, 1, 1) (1, 1, 1)], [(3, 1, 9) (1, 1, 1)] were found to be the good fits for forecasting the prices of wheat in Lakhimpur, Agra, Vidisha, Dewas, Kota and Baran markets respectively. The forecast prices of wheat would be lowest in Dewas market (₹ 2399 per quintal) in December 2023. In case of Lakhimpur, Vidisha, Baran, Kota and Agra markets, the prices would be ₹ 2460, ₹ 2578, ₹ 2636, ₹ 2638 and ₹ 2736 per quintal respectively in the same month. This information on price forecasting could be useful to farmers to make their marketing decisions. Among the best fit models, ARIMA [(12, 1, 1) (0, 1, 0)] model for Vidisha market was found to be the most suitable model. Because, the predicted prices of wheat for Vidisha market were almost similar to actual prices as reflected by good validity value followed by Dewas market predicted prices. Market information, especially price information is very limited among farmers. Farmers are get to know the predicted harvest period prices of different crops before sowing, so that they can take intellectual decisions keeping in the mind resources availability and expected prices of different crops. In the present study, effort was made to build the forecast model and forecasts were determined for the prices of wheat in different markets. The farmers can be advised to make appropriate sowing and marketing decisions. ARIMA does not need the forecaster to select a-priori values for any parameter and is applicable for any time series with any pattern of change. It demands long time series data for analysis. Similar results were reported by Darekar and Reddy (2018) in his work entitled forecasting wheat prices in India.

5. Conclusion

India is the world’s second-largest producer of rice and wheat and by far the largest producer of pulses. Wheat and rice are the cornerstones of India’s food security policy. ARIMA model was employed to forecast the prices of wheat in selected markets. Among six markets, the price forecast model for Vidisha market [(12, 1, 1) (0, 1, 0)] was found to be best model and predicted the good results. ARIMA forecasts indicated the prices of wheat would be maximum in December 2023 for all the selected wheat markets. The forecast prices using ARIMA showed an increasing trend, so farmers need to be advised to plan the production and sales accordingly to get a higher price with strengthened basic infrastructural facilities from APMCs.

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