



Price analysis and forecasting for decision making: Insights from wheat markets in India

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ABSTRACT

Wheat occupies a prime position in supplementing the food security needs of India. Price forecast related to a food commodity is essential in executing policies which ensure market support. Keeping this in view, an attempt was made to forecast monthly wholesale wheat prices adopting ARIMA model in spatially separated markets of India using the historical data sourced from AGMARK price portal (July 2002-June 2018). Wheat prices exhibited a clear-cut seasonality captured through monthly price indices. The prices were found to be highest during the crop season (November-March) as it is the production phase lacking market supply and lowest during post-harvest season (June-October) wherein supply surge is witnessed. The average seasonal price variation and intra-year price rise were found to be highest in Haryana, followed by Punjab. Forecasted prices estimated by fitting the ARIMA model were found to be higher for low or negligible wheat producing states such as Kerala and Karnataka, and lower for higher wheat producing states like Haryana, Punjab, Madhya Pradesh and Uttar Pradesh. Forecast performance the fitted models were further supported by using measures like RMSE, MAPE and MAE with 95% confidence interval. The study emphasized the need for effective dissemination of market information such as price forecast to farmers, agri-based industries and other concerned stakeholders which will help in decision making apart from tracking price volatility.

Key words: ARIMA, Forecasting, Seasonal index, Wheat, Wholesale prices

Wheat is one of the major food crops consumed by about 2.5 billion people all over the world. India is the second largest producer after China with annual production estimated at 107.18 million tonnes for 2019-20 (MoA & FW 2020). Among states, Uttar Pradesh has the maximum area under wheat cultivation but Punjab and Haryana account for higher productivity with lesser land (Khatkar *et al.* 2016). It is an important staple crop both in terms of production and consumption. Although per capita consumption of wheat has been declining, the total demand for the wheat has been increasing due to burgeoning population and income growth (Tripathi and Mishra 2014). The area under wheat cultivation has witnessed a consistent increase in the recent past decades due to significant rise in the minimum support price coupled with government procurement (Ramdas *et al.* 2012). Due to diverse geographical set up, India shows large variation in wheat yield across different regions owing to various factors such as availability of irrigation facilities, usage of high yield varieties *etc.* (Tripathi and Mishra 2014). Agricultural commodity prices play a crucial role in framing the nation's food policies. Rising global prices of

food grains as well as increased volatility in recent years has raised a serious concern for developing countries like India (Ceballos *et al.* 2017). These global trends easily translate into the domestic market which in turn negatively impacts the local producer as well as consumer. In the face of these challenges, it becomes imperative for policymakers to devise an effective pricing policy keeping into consideration the interaction between demand and supply forces which stabilize the domestic production. Analysis of price behavior and expected future price provides an essential input for the planning of farm business and choice of enterprises for farmers. Forecasts help to make timely decisions in the face of uncertainty about the future prices (Gujarati 2003). Therefore forecasting future prices of farm commodities has become a crucial component in price policy. In the milieu, an attempt has been made to forecast the wheat prices in selected spatially separated markets in India.

MATERIALS AND METHODS

Monthly wholesale prices on wheat markets spanning from July 2002 to June 2018 for 15 selected states in India were collected from the AGMARKNET price portal (<https://agmarknet.gov.in>). Conventional techniques like descriptive statistics, instability indices, and the following analytical methods were employed to address the set objectives.

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Seasonal variation: The seasonal variation in prices was calculated using the 12 months ratio-to-moving average method. For measuring the extent of variation in seasonal indices, the coefficient of average seasonal price variation (ASPV), intra-year price rise (IPR) and coefficient of variation (CV) were used following Horo *et al.* (2016) and Mahalle *et al.* (2015).

Compound Annual Growth Rate (CAGR): Annual growth rate in wheat prices was calculated using the compounding formula as mentioned in Gujarati (2013).

Price forecasting by ARIMA Model: Auto-Regressive (AR) models can be effectively coupled with Moving Average (MA) models to form a general and useful class of time series models called Auto-Regressive Moving Average (ARMA) models. However, they can only be used when the data is stationary. It is a stochastic process in which the probability density function of some random variable does not change over time or position. As a result, measures of central tendency and dispersion such as the mean and variance also don't change over time or position.

ARMA class of models can be extended to non-stationary series by allowing differencing of the data series. These are called Auto-Regressive Integrated Moving Average (ARIMA) models. Box and Jenkins (1970) popularized the ARIMA models with a general specification of ARIMA (p,d,q).

- AR (p): Order of Auto-Regressive part
- I (d): Order of Integration, *i.e.*, degree of differencing of time series
- MA (q): Order of the Moving Average part

The Box-Jenkins methodology is as follows consisting of four steps (Makridakis *et al.* 1998).

Identification: This is to find out the appropriate values of p, d and q. For identification, the correlogram and partial correlogram are used followed by order of differencing if the time series is non-stationary (Makridakis *et al.* 1998).

Estimation: Having identified the p and q values, the next step is to estimate the parameters of the Auto-Regressive and Moving Average terms in the model. This calculation is done by the Ordinary Least Squares method. For example, suppose the class of model identified as ARIMA (0,1,1), which is a family of models depending on one MA coefficient θ_1 :

$$(1-B)Y_t = (1 - \theta_1 B) e_t$$

The purpose is to find the best estimate of θ_1 to fit the time series that is being modeled. The method of least squares can be used for ARIMA models, just as with regression.

Diagnostic checking: Having chosen a particular ARIMA model, the next task is to see whether the chosen model fits the data reasonably well, for it is possible that another ARIMA model might do the forecasting in a better way. One simple test of the chosen model is to see if the residuals estimated from this model are white noise and if they are, the fitted model can be accepted and if not, the

process must be started over. After confirmation of this step, the next one will be actual forecasting. Alternatively, the residuals can be checked using the following indicators like Root of Mean Squared Error (RMSE), Mean Absolute Percent Error (MAPE) and Mean Absolute Error (MAE) as outlined in Nasurudeen *et al.* (2007).

Forecasting: ARIMA modeling is widely popular because of its success in forecasting. The forecasts obtained by ARIMA are more reliable than those obtained from the traditional econometric modeling, particularly for short-term (Makridakis *et al.* 1998, Nasurudeen *et al.* 2007).

RESULTS AND DISCUSSION

The monthly wholesale prices of wheat in 15 spatially separated markets in India were analysed and forecasted for decision making. Price analysis highlights the dynamic behaviour of the time series in different regions which helps to draw appropriate economic implications. Wheat prices in selected markets exhibited spatial and temporal variations because of the biological nature coupled with geographical concentration of production across India (Sendhil *et al.* 2018, Sendhil *et al.* 2019).

Seasonal variation in prices: Continuous monitoring of seasonal fluctuation in agricultural commodity prices is required for proper economic decision making as they are cyclical in nature. Seasonal indices of monthly prices captures seasonal variation in wheat prices across spatially separated wheat markets of India (Fig 1). The prices were found to be highest during the crop season (November-March) as it is the production phase and thus the supply will be less in the market corroborating the findings of Darekar and Reddy (2018). The prices are lowest in the post-harvest period (June to October) as the arrivals start to surge and there will be huge supply of wheat in the market which pulls down the prices. The price index fluctuated between 90.92 and 110.61% throughout the year (Fig 1).

Gross returns to storage: Data depicts the seasonal price indices in various states classified based on the production level of wheat (Table 1). On an average, the price index during lean season (June to October) was 97.46% and during crop season (November to March) it was 102.84%. This indicated that the gross returns to storage of wheat was about 5% in six months, which meant storing of produce was not remunerative to the farmers. Darekar and Reddy (2018) had similar results where the gross return to storage was around 6 per cent in five months. The highest gross returns to storage (8.42%) was found in high wheat producing states such as Haryana, Punjab and Madhya Pradesh, which also had highest variation in prices among other states.

Growth and variation in seasonal price index: The estimated growth rate (CAGR) of seasonal price indices was found to be positive for all the states except Maharashtra. The CAGR was highest in Delhi (0.96%), a key market for the staple commodity, followed by Uttarakhand (0.78%). Overall, the growth rates were low across all markets and were found to be less than one per cent (Fig 2). The variation in seasonal indices exhibited a wide range from as low as

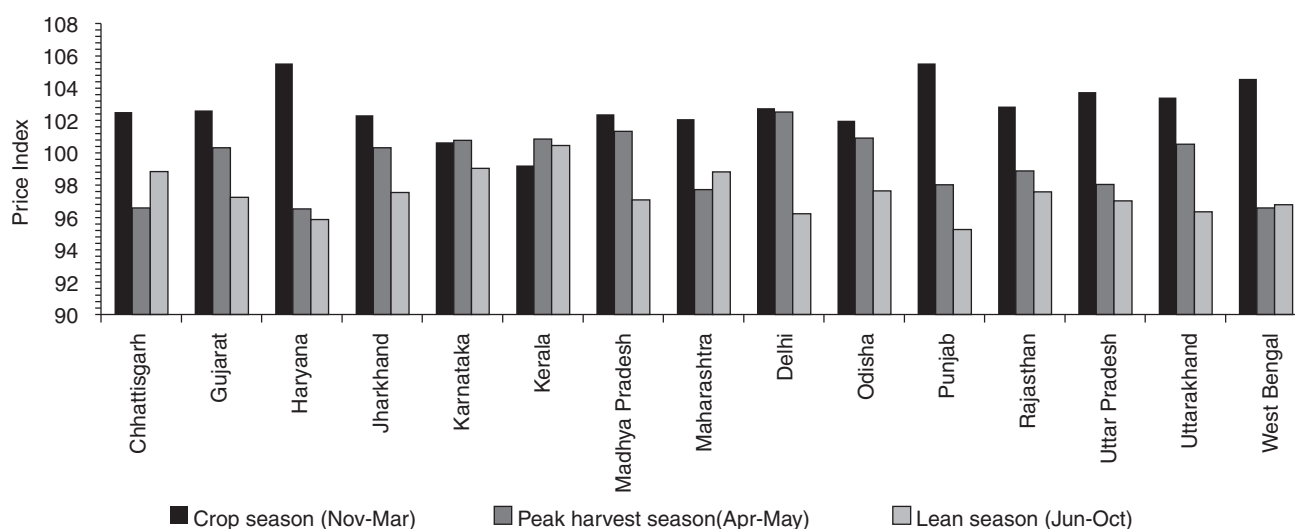


Fig 1 Seasonal indices of monthly wholesale wheat prices (AY 2002-03 to 2017-18).

Table 1 Season-wise wholesale prices indices in different wheat producing states

States (% share to total)	Crop season (Nov-Mar)	Peak harvest season (Apr-May)	Lean season (Jun-Oct)	Gross returns to storage
Very low production (0.16%)	102.58	99.29	97.70	4.88
Low production (2.79%)	102.35	99.02	98.04	4.32
Moderate production (9.15%)	102.87	98.88	97.58	5.29
High production (18.23%)	104.48	98.63	96.07	8.42
Very high production (30.55%)	103.76	98.05	97.02	6.73
Nil/very negligible production	100.99	101.68	98.34	2.65
Pooled	102.84	99.26	97.46	5.38

Source: Authors estimation based on data from AGMARKNET

2.15% in Karnataka to as high as 6.74% in Haryana. The average seasonal price variation (ASPV) and intra-year price rise (IPR) were found to be highest in Haryana followed by Punjab. The reason shall be attributed for being the major procurement centers driven by the rising support price (Ramdas *et al.* 2012). The above analysis provides enough information to make business decisions especially related to buying, selling and storing of the produce by different stakeholders along the wheat value chain (Mahalle *et al.* 2015).

Price forecast: Monthly wholesale prices of wheat

were used to fit suitable ARIMA model. Price series was not stationary and there was a slight seasonality in the data as captured by the time plot. Estimation of ACF and PACF revealed that there was seasonality in the price series, but it was not significant. Therefore, the first difference of prices was taken to make the series stationary. After the first difference the price time series was found to be stationary, since the coefficients dropped to zero after the second lag. The residuals obtained during ARIMA modeling were checked for the adequacy of selected model order. The different model order which was found to be fit and the forecasted values are depicted in Table 2.

The results revealed that forecasts in Kerala and Delhi (no or very negligible production) on an average ranged from around 16-28 ₹ per kg, from 15-23 ₹ per kg in very low producing states (Chhattisgarh, Jharkhand, Karnataka, Odisha, Uttarakhand and West Bengal), from 18-26 ₹ per kg in low producing states (Gujarat and Maharashtra), from 15-22 ₹ per kg in Rajasthan (moderate production), from 15-24 ₹ per kg in high producing states (Haryana, Madhya Pradesh and Punjab) and from ₹ 15 and ₹ 20 per kg in very high producing state (Uttar Pradesh). The above results revealed that in general the forecasts were high for low producing states and less for high producing states corroborating the fact that prices are influenced by local production and supply.

Price analysis on spatially separated markets indicated that the wholesale prices were maximum in Kerala coupled with high variation owing to zero production. Instability in prices was more visible in states like Haryana, Odisha and Kerala. Other markets have shown more stability in the prices over time. Prevalence of higher average prices in southern states like Kerala and Karnataka indicated the growing consumption demand of wheat in the region. Monthly price indices exhibited a clear-cut seasonal variation, and recorded highest during the crop season (November-March) and lowest during post-harvest or lean season (June to October) as the arrivals start to surge and

Table 2 Price forecasts for wheat producing states of India (in ₹ per kg)

Region & Model Fit	Level	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20
<i>A. Nil or negligible production</i>													
Kerala	F	20.6	20.6	20.7	20.7	20.8	20.8	20.9	20.9	21.0	21.0	21.1	21.1
ARIMA(0,1,1)	LL	15.7	15.1	14.7	14.3	13.9	13.6	13.3	13.0	12.7	12.4	12.2	12.0
	UL	26.5	27.4	28.3	29.1	29.9	30.6	31.3	32.0	32.7	33.3	34.0	34.6
Delhi	F	20.3	20.6	20.9	21.2	21.4	21.6	21.8	22.0	22.1	22.3	22.4	22.6
ARIMA(1,1,1)	LL	17.8	17.9	18.0	18.1	18.2	18.3	18.4	18.5	18.7	18.8	18.9	19.0
	UL	23.0	23.7	24.2	24.7	25.0	25.4	25.6	25.9	26.1	26.3	26.5	26.7
<i>B. Very low production</i>													
Chhattisgarh	F	14.0	13.9	13.9	13.8	13.8	13.8	13.7	13.7	13.7	13.6	13.6	13.6
ARIMA(0,1,1)	LL	21.8	22.1	22.4	22.6	22.9	23.2	23.4	23.7	23.9	24.2	24.5	24.7
	UL	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.4	20.4	20.4	20.4	20.4
Jharkhand	F	19.2	19.3	19.4	19.4	19.5	19.5	19.6	19.6	19.7	19.8	19.8	19.9
ARIMA(0,1,0)	LL	17.6	17.3	17.1	16.9	16.7	16.5	16.4	16.3	16.1	16.0	15.9	15.8
	UL	20.8	21.3	21.6	21.9	22.2	22.5	22.8	23.0	23.3	23.5	23.7	24.0
Karnataka	F	26.6	26.6	26.6	26.7	26.7	26.7	26.7	26.8	26.8	26.8	26.9	26.9
ARIMA(1,1,0)	LL	23.2	22.6	22.1	21.7	21.3	20.9	20.6	20.3	20.0	19.8	19.5	19.3
	UL	30.4	31.2	31.9	32.5	33.1	33.6	34.2	34.7	35.1	35.6	36.0	36.5
Odisha	F	21.9	23.1	22.4	22.8	22.6	22.9	22.8	23.0	23.0	23.1	23.2	23.2
ARIMA(0,1,1)	LL	16.4	16.3	15.4	15.1	14.5	14.2	13.8	13.5	13.2	12.9	12.6	12.4
	UL	28.7	31.7	31.6	33.1	33.6	34.9	35.6	36.7	37.4	38.3	39.1	40.0
Uttarakhand	F	19.4	19.7	19.7	19.9	20.0	20.1	20.2	20.4	20.5	20.6	20.8	20.9
ARIMA(0,1,4)	LL	16.9	16.8	16.6	16.6	16.6	16.6	16.6	16.6	16.7	16.7	16.7	16.7
	UL	22.2	22.9	23.3	23.6	23.8	24.1	24.4	24.7	24.9	25.2	25.5	25.8
West Bengal	F	19.3	19.4	19.5	19.5	19.6	19.7	19.7	19.7	19.6	19.4	19.4	19.4
ARIMA(0,1,4)	LL	17.8	17.5	17.2	17.0	16.8	16.6	16.4	16.2	15.9	15.6	15.4	15.1
	UL	20.9	21.3	21.7	22.0	22.4	22.7	22.9	23.1	23.2	23.3	23.4	23.6
<i>C. Low production</i>													
Gujarat	F	20.2	20.2	20.3	20.3	20.3	20.3	20.3	20.4	20.4	20.4	20.4	20.4
ARIMA(1,1,1)	LL	17.5	17.1	16.7	16.4	16.1	15.9	15.6	15.4	15.2	15.0	14.8	14.6
	UL	23.2	23.8	24.3	24.8	25.3	25.7	26.1	26.5	26.8	27.2	27.5	27.9
Maharashtra	F	25.6	25.4	25.6	25.9	26.2	26.5	25.8	25.3	25.2	25.3	25.4	25.4
ARIMA(0,1,4)	LL	21.8	21.2	20.9	20.8	20.6	20.5	19.6	19.0	18.7	18.5	18.3	18.0
	UL	29.8	30.2	31.1	31.9	32.8	33.6	33.2	33.0	33.3	33.8	34.3	35.0
<i>D. Moderate production</i>													
Rajasthan	F	18.7	18.7	18.9	18.9	18.9	19.0	19.1	19.2	19.4	19.4	19.5	19.8
ARIMA(0,1,0)	LL	16.8	16.4	16.2	15.9	15.7	15.5	15.4	15.2	15.2	15.0	14.9	15.0
	UL	20.7	21.3	21.8	22.2	22.6	23.0	23.5	23.9	24.4	24.6	25.0	25.7
<i>E. High production</i>													
Haryana	F	18.6	19.0	19.2	19.4	19.5	19.7	19.8	19.9	20.0	20.1	20.3	20.4
ARIMA(1,1,1)	LL	14.3	14.3	14.4	14.5	14.5	14.6	14.7	14.8	14.8	14.9	15.0	15.0
	UL	23.9	24.6	25.1	25.4	25.7	25.9	26.1	26.3	26.5	26.7	26.9	27.0
MP	F	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	20.0
ARIMA(0,1,0)	LL	16.8	16.4	16.1	15.9	15.7	15.5	15.3	15.1	15.0	14.9	14.8	14.6
	UL	21.3	21.9	22.5	23.1	23.6	24.1	24.6	25.0	25.5	25.9	26.4	26.8

Cond.

Table 2 (Concluded)

Region & Model Fit	Level	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20
Punjab	F	19.3	19.5	19.6	19.7	19.9	20.0	20.1	20.2	20.3	20.5	20.6	20.7
ARIMA(1,1,1)	LL	15.4	15.4	15.5	15.6	15.7	15.7	15.8	15.9	16.0	16.0	16.1	16.2
	UL	23.9	24.2	24.5	24.7	24.8	25.0	25.2	25.4	25.5	25.7	25.9	26.1
<i>F. Very high production</i>													
Uttar Pradesh	F	18.5	18.5	18.6	18.7	18.7	18.8	18.8	18.9	18.9	19.0	19.1	19.1
ARIMA(0,1,0)	LL	17.1	16.8	16.6	16.4	16.3	16.2	16.0	15.9	15.8	15.7	15.6	15.6
	UL	19.9	20.3	20.6	20.9	21.1	21.4	21.6	21.9	22.1	22.3	22.5	22.7

F, Forecast; LL, Lower Limit; UL, Upper Limit

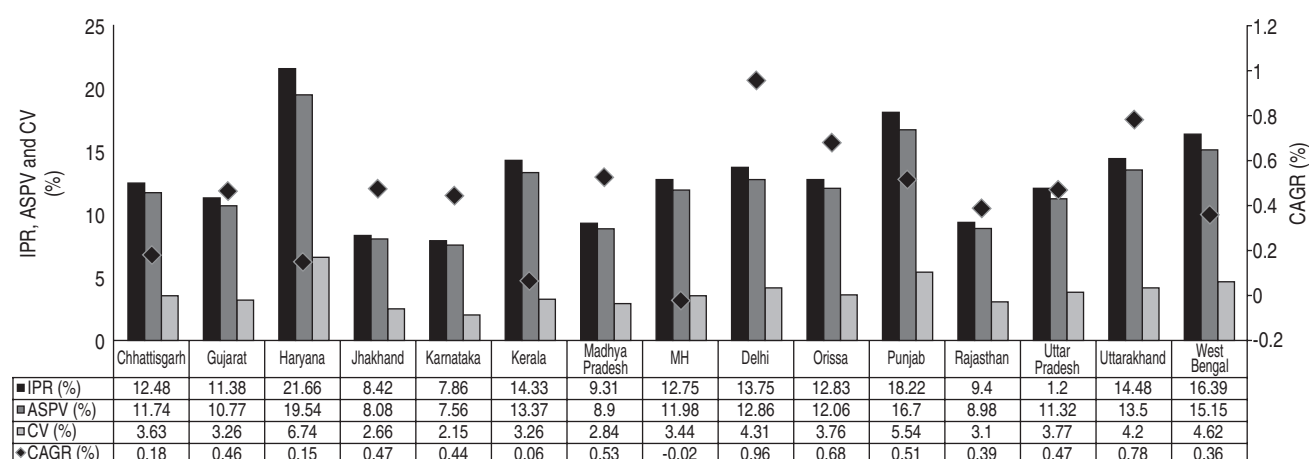


Fig 2 Growth and variation in seasonal price index.

there will be huge supply of wheat in the market which pulls down the prices. The gross returns to storage of wheat was found to be 5% in six months, which meant storing of produce was not remunerative to the farmers. The estimated annual growth rate in seasonal price indices was found to be positive for all the states except Maharashtra. The monthly price forecast for the selected states have been made from July 2019 to June 2020 using ARIMA model. Forecasted prices were found to be higher for low or negligible wheat producing states such as Kerala and Karnataka; and lower for higher wheat producing states like Haryana, Punjab, Madhya Pradesh and Uttar Pradesh. In a majority of the cases, the forecasts were significant with minimum errors indicating the importance of decision making criteria. Effective dissemination of market information such as price forecast to stakeholders can play a great role in farm business decisions and checking price volatility. Market intelligence on agricultural commodities would direct the stakeholders to regulate production, consumption and marketing decisions and conduct the farm business more efficiently.

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