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# Forecasting onion price for Varanasi market of Uttar Pradesh, India

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ABSTRACT

The onion crop is widely seen as the poor man's vegetable, has the power to change electoral results (Anonymous 2019). In India Onion (*Allium cepa*) is cultivated in an area of 12.7 lakh ha and produces 215.64 lakh ton. In Uttar Pradesh it is cultivated in an area of 0.25 lakh ha producing 4.23 lakh ton. The study was done during 2020 at IARI, New Delhi. Development of appropriate price forecasting mechanism and dissemination among the farmers would help alleviate problems faced by the farmers and consumers alike. The average price of onion throughout the year, during the study period of 2015-2020, has been fluctuating between ₹ 900–2200/quintal. The ARIMA (0,1,2)(1,0,0)[52] and ARFIMA(3,0,0)-sGARCH (1,1) model were found to be best fit model. However, on the basis of MAPE, MSE, RMSE and Theil's U statistics it was observed that the ARMA-GARCH model outperformed the ARIMA model.

**Keywords:** ARIMA, GARCH, Onion price, Price forecasting

The onion - ubiquitous in Indian cooking and is widely seen as the poor man's vegetable, has the power to change electoral results (Anonymous 2019). In Uttar Pradesh it is cultivated in an area of 0.25 lakh ha producing 4.23 lakh ton. In Uttar Pradesh it is cultivated in *kharif* (sowing in June-July and harvesting in October-November) and in *rabi* (with sowing in October-November and harvesting in May-June). Rabi and two other harvests, *kharif* (harvested after October) and late *kharif* (harvested in January- March) feed the market round the year. However, the year 2018–19 has seen large volatility in onion prices due to supply shocks resulting due to poor yield, late sowing, spoilage of stored crop due to heavy rains (Biswas 2019, Gettleman *et al*. 2019 and Satish 2018). To overcome the situation government had to stop export of onions, release onion stock at cheaper rate, import from Afghanistan, Egypt, Turkey and Iran (Jain 2019 and Biswas 2019). There exists significant information asymmetry between market participants leading to poor price discovery in the value chain, which often results in economic losses for the farmers (Kumar *et al*. 2020). To overcome information gap, governments, NGOs, and the business sectors are leveraging different information and communication technologies (ICT) to disseminate market information to farmers (Chang and Tang 2018 and Mitra *et al.* 2018). Development of appropriate price forecasting mechanism and dissemination among the farmers would help alleviate problems faced by the farmers and consumers alike. Auto-Regressive Integrated Moving Average (ARIMA) models (Box *et al*. 1994) have been appreciated for crop yield or any other agricultural production forecasting. Paul *et al.* (2009) applied GARCH model for forecasting the spices export from India and concluded that it outperforms the usual ARIMA model. Recent research activity shows that combining different model enhances the accuracy of forecasting as compared to individual model. Therefore, the study was therefore taken up with following specific objectives: 1) To test and identify appropriate statistical model out of ARIMA and ARMA-GARCH models for forecasting prices of onion, and (2) to forecast prices of onion for Varanasi market of Uttar Pradesh, India and suggest policy implications.

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## MATERIALS AND METHODS

Present study was carried out during 2020 at IARI, New Delhi using the weekly price data of onion for Varanasi market of Uttar Pradesh, India. The time series data on price of onion was taken from the website http:/agmarknet.gov.in. The data for the period March 2010 to 23 Feb 2019 was taken as training set and for the period 2$^{nd}$ March 2020 to 18$^{th}$ May 2020 was taken as test period.

An ARIMA model is given by equation 1 (Paul *et al*. 2015).

$$Ø(B)(1-B)^dY_t = θ(B)ε_t \quad (1)$$

Where Autoregressive parameter= Ø(B)

$Ø(B) = 1 - Ø_1B – Ø_2B^2 - ……. - Ø_PB^P$

Moving average parameter= θ(B)

$θ(B) = 1 – θ_1B – θ_2B^2 ….. θ_PB^P$

$ε_t$= White noise or error term

D= Differencing term

B= Backshift operator, i.e. $B^aY_t = Y_{t-a}$

There are three types of time series models such as Autoregressive Moving Average (ARMA) model, Autoregressive Conditional Heteroscedasticity (ARCH) model and Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model. In 1976, Box *et al*. (1994), proposed ARIMA (m,D,n) models where m is the number of autocorrelation terms, D is the number of differencing elements and n is the number of moving average terms. The letter I in ARIMA used to differentiate when the series are not stationary. However, when the time series is stationary, we can model it using three classes of time series process: autoregressive (AR), moving-average (MA) and mixed autoregressive and movingaverage (ARMA).

There are two time-varying volatility models that ispopular among researchers: ARCH model and GARCH model. The aim of ARCH model that was developed by Engle (1982) is to predict the conditional variance of return series. Although, the ARCH model is simple and widely used among researchers, but it has weaknesses, when modeling volatility using ARCH, there might be a need for a large values of the lag q, hence a large number of parameters to be estimated. This may result the difficulties to estimate parameters. After four years an extension from ARCH model was developed by (Bollerslev 1986) namely GARCH model. The GARCH model is more parsimonious (use fewer parameters) than ARCH model (Poon and Granger, 2003)

*Model selection*: When comparing among different specification of ARMA-GARCH models, then we select an appropriate model based on Akaike Information Criteria (AIC), the corrected Akaike Information Criteria (AICC), Schwarz's Bayesian Information Criterion (SBC) and the Hannan-Quinn Information Criterion (HQC).

The accuracy of the forecasted model is assessed with use of mean absolute percentage error, mean squared error, root mean square error and Theil's inequality coefficient.

## RESULTS AND DISCUSSION

The statewise area, production and productivity was analysed and it is revealed that three states namely Maharashtra, Madhya Pradesh and Karnataka account for about 60% of area and production of the country. Uttar Pradesh accounts for 2.13% of total area and 1.88% of countries production. The requirement (38.76 lakh ton) and availability (4.40 lakh ton) of onion across states is estimated and it is revealed that Uttar Pradesh is net deficit state and it needs 34.36 lakh ton of onion from other states. The internal production of Uttar Pradesh comes to the market during the period March. The arrival of local produce in the market will have impact on arrival and prices of onion in Varanasi market of Uttar Pradesh. Except for the small window when the local produce is coming to market, in all other period the due to gap in supply and demand it is the price which will dictate the arrival of onion in the Varanasi market.

The monthly average price and arrivals of onion during the period 2015–20 for Varanasi market is computed (Fig 1). It is observed that during the period Sept-Oct there is peak in arrival of onion and other is during the months of

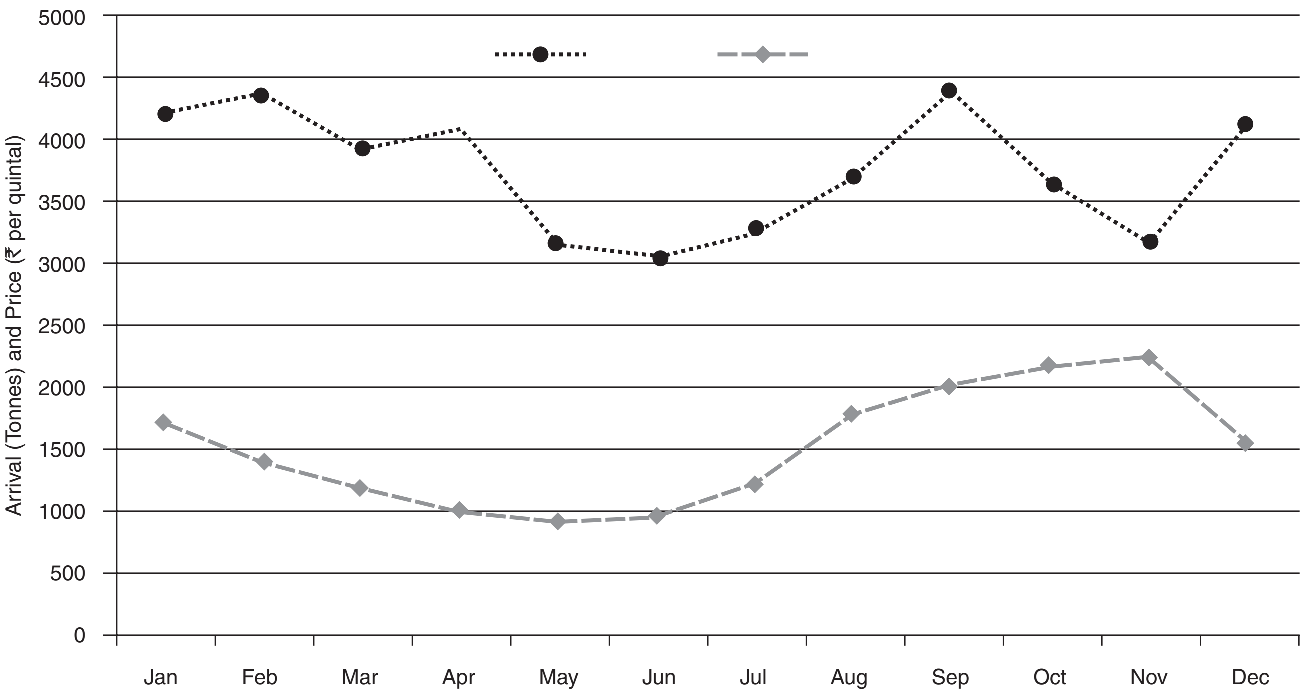


Fig 1 Price and arrival of onion in Varanasi market, Uttar Pradesh, 2015-20

Dec to Feb there is surge in arrival of onion. The surge not only is a reflection of harvest in and around Varanasi but is also influenced by harvests in other parts of the country. It is also a reflection of higher demand for onion during these periods. The price of onion follows similar trend except during the period January–March. The arrival of onion on an average has been hovering around 3000–4500 ton throughout the year.The arrivals are less during the period June-July, primarily due to availability of local produce which comes as a result of *rabi* harvest. Local produce is sold through the local markets and therefore the arrivals are not reflected in the major mandi's (state government managed Agricultural Produce Market Committee (APMC) markets).The average price of onion throughout the year, during the study period of 2015–2020, has been fluctuating between ₹ 900–2200/q. The price of onion is low during May-July period due to arrival of local produce from *rabi* harvest which is bereft (though it is there is very minimal) of transportation cost, storage cost, handling charges. The *rabi* onion produce is stored by the farmers and is released slowly in later parts of year foreseeing the price prevailing in the APMC market. It is essential for the farmers to know what would be future price of onion during different times of the year to be able to realize maximum income. This will help the farmers to decide the area to be allocated under the crop. It will also help them to decide how much of the produce to store and how much and when to release it in the market. The central and state government can decide when and how to intervene in the market. The government has been doing market procurement of onion through NAFED and selling at regulated prices to needy people. The government has also been importing the onion from other countries like Afghanistan, Iran, etc.

The study analysed the onion price forecast using the models ARIMA and ARMA-GARCH. The seasonal ARIMA (0,1,2)(1,0,0)[52] emerged outto be a better fit model among the class of models of ARIMA on the basis of AIC value and the significane of the parameters (Table 1). The strength of the mdoel was assessed with the Ljung-Box test. The non significance of the test shows that the chosen model is a good model. To evaluate the performance of ARMA-GARCH model the study assessed different variants of GARCH like eGARCH, fGARCH, etc.The ARFIMA (3,0,0)-sGARCH(1,1) emerged out to be the best fit models on the basis of various tests and the significane of the parameters (Table 2). To test the sutability of model fit, the Ljung Box test for standardised residuals and standardised squared residuals were performed and the result showed that there is no serial auto-correlation. In the present study, ARCH-LM test is not significant at 5% level of significance therefore we accept the null hypothesis that the residuals of ARIMA model are homoscedastic. The Nyblom stability test reveals that there is no structural change within a time series. The probability values of the Engle & Ng sign bias tests are greater than 0.05% which means that the null hypothesis is accepted. Thus, it is revealed that the model is not specified properly.The sign bias test is non-significant at 5% level. The adjusted pearson goodness of fit test reveals that the distribution is identical. Thus, the selected ARMA-GARCH model is a best fit model according the different tests used to assess the model.

Table 1 Estimates of ARIMA model for forecasting onion price of Varanasi market

| | Coefficient | Standard error | Z value | Pr(>z) |
|---|---|---|---|---|
| ARIMA Model: (0,1,2)(1,0,0)[52] | | | | |
| MA(1) | 0.316 | 0.046 | 6.910 | 4.833e-12*** |
| MA(2) | 0.087 | 0.044 | 1.985 | 0.047* |
| SAR(1) | -0.011 | 0.059 | -0.179 | 0.858 |
| $\sigma^2$ = 50366; LogLikelihood=-3544.61 | | | | |
| AIC=7097.2; AICc=7097.29; BIC=7114.2 | | | | |
| Ljung-Box test | | | | |
| Q*=78.81, df=101, P-value=0.95; model df=3; total lags used=104 | | | | |

Note: '***' & '*' indicates 1% and 5% level of significance

The accuracy of the onion price forecast models i.e., ARIMA and ARFIMA-GARCH was tested using the statistical tools like mean absolute percentage error (MAPE), mean squared error (MSE), root mean square error (RMSE) and Theil's U statistics (Table 3). It is observed that, all of the statistical measures as stated above indicated the superiority of ARFIMA-GARCH model. The MAPE value was 27.37% for ARFIMA-GARCH while the same was 39.38% for ARIMA model. The Theil's U statistics was 0.54 for ARFIMA-GARCH while the same was 0.68 for ARIMA. It is thus stated that for forecasting the price of onion for Varanasi market the ARFIMA-GARCH model should be used instead of the ARIMA model (Fig 2, 3).

The weekly onion price forecast for the Varanasi market is made for the period 18$^{th}$ May 2020 to 25$^{th}$ Jan 2021. It is observed that according to ARFIMA-GARCH model the price of onion is likely to fall from ₹ 1650 per quintal in 18$^{th}$ May 2020 to ₹ 1311/q by 25$^{th}$ Jan 2021. The value associated with sigma is likely to increase from

Table 2 Estimates of ARMA-GARCH onion price forecast model for Varanasi market

| | Estimate | Standard error | t value | Pr(>t) |
|---|---|---|---|---|
| Model: ARFIMA (3,0,0)-sGARCH (1,1) | | | | |
| Mu | 874.436 | 9.639 | 9.049 | <0.0001 |
| AR(1) | 1.424 | 0.063 | 22.767 | <0.0001 |
| AR(2) | -0.488 | 0.088 | -5.545 | <0.0001 |
| AR (3) | 0.048 | 0.015 | 3.204 | 0.0013 |
| Omega | 1183.257 | 306.013 | 3.867 | <0.0001 |
| Alpha1 | 0.485 | 0.089 | 5.459 | <0.0001 |
| Beta1 | 0.514 | 0.053 | 9.619 | <0.0001 |
| Shape | 3.134 | 0.251 | 12.475 | <0.0001 |
| LogLikelihood= -3160.33 | | | | |
| AIC=12.186 BIC=12.251 SIC=12.185 HQIC=12.212 | | | | |

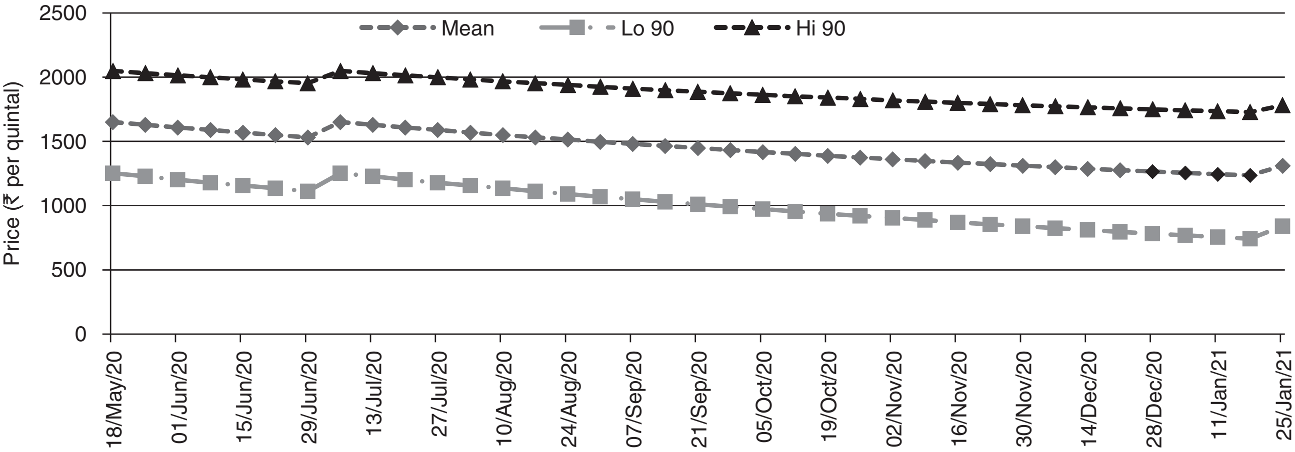


Fig 2 Forecast of onion price for Varanasi market using ARFIMA-GARCH for 2020-21

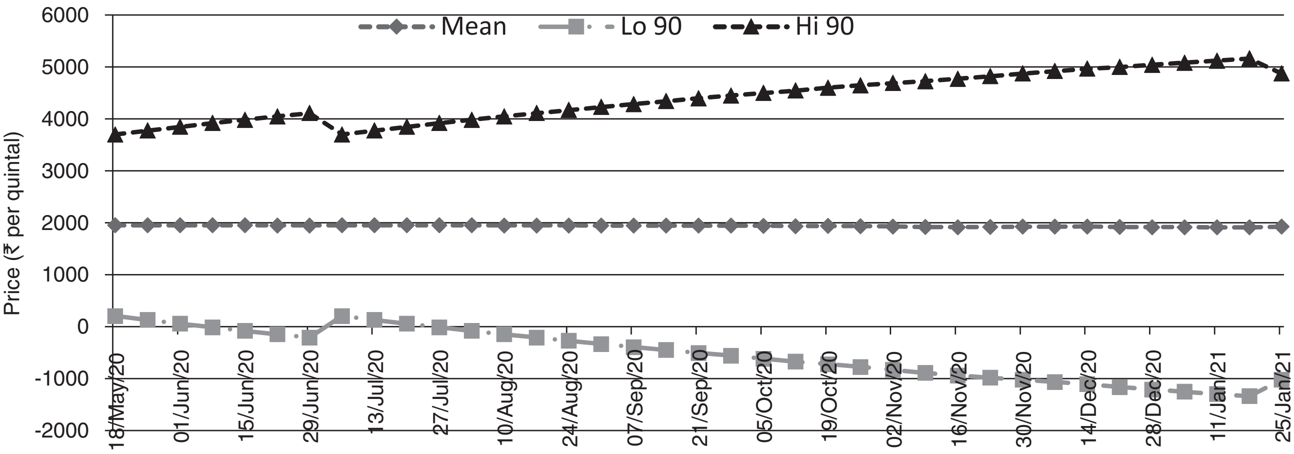


Fig 3 Forecast of onion price for Varanasi market using ARIMA for 2020-21

Table 3 Accuracy test of estimates for onion price forecast of ARIMA and ARFIMA-GARCH models for Varanasi market, India

| Week starting from | Actual value | ARMA-GARCH | | ARIMA |
|---|---|---|---|---|
| | | Mean | Sigma | Point estimate |
| 2nd Mar 2020 | 1971.7 | 1927 | 214.9 | 1953.0 |
| 9th Mar 2020 | 1910.0 | 1895 | 217.5 | 1950.8 |
| 16th Mar 2020 | 1837.0 | 1866 | 220.1 | 1950.1 |
| 23rd Mar 2020 | 1845.0 | 1839 | 222.7 | 1950.5 |
| 30th Mar 2020 | 1855.0 | 1813 | 225.2 | 1950.5 |
| 6th Apr 2020 | 1667.9 | 1788 | 227.7 | 1951.1 |
| 13th Apr 2020 | 1364.3 | 1763 | 230.2 | 1950.6 |
| 20th Apr 2020 | 1185.7 | 1739 | 232.6 | 1950.3 |
| 27th Apr 2020 | 1050.0 | 1716 | 235.1 | 1949.8 |
| 4th May 2020 | 1040.0 | 1693 | 237.4 | 1949.8 |
| 11th May 2020 | 905.0 | 1671 | 239.8 | 1950.4 |
| MAPE | | 27.37% | | 39.38% |
| MSE | | 176464.6 | | 343077.9 |
| RMSE | | 420 | | 585.7 |
| Theil's U statistics | | 0.54 | | 0.68 |

₹ 242quintal in 18th May 2020 to ₹ 286.4/q by 25th Jan 2021. The ARIMA model shows marginal decline in price of onion from 1950.2–1922.2 per q. The price of onion on higher side of the mean price of onion with 90% confidence is also estimated by both the ARIMA model and ARFIMA-GARCH. It is observed that the estimates by ARIMA model show that the price of onion is likely to increase from ₹ 3607.8 in 18th May 2020 to ₹ 4869.4 on 25th Jan 2020. While the estimates on lower side of mean onion price with 90% confidence is ₹ 202.6/q in 18th May 2020 and is likely to fall to ₹ -1025.1/q. It is observed that the estimates by ARFIMA-GARCH model reveal the price of onion to be ₹ 2048/q on 18th May 2020 and is likely to fall to ₹ 1782/q by 25th Jan 2021. On the lower side of the mean forecast the price is estimated to be ₹ 1252/q for 18th May 2020 and is likely to fall to ₹ 840/q by 25th Jan 2021.

Thus, on comparison of the ARIMA and ARFIMA-GARCH models it can be stated that the ARfIMA –GARCH model looks plausible and gives far more acceptable results. The forecast of ARIFMA-GARCH model gives an encouraging picture of onion farmers. The risk takers can expect to earn a good price all through the study period up to 25th Jan 2021. The risk adverse farmers also can be certain to get a respectable price for their produce. The fall in price with time is not much and therefore the farmers can store the produce and release it slowly and slowly and also allocate more area under the crop. The storage of onion is essential since if all the produce is brought to market would lead to fall in prices. This also demands creation of suitable storage infrastructure in the region. The farmers practice storage of produce as it serves as ready cash to meet any eventuality or day to day needs. The forecasted price is also not a single price rather it is shown in terms of a bandwidth in which it is expected to fall at a given point of time. The farmers may encounter any price within this bandwith on a particular day. What price the farmer would encounter would depend on so many other factors like his bargaining power, size of lot, his business acumen, etc. The result of the study would help extension agencies to guide the farmers with respect to allocation of resources to the crop as also when and what volume of the produce to be brought to market. They can also collectivise the farmers in the form of self help groups and farmers producer organizations who can better be in a position to use the price information to realize better income (Varkey *et al*. 2013 and Manaswi *et al*. 2020). The price information need to be disseminated to farmers using cellphones or other low-cost IT based interventions which will increase farm-gate prices and output sales which in turn could boost agricultural productivity and farmer incomes (Mitra *et al*. 2018, Chen and Tang 2015).

India is second largest producer of onion after China with a production of 215 lakh ton but due to cyclic and occasionally volatile nature of its prices, it has great implications on both consumers and producers. It is important to develop an appropriate model for forecasting the prices of onion. The study examined two models, i.e. ARIMA and ARFIMA-GARCH. The ARIMA (0,1,2)(1,0,0)[52] was the best fit model among various ARIMA models on the basis of criteria of lowest AIC, BIC value. The parameters of the ARIMA model have emerged significant. The model was found to be best fit model on the criteria of Ljung-Box test. Similarly the ARFIMA (3,0,0)-sGARCH(1,1) model was found to be best fit model. However, on the basis of MAPE, MSE, RMSE and Theil's U statistics it was observed that the ARMA-GARCH model outperformed the ARIMA model. The forecast also seemed more plausible with ARMA-GARCH model. The forecast value with ARMA-GARCH model showed a consistent fall in the price of onion from ₹ 1650 in 18th May 2020 to ₹1311 by 25th Jan 2021. The farmers would find the forecast very useful in order to decide when to sell and how long to store the produce. The extension agencies can use the information thus generated to advise the farmers to take appropriate decision. The government can plan to protect the consumers and also the producers. It can take decision as to whether to resort to market intervention, to promote imports, to boost export, etc. All these decisions would be now based on facts which are made available from the forecasting model.

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