



Forecasting price index of finger millet (*Eleusine coracana*) in India under policy interventions

ACHAL LAMA*, K N SINGH, RAVINDRA SINGH SHEKHAWAT, KRISHNA PADA SARKAR
and BISHAL GURUNG

ICAR-Indian Agricultural Statistics Research Institute, New Delhi 110 012, India

Received: 08 January 2019, Accepted: 11 September 2019

ABSTRACT

Millets are the major substitute for cereals such as rice and wheat. For developing country like India, millets hold immense importance as the cost of production is low and has high nutritional values. Various policy interventions are made by government of India from time to time to popularise its consumption and production. Few major policy interventions were made in last decade and inclusion of coarse cereals under Food Security Bill is one among them. Keeping this in mind, the present study was carried out at ICAR- Indian Agricultural Statistics Research Institute, New Delhi during 2018 to know the impact of policy interventions on the price index of Ragi. Further, we have introduced these interventions in the model using structural break analysis. The volatile Ragi price index series were modelled and forecasted using popular class of Generalised Autoregressive Conditional Heteroscedastic (GARCH) models and its asymmetric extensions. The results indicated improvement in modelling and forecasting performance of the models after incorporation of the policy interventions. Study has empirically highlighted the positive impact of policies introduced.

Key words: GARCH, Policy interventions, Structural break, Volatile

Owing to diverse agro-climatic regions, a number of millets are grown across India. Despite of almost equal nutritional value, acreage under different millets varies significantly with each other. The most important concern about millets is the significantly declining acreage under Sorghum, Pearl millet and Ragi. The reasons behind the decline in acreage under millet can be attributed to stagnant productivity and lower return due to inadequate market prices. Market prices and appropriate government interventions are the major driving forces for farmers to cultivate any crop in suitable agro-climatic region. Recently, in last decade government has announced many major policies breakthrough in form of Initiatives for Nutritional Security through Intensive Millets Promotion (INSIMP) and Accelerated Fodder Development Programme (AFDP) in the year 2011, inclusion of coarse cereals under Food Security Bill and inclusion of coarse cereals under National Food Security Mission during XII Plan (2014-15) during 2013 (GOI 2014). These policies were launched with specific target of enhancing production of millets in the country with high anticipation of positive impact on millets production in India. We could not find any study which has documented the impact of these policies in modelling and forecasting

the prices of millets as whole and on Ragi specifically. Hence, in this study we have attempted to capture the impact of these policies on price index of Ragi, and also model and forecast its price index by incorporating the policy interventions in the model to improve the accuracy of the forecast. Incorporation of these policy interventions in a model is possible statistically using the change point analysis technique. The agricultural commodity prices exhibit a fair degree of variation in them, and Ragi being no exception also has this inherent property. The popular generalized autoregressive conditional heteroscedastic (GARCH) model is being applied to such type of data sets for decades now (Li *et al.* 2017) along with its asymmetric extensions (Lama *et al.* 2015, Ding *et al.* 2018). This study uses the Pruned Exact Linear Time (PELT) algorithm (Killick *et al.* 2012) for detection of multiple change points in the series.

MATERIALS AND METHODS

The models explored in this study are mainly the GARCH models along with its asymmetric extensions. Approach followed in this investigation is three staged. In the first stage we modelled the mean using Autoregressive Integrated Moving Average (ARIMA) and then in second stage volatility was captured using GARCH models. Finally we have incorporated the policy interventions in the model using change point analysis technique. The study was carried out during 2018 at ICAR- Indian Agricultural Statistics

*Corresponding author e-mail: chl1m6@gmail.com

Research Institute, New Delhi.

ARIMA model

In an autoregressive integrated moving average model, the future value of a variable is assumed to be a linear function of several past observations and random errors. That is, the underlying process that generate the time series has the form:

$$y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \dots + \theta_q \varepsilon_{t-q} \quad (1)$$

where, y_t and ε_t are the actual and random error at time period t , respectively; ϕ_i ($i=1, 2, \dots, p$) and ($j=1, 2, \dots, q$) are model parameters. p and q are integers and referred to as orders of the model. Errors ε_t are assumed to be independently and identically distributed with a mean zero and a constant variance of σ_ε^2 .

GARCH Model

Bollerslev (1986) proposed the Generalized ARCH (GARCH) model in which conditional variance is also a linear function of its own lags and has the following form:

$$\varepsilon_t = \xi_t h_t^{1/2} \dots \dots \dots$$

$$h_t = a_0 + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 + \sum_{j=1}^p b_j h_{t-j} \quad (2)$$

where, $\xi_t \sim N(0,1)$. A sufficient condition for the conditional variance to be positive is

$$a_0 > 0, a_i \geq 0, i = 1, 2, \dots, q, b_j \geq 0, j = 1, 2, \dots, p$$

The GARCH (p, q) process is weakly stationary if and only if

$$\sum_{i=1}^q a_i + \sum_{j=1}^p b_j < 1$$

The conditional variance defined by (2) has the property that the unconditional autocorrelation function of ε_t^2 ; if it exists, can decay slowly.

EGARCH Model

The EGARCH model (Nelson 1991) was developed to allow for asymmetric effects between positive and negative shocks on the conditional variance of future observations. Another advantage, as pointed out by Nelson and Cao (1992), is that there are no restrictions on the parameters. In the EGARCH model, the conditional variance, h_t , is an asymmetric function of lagged disturbances. The model is given by

$$\ln(h_t) = a_0 + \frac{1 + b_1 B^1 + \dots + b_{q-1} B^{q-1}}{1 - a_1 B^1 + \dots + a_p B^p} \bar{g}(\varepsilon_{t-1}) \quad (3)$$

where,

$$g(\varepsilon_t) = (\theta + \gamma) \varepsilon_t - \gamma E(|\varepsilon_t|), \text{ if } \varepsilon_t \geq 0, \\ = (\theta - \gamma) \varepsilon_t - \gamma E(|\varepsilon_t|), \text{ if } \varepsilon_t < 0,$$

B is the backshift (or lag) operator such that

$$Bg(\varepsilon_t) = g(\varepsilon_{t-1})$$

The EGARCH model can also be represented in another way by specifying the logarithm of conditional variance as

$$\ln(h_t) = a_0 + b \ln(h_{t-1}) + a \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \quad (4)$$

This implies that the leverage effect is exponential, rather than quadratic, and that forecasts of the conditional variance are guaranteed to be nonnegative.

TGARCH model

Zakoian (1994) proposed TGARCH model to accommodate asymmetric pattern of volatility. This model instead of conditional variance, conditional standard deviation is modelled. The model has the following form

$$\sqrt{h_t} = \bar{c} + \sum_{i=1}^q a_i^+ \varepsilon_{t-i}^+ + \sum_{i=1}^q a_i^- \varepsilon_{t-i}^- + \sum_{j=1}^p b_j \sqrt{h_{t-j}} \dots \dots \dots (5)$$

$$\text{where, } \varepsilon_{t-i}^+ = \begin{cases} 0, & \text{if } \varepsilon_{t-i} \leq 0 \\ \varepsilon_{t-i}, & \text{if } \varepsilon_{t-i} > 0 \end{cases} \text{ and}$$

$$C > 0, a_i \geq 0, i = 1, 2, \dots, q, b_j \geq 0, j = 1, 2, \dots, p.$$

In this model the positive and negative shocks are modeled separately, this allows the researchers to understand the impact of shocks differently.

GARCH model with structural Break

Lamoureux and Lastrapes (1990) showed that standard GARCH models overestimate the underlying volatility persistence and structural breaks should be incorporated into a GARCH model to get reliable parameter estimates. The augmented GARCH model with structural breaks as:

$$h_t = a_0 + d_1 D_1 + d_2 D_2 + \dots + d_n D_n + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 + \sum_{j=1}^p b_j h_{t-j} \quad (6)$$

where, following Aggarwal, Inclan and Leal (1999) $D_1, \dots, D_n$, are the set of dummy variables taking a value of one from each point of structural break in variance onwards and zero elsewhere. Following the above mentioned procedure Ewing and Malik (2016) modeled the series of crude oil prices with and without considering the change-points. Their results clearly indicate the improvement in the estimates of the model after incorporating change-points in the model. In similar way EGARCH model was also modified to incorporate the effect of structural break for oil prices (Ewing and Malik 2017). In this study, the above mentioned methodology is applied using SAS 9.4 software to the data set.

Data description

The price index of Ragi was collected from Office of the Economic Adviser, Ministry of Commerce, Government of India (www.eaindustry.nic.in) and it contained 160 data points (January, 2005 to April, 2018). The time plot of the

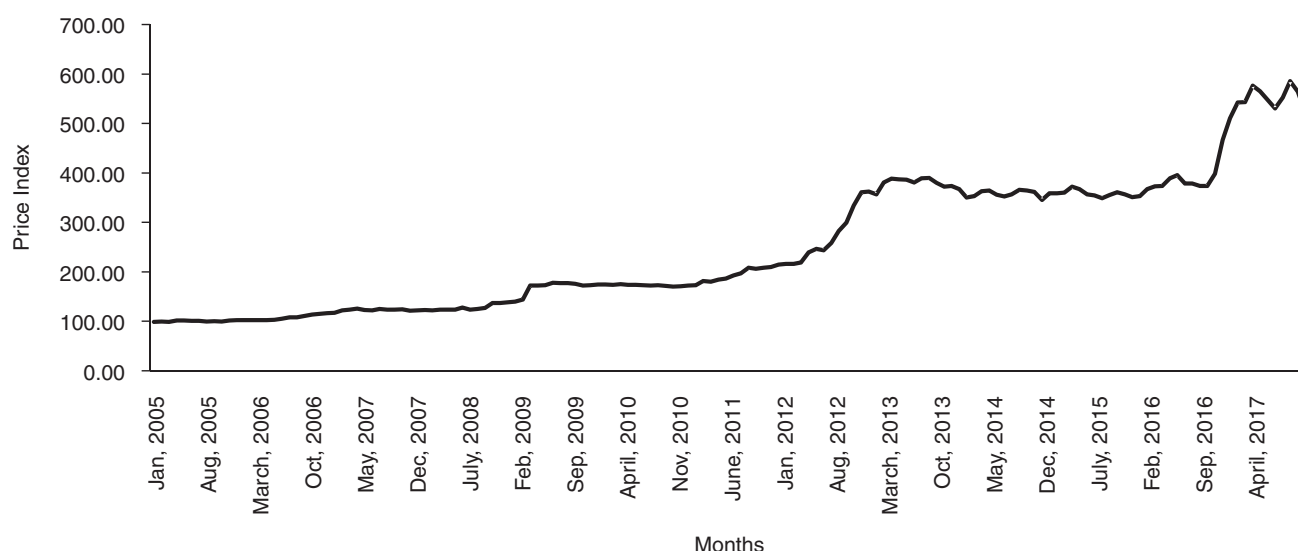


Fig 1 Time plot of Ragi price index.

series (Fig 1) is indicative of the presence of volatility at different time epochs. At closer look into the plot we can visually identify two distinct change-points at August, 2012 and September, 2016. Further, on obtaining the descriptive statistics of the series we observed asymmetry in the series (Skewness: 0.56). All these factors encouraged us to employ the above mentioned methodology to price index series of Ragi and investigate the results obtained.

RESULTS AND DISCUSSION

To begin with we analysed the price index of Ragi during the period 2005 to 2011 and from 2012 to 2017. The series was split to have an idea regarding the scenario pre and post implementation of the policies. It was interesting to note that the price index of Ragi have increased significantly during the period 2012 to 2017, which is post the implementation of the policies. The differences in the mean as well as standard deviation values of these two periods are significant. Mean and standard deviation value of Ragi during 2005-2011 was 142.25 and 34.85 respectively, which increased to 384.69 and 86.61 during 2012-2017. The increase in mean and standard deviation was 2.78 times and 2.48 times respectively. The variability in the Ragi series for the two time periods has made the series volatile in nature.

The time series data of Ragi was then analyzed according to steps defined in the methodology section. The level series was found to be non-stationary hence it was differenced once to obtain stationarity. After obtaining stationary series we started with identification of mean model using ARIMA class of model. The identified mean model with drift was ARIMA (1,1,2) with parameter estimates found to be significant at 5%. Next we checked the residuals for white noise property using Q statistic. The value of Q statistic obtained leads to non-acceptance of null hypothesis of uncorrelated errors. We also tested the residuals for presence of heteroscedasticity using ARCH-LM test up

to lag 12. The significant values of Q and LM statistic up to lag 12 confirmed the presence of heteroscedasticity in the residual series. With substantial evidence of volatility in the series we further model the series using symmetric and asymmetric GARCH models. We have used GARCH, EGARCH and TGARCH models to the data set. The models were selected based on the lowest AIC and SBC criterion. Parameter estimates of the selected models are reported in Table 1.

Looking into the estimates of GARCH model the coefficient of ARCH effect (a) is itself greater than 1. This clearly violates the stationary assumption of GARCH model which demands the sum of ARCH and GARCH (b) coefficients to be strictly less than 1. Thus we can infer that GARCH model is producing unstable estimates. Such result is mainly due to the presence of asymmetry in the series. Further, we investigate the series using EGARCH model. The parameter estimates of the model were found to be statistically significant. Hence, we were able to achieve a concrete base to our assumption of asymmetry in the

Table 1 Parameter estimates of the model

Model	Parameters				
	a	b	γ	a_i^+	a_i^-
GARCH	1.01 (0.25)	0.49 (0.07)			
EGARCH	2.85 (0.23)	0.17 (0.06)	-0.17 (0.08)		
TGARCH		0.52 (0.08)		1.17 (0.30)	0.73 (0.36)
GARCH-SB	1.05 (0.26)	0.47 (0.08)			
EGARCH-SB	4.12 (0.27)	0.12 (0.04)	0.12 (0.06)		

Note: Values in the parenthesis are standard errors

data set. Once the asymmetry in the series is captured, it is essential to identify the impact of negative and positive shocks to the series. This cannot be inferred from EGARCH model; hence we turned our attention towards TGARCH model which models both negative and positive shocks to volatility differently. The parameter estimates of the model were significant and revealed different level of effect of positive as well as negative shocks. The magnitude of positive shock (a_i^+) to volatility was 1.17 and that of negative shock (a_i^-) was 0.73.

The other aspect of this study was to identify the change-points, accordingly change points were identified using PELT algorithm. Identified change-points are 50 (Feb, 2009), 87 (March, 2012), 91 (July, 2012), 142 (Oct, 2016). Although the method had identified 4 change points, but for analysis we have used only 2 change-points (March, 2012 and October, 2016). The choice of change-points was made looking into the implementation of the policies. Major policy intervention in India regarding food security has been carried out in 2011-12 (National food security bill passed in 2014) and it was expected that the positive impact in price index will be observed after 2-3 year. The GARCH and EGARCH model were modified for incorporating the change-points in them. Inclusions of change points statistically have economic importance as they signify the impact of policy intervention in the model. Thus we would call GARCH-SB model for the GARCH model with change-points, on similar lines the EGARCH-SB. The series was modeled using these two modified models and parameter estimates are reported in Table 1. Noteworthy, is the fact that the estimates have changed after incorporation of the change-points as well as the AIC and SBC values have lowered. This justifies the modified approach of modeling the series by GARCH-SB and EGARCH-SB models. Finally, we forecasted the series from November, 2017 to April, 2018 (6 months) using six models ARIMA, GARCH, EGARCH, TGARCH, GARCH-SB and EGARCH-SB. The forecasted values are reported in Table 2. The forecasting efficiency of these models was

compared using RMSE (Root Mean Square Error), MAPE (Mean Absolute Percentage Error) and VAPE (Variance of Absolute Percentage Error) criterion.

TGARCH model was found to be the best model for modeling and forecasting the Ragi price series, as it has lowest RMSE (19.18), MAPE (3.47) and VAPE (2.38) values along with lowest AIC (1060.87) and SBC (1082.13) values among all the models. The original and predicted values obtained using TGARCH model is depicted in Fig 2. The figure gives an idea regarding the appropriateness of the selected model for the Ragi price series.

GARCH model closely followed TGARCH model and then EGARCH-SB model. Another, significant note related to EGARCH models is the fact that its modeling and forecasting capabilities improves with incorporation of the change-points in the model. We restrict our discussion with regard to GARCH model as the parameter estimates of the model are non-stationary, even after incorporating the change-points. The ARIMA model had poor forecasting efficiency among the six models owing to its linearity nature.

The other major thrust area of this study was to understand the impact of the major policies introduced by Government during the period 2011-2015. Hence accordingly compound growth rate (CGR) in WPI of Ragi was calculated during 2005-2014 and 2015-2017 which were found to be 1.29 and 1.57% respectively and statistically significant during both the periods. CGR for the entire period of study (2005-2017) was observed to be 1.20%. It is evident from CGR that post the implementations of the policies CGR has increased substantially and increase in mean prices (2012-2017) has already been discussed.

This study empirically highlights three major findings. Firstly, for asymmetric volatile time-series data EGARCH and TGARCH models are efficient as compared to simple GARCH model. Secondly, incorporation of policy interventions in form of change-points in the model improves its modeling and forecasting capabilities which is indicative by the results obtained from EGARCH model. Finally,

Table 2 Forecast obtained from models for Ragi price index series

Months	Original series	Forecasted values from models					
		ARIMA	GARCH	EGARCH	TGARCH	GARCH-SB	EGARCH-SB
Nov, 2017	485.67	508.04	508.65	508.90	507.73	509.00	508.03
		(10.50)	(43.06)	(18.21)	(33.36)	(43.34)	(32.89)
Dec, 2017	486.34	508.45	502.46	504.58	501.53	502.96	502.00
		(19.24)	(52.84)	(26.01)	(38.41)	(53.51)	(37.83)
Jan, 2018	464.66	508.16	498.27	503.16	497.91	498.79	498.44
		(25.76)	(64.85)	(27.70)	(44.22)	(66.05)	(43.52)
Feb, 2018	480.30	508.37	494.63	502.67	495.08	495.11	495.63
		(30.55)	(79.58)	(28.01)	(50.90)	(81.52)	(50.05)
Mar, 2018	493.49	508.22	491.15	502.47	492.52	491.58	493.05
		(34.92)	(97.64)	(28.06)	(58.59)	(100.62)	(57.56)
Apr, 2018	477.17	508.32	487.74	502.36	490.04	488.11	490.55
		(38.65)	(119.80)	(28.07)	(67.44)	(124.18)	(66.18)

Note: Values in the parenthesis are corresponding standard errors

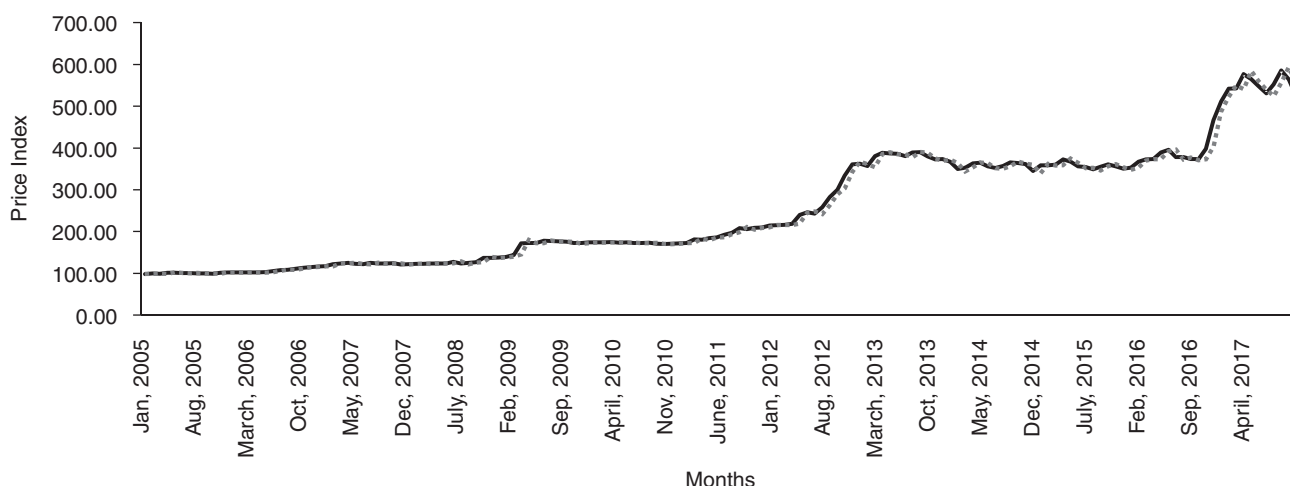


Fig 2 Fitted (dashed) vs original (bold) Ragi series using TGARCH model.

the policy interventions made by Government of India for popularizing millets production has positive impact in its prices. Thus, we can predict higher acreage under Ragi due to high growth in WPI for upcoming years and better nutritional security along with food security. This study has predicted the prices of Ragi efficiently which will help the farmers as well as policy makers to plan any future programmes related to Ragi. As already mentioned price and government initiatives for a commodity are the major driving forces for its increased rate of adoption among the farmers. This type of study will come very handy in situations where efforts are being made by different stakeholders to popularize the adoption of millets.

REFERENCES

- Aggarwal R, Inclan C and Leal R. 1999. Volatility in emerging markets. *Journal of Financial and Quantitative Analysis* **34**(1): 33–55.
- Bollerslev T. 1986. Generalized autoregressive conditional heteroscedasticity. *Journal of Econometrics* **31**(3): 307–27.
- Ding C, Duan J, Zhang Y, Wu X and Yu G. 2018. Using an ARIMA-GARCH modelling approach to improve subway short-term ridership forecasting accounting for dynamic volatility. *IEEE transactions on Intelligent Transportation Systems* **19**(4): 1054–64.
- Ewinga B T and Malik F. 2016. Volatility spillovers between oil prices and the stock market under structural breaks. *Global Finance Journal* **29**(C): 12–23.
- Ewinga B T and Malik F. 2017. Modelling asymmetric volatility in oil prices under structural breaks. *Energy Economics* **63**(C): 227–33.
- Government of India. 2014. *Status paper on coarse cereals (sorghum, pearl millet, finger millet, small millets, maize and barley)*. Department of Agriculture and Cooperation, Ministry of Agriculture.
- Killick R, Fearnhead P and Eckley I A. 2012. Optimal detection of change-points with a linear computational cost. *Journal of the American Statistical Association* **107**(500): 1590–8.
- Lamoureux C G and Lastrapes W D. 1990. Persistence in variance, structural change and the GARCH model. *Journal of Business and Economic Statistics* **8**(2): 225–34.
- Lama A, Jha G K, Paul R K and Gurung B. 2015. Modelling and forecasting of price volatility: An application of GARCH and EGARCH models. *Agricultural Economics Research Review* **28**(1): 73–82.
- Li N, Ker A, Sam A G and Aradhyula S. 2017. Modeling regime-dependent agricultural commodity price volatilities. *Agricultural Economics* **48**(6): 683–91.
- Nelson D. 1991. Conditional heteroskedasticity in asset returns: A new approach. *Econometrica* **59**(2): 347–70.
- Nelson D and Cao C. 1992. Inequality constraints in the univariate GARCH model. *Journal of Business & Economic Statistics* **10**(2): 229–35.
- Zakoian J. 1994. Threshold heteroskedastic models. *Journal of Economic Dynamics and Control* **18**(5): 931–55.