Price Transmission, Volatility and Discovery of Gram in Some Selected Markets in Rajathan State, India

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Abstract*—Market integration in many agricultural commodities had been extensively studied for the insight it provides into the functioning of such markets, thus giving valuable information about the dynamics of market adjustment, and whether there exist market imperfection, which may justify government intervention. This study empirically investigated price transmission, volatility and discovery of gram across four wholesale gram markets, viz. Jaipur, Kishangarh, Chomu and Malpura in Rajasthan state of India using Johansen's multivariate cointegration approach, VECM, Granger causality tests, GARCH, EGARCH and ARIMA. Monthly wholesale gram price data spanning from January 2011 to December 2015 sourced from AGMARKNET were used. Multivariate cointegration showed that all the selected gram markets were cointegarted in the long-run, meaning long-run price association among these markets. The degree of market integration observed is consistent with the view that Rajasthan state gram markets are quite competitive; thus, provide little justification for extensive and costly government intervention designed to enhance market efficiency through improve competitiveness. Therefore, in order to sustain the present system of market integration, there is need to evolve mechanism that will generate market information and market intelligence which would serve as a platform for guiding farmers in marketing their produce.*

Keywords*—*Price transmission, Volatility, Discovery, Gram, Market, Rajasthan.

I. INTRODUCTION

One of the most important goals of development is eliminating hunger, food insecurity and malnutrition. Orderly and efficient marketing of agricultural commodities plays an important role in solving the problem of hunger. Most of those who go hungry do so because they cannot get food at affordable prices. If marketing system is not efficient, price signals arising at the consumers' level are not adequately transferred to the producers, as a result farmers do not get sufficient price incentive to increase the production of the commodities which are in short supply. Further considerable quantity of food gets lost in the marketing chain. Thus, an inefficient marketing system adversely affects the living standard of both the farmers and consumers. In agricultural-oriented developing countries like India, agricultural marketing plays a pivotal role in fostering and sustaining the tempo of rural and economic development, thus, triggering the process of development. Development of an efficient marketing system is important in ensuring that scarce and essential commodities reach different classes of consumers. Marketing is not only an economic link between the producers and the consumers; it maintains a balance between demand and supply. The objective of price stability, rapid economic growth and equitable distribution of goods and services cannot be achieved without the support of an efficient marketing system. Rajasthan state was purposively selected to study market integration of gram, because it account for the highest quantity of gram production in India. However, literature revealed few studies on market integration of gram in India (Patil *et al.* 2014; Sharma and Burark, 2015; Patil and Tingre, 2015) and neighbouring country (Pakistan) e.g Hussain *et al*., 2010. Therefore, investigating the extent and pattern of spatial integration, price volatility and future prices in gram markets would provide an insight into the dynamics of market integration. Also, it will provide an insight on the efficiency of marketing system in the state, thus, helping the policymakers and planners in identification of the integrated markets to decide whether government should intervene in the gram markets or not. Also, findings from this study will add to literatures on market efficiency of gram in India.

II. METHODOLOGY

Time series data containing monthly wholesale prices per quintal of gram for Jaipur, Kishangarh, Chomu and Malpura markets in Rajasthan State, spanning from January, 2011 to December, 2015, sourced from AGMARKNET were used. Data collected were analyzed using series of statistical and econometric techniques ranging from; Graphical, ADF, DF-GLS, Johansen Co-integration test, Vector Error Correction Model (VECM), Granger Causality tests, Impulse response functions, ARIMA, GARCH, EGARCH and Index of Market Connection.

Empirical Models

1. Model Selection Criteria

The information criteria are computed for the VAR models of the form:

$Y_t = A_1Y_{t-1} + \ldots + A_nY_{t-n} + B_q X_t + \ldots + B_qX_{t-q} + CD_t + \mathcal{E}_t$ ……………………. (1)

Where Y_t is *K*-dimensional. The lag order of the exogenous variables X_t, q, and deterministic term D_t have to be pre-specified. For a range of lag orders n the model is estimated by OLS. The optimal lag is chosen by minimizing one of the following information criteria:

$AIC\ (n) = \log \det \{\sum_u(n)\} + (2/T)\ nK^2$ ……………………….. (2)

$HQ\ (n) = \log \det \{\sum_u(n)\} + (2\log \log T/T)\ nK^2$ ………………….. (3)

$SC\ (n) = \log \det \{\sum_u(n)\} + (\log T/T)\ nK^2$ …………………………… (4)

$FPE\ (n) = (T + n^*/T-n^*)^k \det \{\sum_u(n)\}$ …………………………….. (5)

Where $\sum_u(n)$ is estimated by $T^{-1} \sum_{t=1}^{T} UtU^1t$, n^* is the total number of parameters in each equation of the model when n is the lag order of the endogenous variables, also counting the deterministic terms and exogenous variables. The sample length is the same for all different lag lengths and is determined by the maximum lag order.

2. Augmented Dickey Fuller Test

The Augmented Dickey-Fuller test (ADF) is the test for the unit root in a time series sample. The autoregressive formulation of the ADF test with a trend term is given below:

$\Delta p_t = \alpha + p_{t-1} + \sum_{j=2}^{it} \beta i \Delta p_{it-j+t} + \mathcal{E}$ ……………… (3)

Where, p_{it} is the price in market i at the time t, Δpit $(p_{it} - p_{t-1})$ and α is the intercept or trend term. The joint hypothesis to check the presence of unit root is: H_0: $\gamma = \alpha_0 = 0$ using ϕ_1 statistic. Failure of the rejection of null hypothesis means that the series is non-stationary.

3. Johansen's Co-integration Test

The Johansen procedure is a multivariate generalization of the Dickey-Fuller test and the formulation is as follows (Johansen, 1988):

$p_t = A_1 p_{t-1} + \mathcal{E}_t$ ……………………. (4)

So that

$\Delta p_t = A_1 p_{t-1} - p_{t-1} + \mathcal{E}_t$ ………………… (5)

$p_t = (A_1 - I) p_{t-1} + \mathcal{E}_t$ ………………………. (6)

$\Delta p_t = \prod p_{t-1} + \mathcal{E}_t$ ………………………….... (7)

Where, p_t and $\mathcal{E}_t$ are (n×1) vectors; A_t is an (n x n) matrix of parameters; I is an (n x n) identity matrix; and ∏ is the (A_1-1) matrix. The rank of (*At* -1) matrix equals the number of co-integrating vectors. The crucial thing to check is whether (A_1-1) consists of all zeroes or not. If it does, then it implies that all the $\{p_t\}$ in the above VAR are unit root processes, and there is one linear combination of which is stationary, and hence the variables are not co-integrated. The rank of matrix ∏ is equal to the number of independent co-integrating vectors. Both trace and max test were used to determine the presence of co-integrating relationship among and between the price series. Using the estimates of the characteristic roots, the tests for the number of characteristic roots that are insignificantly different from unity were conducted using the following statistics:

$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1-\lambda_i)$ …………………………………….. (8)

$\lambda_{max} = -T \ln(1-\lambda_i + 1)$ ………………………………………… (9)

Where, λ_i denotes the estimated values of the characteristic roots (eigen values) obtained from the estimated ∏ matrix; and *T* is the number of usable observations.

4. Granger Causality Test

Granger (1969) causality test was used to determine the order and direction of short-term and long-term equilibrium relationships. Whether market p_1 Granger causes market p_2 or vice-versa was checked using the following model:

$p_t = c + \sum_{i=1}^{n}(\phi p_{1t-i} + \delta_i p_{2t-i}) + \mathcal{E}_i$ …………… (10)

A simple test of the joint significance of δ_i was used to check the Granger causality, i.e.

H_0: $\delta_1 = \delta_2 =$ …….. $\delta_n = 0$.

5. Vector Error Correction Model (VECM)

After establishing the multiple co-integrating relationships among price series, Vector Error Correction Model (VECM) was constructed to determine the short-term disturbances and the adjustment mechanism to estimate the speed of adjustment. The VECM explains the difference in y_t and y_{t-1} (i.e. Δy_t) and it is shown below:

$\Delta y_t = a + \mu(y_{t-1} - \beta x_{t-1}) + \sum_{i=0}^{i=t} \delta_i \Delta x_{t-1} + \sum_{i=1}^{i=t} \gamma_i \Delta \gamma_{t-1}$ …………………. (11)

It includes the lagged differences in both x and y, which have a more immediate impact on the value of Δy_t. For example, if Δx_t increases by one percentage point, then Δy_t would increase by δ percentage point. The value of β indicates the percentage point would change in the long-run in response to changes in x. Therefore, part of the change in Δy_t could be explained by y correcting itself in each period to ultimately reach the long-run path with x. The amount by which the value of y changes (or corrected) in each period is signified byμ. This coefficient (μ) indicates the percentage of the remaining amount that y has to move to return to its long- run path with x. In explaining changes in a variable, the VECM accounts for its long-run relationship with other variables. The advantage of VECM over an ordinary OLS model is that it accounts for dynamic relationships that may exist between a dependent variable and explanatory variable, which may span several periods.

6. Impulse Response Functions

Granger causality tests do not determine the relative strength of causality effects beyond the selected time span. In such circumstances, causality tests are inappropriate because these tests are unable to indicate how much feedback exists from one variable to the other beyond the selected sample period (Rahman and Shahbaz, 2013). The best way to interpret the implications of the models for patterns of revenue transmission, causality and adjustment are to consider the time paths of revenues after exogenous shocks, i.e. impulse responses. The impulse response function traces the effect of one standard deviation or one unit shock to one of the variables on current and future values of all the endogenous variables in a system over various time horizons (Rahman and Shahbaz, 2013). For this study the generalized impulse response function (GIRF) originally developed by Koop *et al*. (1996) and suggested by Pesaran and Shin (1998) was used. The GIRF in the case of an arbitrary current shock, δ, and history, ω_{t-1} is specified below:

$GIRF_Y(h, \delta, \omega_{t-1}) = E[Y_t + h/\delta, \omega_{t-1}] - E[y_{t-1}/\omega_{t-1}]$ ………………………. (12)

For $n = 0, 1$

7. Index of Market Connection (IMC)

The index of market concentration was used to measure price relationship between integrated markets, and the model is specified below:

$S_t = \beta_0 + \beta_1 S_{t-1} + \beta_2 (T_t - T_{t-1}) + \beta_3 T_{t-1} + \mathcal{E}$ ………………….. (13)

T_t = Terminal market price or reference price

S_t = Secondary whole sale market price

T_{t-1} = lagged price for Terminal market

T_t-T_{t-1} = difference between Terminal market current price and its lag

Ɛ = stochastic/ noise/disturbance term

β_0 = Intercept

β_1= coefficient of secondary wholesale market price

β_2 = coefficient of the difference between Terminal market current price and its lag

β_3 = coefficient of Terminal market lagged price

IMC = β_1 / β_3, where $0 \leq IMC \leq \infty$

Where,

IMC < 1 implies high short-run market integration;

IMC > 1 implies low short-run market integration;

IMC = ∞ implies no integration; and,

IMC = 1 implies moderate short-run integration.

8. GARCH Model

The representation of the GARCH (p, q) is given as:

$Y_t = \alpha + b_1 Y_{t-1} + b_2 Y_{t-2} + \mathcal{E}_i$

(Autoregressive process) …………………………. (14)

And the variance of random error is:

$\sigma^2_t = \lambda_0 + \lambda_1 \mu^2_{t-1} + \lambda_2 \sigma^2_{t-1}$ …………………. (15)

$\sigma^2 t = \omega + \sum_{i=1}^{p} \beta_i \sigma^2_{t-i} + \sum_{j=1}^{q} \alpha_i \mathcal{E}^2_{t-i}$ ……………… (16)

Where, Y_t is the price in the i^{th} period of the i^{th} market, p is the order of the GARCH term and q is the order of the ARCH term. The sum of $(\alpha + \beta)$ gives the degree of persistence of volatility in the series. The closer is the sum to 1; the greater is the tendency of volatility to persist for a longer time. If the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from the mean value.

9. EGARCH Model

The EGARCH model 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 below:

$ln\ (h_t) = a_0 + \beta\ ln\ (h_{t-1}) + \alpha\ [\mathcal{E}_{t-1}/\sqrt{h_{t-1}}] + \gamma\ [\mathcal{E}_{t-1}/\sqrt{h_{t-1}}]$ …………….. (17)

This implies that the leverage effect is exponential, rather than quadratic and the forecasts of the conditional variance are guaranteed to be non-negative. Karanasos and Kim (2003) carried out a detailed analysis of moment's structure of the ARMA-EGARCH model, while Kobayashi and Shi (2005) studied the testing for EGARCH against stochastic volatility models.

10. ARIMA Model

A generalization of ARMA models which incorporates a wide class of non-stationary time-series is obtained by introducing the differencing into the model. The simplest example of a non-stationary process which reduces to a stationary one after differencing is Random Walk. A process $\{y_t\}$ is said to follow an integrated ARMA model, denoted by ARIMA (p, d, q), if $\nabla^d\ y_t = (1-\beta)^d\ \mathcal{E}_t$ is ARMA (p, q), and the model is written below:

$\varphi(\beta)\ (1-\beta)^d\ y_t = \theta\ (\beta)\ \mathcal{E}_t$ …………………………….(18)

Where, $\mathcal{E}t \sim WN(0, \sigma^2)$, and WN indicates white noise. The integration parameter d is a non-negative integer. When d = 0, ARIMA (p, d, q) = ARMA (p, q).

Forecasting Accuracy

For measuring the accuracy in fitted time series model, mean absolute prediction error (MAPE), relative mean square prediction error (RMSPE) and relative mean absolute prediction error (RMAPE) were computed using the following formulae (Paul, 2014):

MAPE = 1/T ∑ {At – Ft} ………………………………. (19)

RMPSE = 1/T ∑ $\{(At - Ft)^2 / At\}$ ………………………….. (20)

RMAPE = 1/T ∑ $\{(At - Ft)^2 / At\}$X 100 …………………… (21)

Where, At = Actual value; Ft = Future value, and T= Time period(s)

III. RESULTS AND DISCUSSION

Lag Selection Criteria

Sensitivity of time series to lag length necessitate the application of lag selection criteria using Vector Autoregression (VAR) selection order criteria to determine the suitable number of lag(s) to be included in the model. Lag selection criteria *viz.* Akaike information criterion (AIC), Hannan–Quinn criterion (HQC) and Schwarz Bayesian criterion (BIC) advised us to select lag 1 for the analyses (Table 1). The asterisks indicate the best (that is, minimized) values of the respective information criteria, AIC, BIC and HQC. Detailed iteration of the lag selection process from lag 1to 8 are shown in Table 1. However, it should be noted that when all the selection criteria agree, the selection is clear, but in situation of conflicting results, the selection criteria with the highest lag order is considered or chosen.

Table 1: Lag selection criteria

Lag(s)	AIC	BIC	HQC
1	50.33*	51.23*	50.67*
2	50.52	52.02	51.09
3	50.71	52.81	51.51
4	50.90	53.60	51.93
5	50.99	54.30	52.26
6	51.13	55.03	52.62
7	51.02	55.52	52.75
8	51.07	56.20	53.05

Unit Roots Test

The stationarity of the price indices were tested before establishing the causal relationship between different markets. The Augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979) was employed and the presence of unit root was checked under the scenario of the equation with intercept and trend. ADF-GLS test, which provides an alternate method for correcting serial correlation and heteroscedasticity was also used to validate the results (Table 2). The ADF values at level were higher than the critical values at 5 per cent level, indicating the existence of unit root in the series; that is, non-stationary nature of the data. But at first difference, the ADF values were lower than the critical values at 5 per cent level of significance, meaning that the price series were free from the consequences of unit root; implying that the price series were stationary at first difference, i.e, the series are integrated of order one. ADF-GLS test results confirm the robustness of the ADF test, as indicated by non-stationarity of the series at level as evident by t-statistic values which were higher than t-critical values at 5 percent, but at first difference they became stationary as evident by t-statistic values which were lower than t-critical values at 5 percent. Through a visual examination of the series at level, one can observed that there was an upward movement of prices (Figure 1), indicating presence of unit roots, but after first difference the series became stationary at this point (Figure 2). Having ensured non-stationarity of the price series, relationship between these markets was estimated using the co-integration test.

Table 2: Unit roots test with constant and trend

Market	Stage	ADF		ADF-GLS		Remarks
		T-stat	P<0.05	T-stat	T-critical (5%)	
Jaipur	Level	-1.58	0.801	-1.71	-3.03	Non-stationary
	1st Difference	-5.21**	0.000068	-5.10**	-3.03	Stationary
Kishangarh	Level	-1.98	0.611	-2.00	-3.03	Non-stationary
	1st Difference	-5.33**	0.000038	-5.22**	-3.03	Stationary
Chomu	Level	-1.72	0.7448	-1.72	-3.03	Non-stationary
	1st Difference	-5.14**	0.000095	-5.18**	-3.03	Stationary
Malpura	Level	-1.85	0.681	-1.89	-3.03	Non-stationary
	1st Difference	-4.90**	0.00028	-4.99**	-3.03	Stationary

Note: ** indicate that unit root at level or at first difference was rejected at 5 per cent significance.

Figure 1: Unit roots test at Level

Figure 2: Unit roots test at First Difference

Johansen's Multiple Co-integration Test

To determine the long-run relationship between price series from a range of four price series, Johansen multiple co-integration test was used. The results of Johansen's maximum likelihood tests (maximum eigen-value and trace test) are shown in Table 3. To check the first null hypothesis that the variables were not cointegrated ($r = 0$), trace and max value statistics were calculated, both of which rejected the null hypotheses as trace and max test statistics values were higher than 5 per cent critical values and accepted the alternative of one or more cointegrating vectors. Similarly, the null hypotheses of $r \leq 1$ from both statistics were rejected against their alternative hypotheses of $r \geq 1$. The null hypotheses $r \leq 2$ from both the tests were accepted and their alternative hypotheses $r = 3$ were rejected as the trace and max values were less than their corresponding critical values at 5 per cent significance level. Both tests confirmed that the four selected gram markets had two cointegrating vectors out of four cointegrating equations, indicating that they are well integrated and price signals are transferred from one market to the other to ensure efficiency; the selected gram markets had long-run equilibrium relationship and there existed co-integration among these markets. Thus, Johansen cointegration test showed that even though the selected gram markets in Rajasthan are geographically isolated and spatially segmented, they are well-connected in terms of gram prices, indicating that the selected markets have long-run price linkage across them.

Table 3: Multiple cointegration analysis

H_0	H_1	Eigen value	Trace test	P-value	Lmax test	P-value
r = 0	r ≥1	0.4973	76.991*	0.0000	40.583*	0.0003
r ≤ 1	r ≥2	0.3710	36.408*	0.0068	27.358*	0.0044
r ≤ 2	r =3	0.0895	9.0504	0.3674	5.5336	0.6771

Note: *denotes rejection of the null hypothesis at 5 per cent level of significance

However, integration of gram prices between market pair was also tested using Johansen's Cointegration test (Table 4). Results showed these market pairs; Kishangarh-Chomu, Kishangarh-Malpura, and Chomu-Malpura to be cointegrated. Although these market pairs are isolated geographically, they had one cointegration equation, meaning that these market pairs in the state are cointegrated and there exists long-run price association between them. However, Jaipur market was not cointegrated with any of the selected markets, meaning that there do not exists any cointegration between them and thus, no long-run price association exists between these market pairs. Therefore, it could be inferred that to certain extent gram markets in the state are integrated.

Table.4: Pair-wise cointegration in major cocoa markets

Market pair	H0	H1	Trace test	P-value	Lmax test	P-value	CE
Jaipur-Kishangarh	r = 0	r ≥1	7.59	0.52	4.65	0.78	NONE
	r ≤ 1	r ≥2	2.94	0.09	2.94	0.09	
Jaipur–Chomu	r = 0	r ≥1	8.49	0.42	5.05	0.74	NONE
	r ≤ 1	r ≥2	3.44	0.06	3.44	0.06	
Jaipur – Malpura	r = 0	r ≥1	8.74	0.40	5.63	0.67	NONE
	r ≤ 1	r ≥2	3.11	0.08	3.11	0.07	
Kishangarh–Chomu	r = 0	r ≥1	25.95	0.00	24.04	0.00	1CE
	r ≤ 1	r ≥2	1.92	0.17	1.92	0.17	

Kishangarh–Malpura	r = 0	r ≥1	33.17	0.00	30.94	0.00	1CE
	r ≤ 1	r ≥2	2.24	0.17	2.24	0.14	
Chomu – Malpura	r = 0	r ≥1	31.78	0.00	29.92	0.00	1CE
	r ≤ 1	r ≥2	1.86	0.17	1.86	0.17	

Note:*denotes rejection of the null hypothesis at 5 per cent level of significance
CE- Cointegration Equation

Vector Error Correction Model

The estimates of vector error correction model reveals that the coefficient of speed of adjustment was negative in all the markets, with only Jaipur and Malpura markets coefficients being significant, implying that prices in these markets tend to converge in the long-run (Table 5). The coefficient of speed of adjustment from displacement equilibrium to equilibrium for Jaipur and Malpura markets were -0.019 and -0.129, which indicates that 1.9 per cent and 12.9 per cent of divergence from the long-run equilibrium were being corrected each month. In other words, it means that Jaipur and Malpura markets adjust/fall back to the equilibrium level at 1.9 percent and 12.9 percent respectively. Therefore, it will take approximately 1 and 4 days in Jaipur and Malpura markets respectively, to restore back to equilibrium. Based on findings it can be inferred that Jaipur and Malpura markets are efficient in the long run; while Chomu and Kishangarh markets are inefficient in the long run, because they do not adjust to the equilibrium in the long run due to disturbances of the short run markets as evident by non-significance of their ECT values. The process of adjustment, however, was much relatively faster in Jaipur market than Malpura market; meaning that, the price transmission mechanism in Jaipur market is faster and more efficient in relation to price transmission in Malpura market, and this might be due to lesser transfer and transaction costs in Jaipur market due to better infrastructure. The constant terms in the long run equations for Jaipur and Malpura gave the picture of the transfer costs or the extent of price differentials in Jaipur market on Kishangarh, Chomu and Malpura markets; and Malpura market on Jaipur, Kishangarh and Chomu markets due to arbitrage activities. Results revealed insignificant influence of the transfer costs in the marketing process of gram in Jaipur and Malpura in the state. This perhaps suggests high efficiency in information transmission between Jaipur market and Kishangarh-Chomu-Malpura markets; between Malpura market and Jaipur-Kishangarh-Chomu markets; and also improvement in the marketing infrastructures in Jaipur and Malpura markets.

The effects of lagged prices in the selected markets were both negative and positive, suggesting that, in the short-run, price shocks were contemporaneously transmitted in these markets but not fully (Table 5). Results revealed that the adjustment that occurs in Jaipur market prices was influenced by changes in one month lagged prices of gram in Kishangarh and Chomu markets, while adjustment in the prices of gram in Malpura market was influenced by change in its one month lagged gram prices and other exogenous factors. The short-run dynamics, thus, indicates that the changes in one month lagged gram prices in Kishangarh and Chomu markets were transmitted to Jaipur market, while change in one month lagged gram prices in Malpura market was transmitted to the current gram prices in Malpura. To strength the linkage and interconnectedness among markets for faster transmission of price and management of commodity from surplus area to deficit area, development of market infrastructure, use of information and technology in transaction of goods, processing, transportation and other back-end supply chain of gram need to be enhanced. This would definitely help in the development of single integrated economic market in the state.

Table.5: Vector Error Correction Model of selected gram markets

Variable	D(Jaipur)	D(Kishangarh)	D(Chomu)	D(Malpura)
ECT	-0.019	-0.008	-0.007	-0.129
	(0.011)	(0.04)	(0.0.03)	(0.044)
	{-1.698}*	{-0.201}^{NS}	{-0.185}^{NS}	{-2.910}***
D(Jaipur)	0.145	0.109	0.185	0.0058
	(0.166)	(0.189)	(0.181)	(0.2067)

	{0.873}NS	{0.577}NS	{1.021}NS	{0.028}NS
D(Kishangarh)	0.944	0.299	0.571	0.703
	(0.406)	(0.462)	(0.443)	(0.505)
	{2.33}**	{0.648}NS	{1.29}NS	{1.393}NS
D(Chomu)	-0.835	-0.284	-0.475	0.177
	(0.418)	(0.477)	(0.457)	(0.521)
	{-1.99}*	{-0.596}NS	{-1.038}NS	{0.338}NS
D(Malpura)	-0.229	-0.168	-0.271	-0.757
	(0.208)	(0.237)	(0.227)	(0.259)
	(-1.101)NS	{-0.710}NS	{-1.197}NS	{-2.929}***
Constant	-100.27{-1.39}NS	65.25{0.82}NS	-23.96{-0.31}NS	-76.76{-0.88}NS

Note: *** ** * implies significance at 1%, 5% and 10% respectively
NS: Non-significant
(); {} implies Standard error and t-statistic

Granger Causality Tests

The granger causality shows the direction of price formation between two markets and related spatial arbitrage, i.e., physical movement of goods to adjust the prices difference. According to the granger causality test, there was unidirectional causality between the market pair: Kishangarh–Chomu wholesale markets, meaning that a price change in the former market in granger cause the price formation in the latter market, whereas the price change in the latter market does not granger cause price change in the former market. Also, it can be seen that there exists bidirectional causality between Kishangarh–Chomu and Chomu–Malpura market pairs. In these cases, the former market in each pair granger causes the wholesale price formation in the latter market which in turn provides the feedback to the former market as well. Further, three market pairs, Kishangarh-Jaipur, Chomu-Jaipur and Malpura–Jaipur, have no direct causality between them, indicating that neither Kishangarh nor Chomu nay Malpura market granger causes the price formation in Jaipur market, nor Jaipur market granger causes the price formation in Kishangarh, Chomu and Malpura markets. In other words, there is no long-run price association between these market pairs (Table 6). Therefore, it can be inferred that gram prices adjust in some markets according to demand and supply situation in the state.

Table.6: Pair wise Granger causality tests of selected markets

H_0	**t-stat**	**Prob.**	**Granger cause**	**Direction**
Jaipur → Kishangarh	0.542	0.590	No	**None**
Jaipur ← Kishangarh	0.102	0.919	No	
Chomu → Jaipur	1.237	0.222	No	**None**
Chomu ← Jaipur	1.348	0.183	No	
Malpura → Jaipur	1.614	0.112	No	**None**
Malpura ← Jaipur	1.181	0.243	No	
Kishangarh → Chomu	2.058	0.044**	Yes	**Unidirectional**
Kishangarh ← Chomu	1.665	0.102	No	
Kishangarh → Malpura	3.223	0.002**	Yes	**Bidirectional**
Kishangarh ← Malpura	2.702	0.001**	Yes	
Chomu → Malpura	2.769	0.008**	Yes	**Bidirectional**

Chomu ← Malpura	3.674	0.001**	Yes	

Note:**denotes rejection of the null hypothesis at 5 per cent level of significance

IMPULSE RESPONSE

Estimation of impulse response function was inconsistent at long horizon when estimated from the unrestricted VAR, if there was unit root or cointegration. So the stable impulse response function was derived from the error correction model. The response of price series with respect to the shocks from other variables are captured through the impulse response function, showing how and to what extent a standard deviation shock in one of the gram markets affects the future prices in all the integrated markets over a period of twelve months. When the effect of a shock dies out over time, the shock is said to be transitory, while if the effect of a shock does not die out over time, the shock is said to be permanent.

A perusal of Figure 3 indicate that orthogonalized shocks to the prices of gram in Jaipur market will have permanent effects on its own prices and prices in Chomu market, and a transitory effects on the prices in Kishangarh and Malpura markets. Unexpected shocks that are local to prices of gram in Kishangarh market will exert a permanent effect on the prices in Jaipur and Chomu markets, and transitory effects on prices in its own market and Malpura market. Likewise unexpected shocks that are local to prices in Chomu market will have permanent effects on Kishangarh and Malpura markets, and transitory effects on prices in its own market and Jaipur market. However, orthogonalized shocks on Malpura market will exert transitory effects on the prices in all the selected gram markets in the state. It was observed that three price series, namely Kishangarh, Chomu and Malpura markets will yield negative response (decrease) to their own shock (unexpected increase). Prices in Jaipur market will respond positively to shocks that occur in the prices of gram in its own market and Kishangarh market, and the response will not be prominent for any shocks from gram prices that will occur in Chomu and Malpura markets; Prices in Kishangarh market will respond positively to bad news that will occur to prices of gram in Chomu market, and a negative response to shocks that in Jaipur, Kishangarh and Malpura markets; prices in Chomu market will respond to bad innovation that will occur in Jaipur and Kishangarh markets, and a negative response to shocks that will occur in Chomu and Malpura markets; and, prices in malpura market will respond positively to local shocks that occur in Kishangarh and Chomu markets, and negatively to local shocks that will occur in its own market and Jaipur market. In otherwords, a shock originating from the Kishangarh market is more transmitted to all the selected gram markets in the state, but a shock originating from any other gram market (except Chomu market) is relatively less transmitted to Kishangarh market; implying Kishangarh market has dominance in price determination in other gram markets in the state. A shock given to Chomu market is transmitted in large proportion to Kishangarh and Malpura markets, and dies out over time in its own market and Jaipur market. A shock originating from Jaipur market will not dies out over time in its own market and Chomu market, but will dies out over time in Kishangarh and Malpura markets. On the other hand, the results of Malpura market impulse response confirm that the price transmission from Malpura to other markets will dies out over-time, implying Malpura market is relatively market follower and do not play a significant role in the state gram markets.

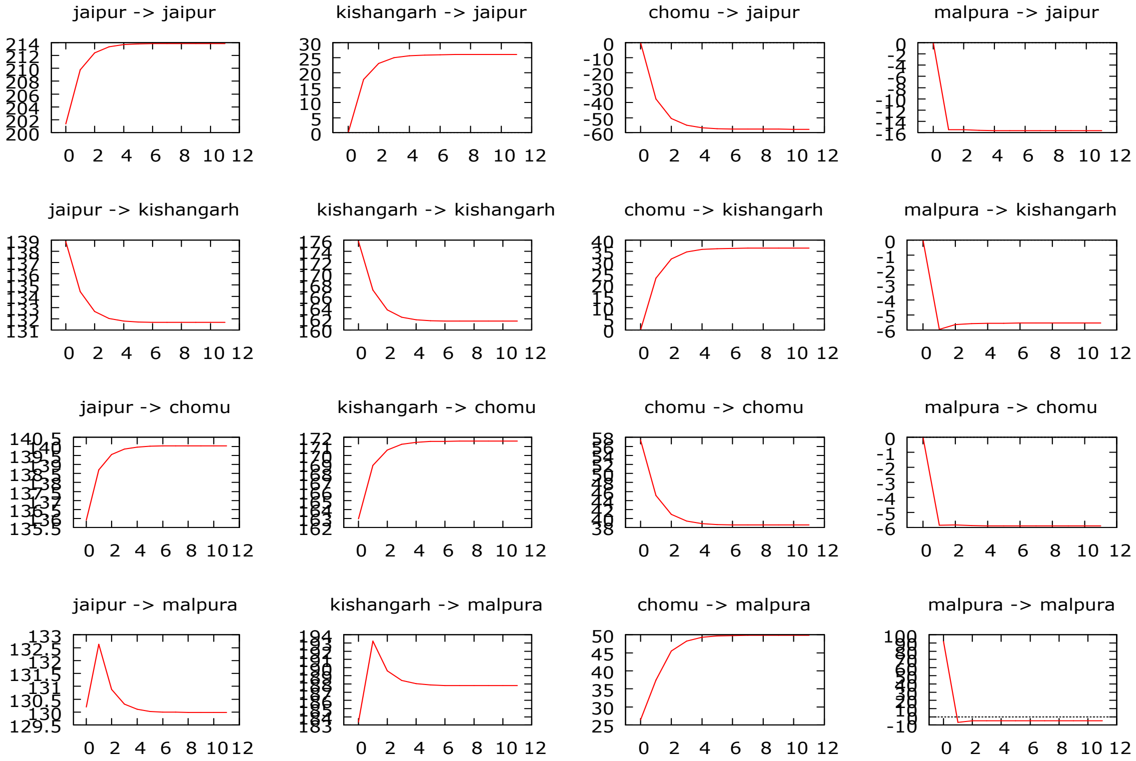

Fig.3: Impulse response functions

Diagnostic checking (VECM)

One of the basic assumptions of Box-Jenkins is that residuals are not correlated. Diagnostic checking *viz.* autocorrelation and normality tests for residuals were conducted to determine the suitability of VECM. The test indicates no autocorrelation in the residuals as evident from the Q-statistics which were not different from zero at 5 percent probability level (P>0.05), thus, the null hypothesis of no autocorrelation was accepted and the alternative rejected. For normality test, results indicate that the residuals were normally distributed as evident from Doornik-Hansen test which was different from zero, i.e were significant at 5 percent probability level (P<0.05), thus, the alternative hypotheses was accepted while the null was rejected. Therefore, it can be inferred that the model used certified all the necessary criteria for it to be term best fit (Table 7)

Table.7: VECM Diagnostic checking

Test		Statistic	P-value
Autocorrelation	Ljung-Box Q (Eq1)	0.051	0.821
	Ljung-Box Q (Eq2)	0.185	0.667
	Ljung-Box Q (Eq3)	0.539	0.463
	Ljung-Box Q (Eq4)	0.126	0.723
Normality	Doornik-Hansen test	110.97	0.000

The Index of Market Connection between Secondary wholesale market and Terminal market

The results of index of market connection (IMC) are presented in Table 8. The index is used to show short run relationship between integrated markets. The IMC obtained were 0.103; 0.133 and 0.074 for market pairs' viz. Kishangarh-Jaipur, Chomu-Jaipur and Malpura-Jaipur, respectively. These are less than one, indicating that the market pairs exhibits high short run market integration. These results imply that price changes in the Terminal market cause immediate and accurate change in the prices of Secondary wholesale markets. The short run market integration was faster between Kishangarh and Jaipur market pair, relative to other secondary markets in pair with Jaipur market. These indicate perfect price transmission mechanism between these market pairs.

Table.8: Indices of market connection

Market pair	β_1	β_3	IMC	R^2	Classification
Kishangarh – Jaipur	-0.065	0.63	-0.103	53.8	High short-run market integration
Chomu – Jaipur	0.085	0.64	0.133	58.8	High short-run market integration
Malpura – Jaipur	0.046	0.62	0.074	46.3	High short-run market integration

Diagnostic checking (IMC)

Results indicated no arch effect as evident from the LM tests which were not different from zero at 5 percent probability level. Also Durbin-Watson statistics ranged within 1.5 to 2.5, indicating no autocorrelation among the residuals. Normality tests showed that the residuals were normally distributed as evident from the chi^2 value which were different from zero at 5 percent probability level (Table 9).

Table.9: Diagnostic checking (IMC)

Market pair	Arch LM-test	D-W stat	Normality test (chi^2)
Kishangarh – Jaipur	1.89 (0.9996)	2.02	63.74 (0.000)
Chomu – Jaipur	1.55 (0.9999)	2.00	112.69 (0.000)
Malpura – Jaipur	4.86 (0.963)	1.998	32.66 (0.000)

Extent of Price Volatility in gram markets

The results of GARCH model indicated that different models of the same order fit different markets, with GARCH (1,1) found as the highest GARCH order for all the selected markets during period 2011-2015 (Table 10). With the exception of Jaipur market, the sum (α_i + β_i) coefficients for rest of the markets were estimated closer to 'one', indicating the persistence of volatility in gram prices of selected markets. Results of GARCH analysis indicated that volatility in the current month prices in Jaipur market was caused by information on volatility in the preceding month prices, which was evident from the significant ARCH-term termed family shock. Further, external shocks which originated from Kishangarh and Chomu markets also contributed to the current month volatility in prices of gram in Jaipur market. Also, GARCH analysis results indicated that volatility in the current month prices in Kishangarh market was caused by internal shock viz. information on volatility in the preceding month prices, as evident from the significant ARCH-term, and external shocks which originated from Jaipur, Chomu and Malpura markets also add to the current month volatility in prices of gram in Kishangarh market; GARCH results indicated that internal shocks did not caused volatility in the current month prices in Chomu market as evident from non-significant GARCH and ARCH terms, but rather by exogenous shocks which originated from Kishangarh and Malpura markets; lastly, GARCH results revealed that volatility in the current month prices of gram in Malpura market was not caused by family shocks as evident from non-significant GARCH and ARCH terms, but probably exogenous factor(s) might caused it. A noteworthy point was that volatility in the current prices of gram for each selected markets was not caused by volatility in the preceding month prices of gram in respective selected markets, which was evident from non-significant GARCH term.

However, Jaipur market showed an explosive pattern as the value (α_i + β_i) exceeded one, which indicates high risk in gram market, while rest of the selected markets showed non-explosive pattern as the sum of (α_i + β_i) did not exceed one, which infers the usefulness of gram marketing in these markets. The reason for persistence of volatility in prices of gram in Kishangarh, Chomu and Malpura markets could be due to market arrivals.

Table 10: Estimates of GARCH model for measuring volatility in prices of gram from Jan. 2011-Dec. 2015

Particulars	Jaipur market	Kishangarh market	Chomu market	Malpura market
Family shocks				
Constant	7008.93(2.00)**	1313.55(1.01)^{NS}	1230.51(0.75)^{NS}	395395(0.15)^{NS}
Alpha	1.00 (4.82)***	0.464(1.90)*	0.127(0.67)^{NS}	0.909(0.91)^{NS}
Beta	1.0E-012(0.000)***	0.300(0.92)NS	0.598(1.21)^{NS}	0.0396 (0.04)^{NS}
External shocks				
Jaipur	-	0.074(3.12)***	0.025(1.08)^{NS}	-
Kishangarh	-0.406 (1.91)*	-	0.696(6.62)***	-

Chomu	1.37(6.65)***	0.619 (6.45)***	-	-
Malpura		0.303(3.71)***	0.287(3.16)***	-
Log likelihood	-415.53	-333.18	-336.01	-554.56
GARCH fit	1,1	1,1	1,1	1,1
α + β	**1.0**	**0.764**	**0.725**	**0.949**

Notes: Figures within the parentheses indicate the calculated t-statistic
*** ** and * indicate the significance at 1%, 5% and 10% probability levels respectively
NS: Non-significant

Testing of ARCH Effect in GARCH Models

The Box-Jenkins approach has a basic assumption that the residuals are independent of each other. Thus, the ARCH tests were carried out on the residuals obtained after fitting the GARCH model on all the four series to test whether residuals are not correlated. Test results revealed non-presence of ARCH effect for all the series. Also the normality tests indicated that the residuals for all the series were normally distributed, as evident by the p-values which were less than 5 percent (Table 11).

Table.11: Diagnostic checking for GARCH

Model	Market	ARCH-LM Test	Normality Test (Chi^2)
GARCH	Jaipur	0.055 (0.81)	36.56 (0.000)
	Kishangarh	0.085 (0.77)	4.83 (0.009)
	Chomu	0.063 (0.80)	0.033 (0.001)
	Malpura	0.004 (0.95)	54.24 (0.000)

Note: Values in parentheses are probability

Fitting of ARIMA Model

Various combinations of the ARIMA specifications were tried after first differencing of all the series. We obtained the best ARIMA model for each series based on the lowest AIC information criteria. We selected ARIMA (0, 1, 1) for Jaipur and Kishangarh markets, and ARIMA (1, 1, 0) for Chomu and Malpura markets. Due importance was given to the well-behaved residuals while selecting the best model.

Out of total 60 data points (January, 2011 to December, 2015), first 55 data points (January, 2011 to July, 2015) were used for model building and the remaining 5 data points (August, 2015 to December, 2015) were used for model validation (Table 12a).

Table.12a: AIC values of different ARIMA models

Market		1,1,1	1,1,0	0,1,1
Jaipur	AIC	804.4197	802.4231	802.4203**
	BSC	812.7298	808.6557	808.6530
Kishangarh	AIC	814.0692	812.5382	812.5336**
	BSC	822.3793	818.7708	818.7662
Chomu	AIC	811.5530	809.6387**	809.6784
	BSC	819.8631	815.8713	815.9110
Malpura	AIC	830.8506	830.1729**	830.2654
	BSC	839.1607	836.4055	836.4980

Note:**denotes best ARIMA model

Validation

One-step ahead forecasts of wholesale prices using naïve approach for the last 5 months (August, 2015 to December, 2015) in respect of above fitted model were computed (Table 12b).

Table.12b: One step ahead forecast of prices

Date	Jaipur market		Kishangarh market		Chomu market		Malpura market	
	Actual	Forecast	Actual	Forecast	Actual	Forecast	Actual	Forecast
2015:08	2745	2736.63	2865	2957.59	2865	2956.86	2865	2960.71
2015:09	2765	2757.19	2865	2886.96	2865	2885.21	2865	2884.99
2015:10	2636	2777.17	2936	2881.47	2936	2880.04	2936	2878.70
2015:11	2678	2642.33	2878	2946.51	2978	2944.91	2765	2942.26
2015:12	2800	2691.26	2970	2898.09	2945	2989.42	2755	2796.62

The forecasting ability of the models were judged on the basis of relative mean square prediction error (RMSE) mean absolute prediction error (MAPE) and relative mean absolute prediction error (RMAPE). Perusal of Table 12c revealed that in all the price series, RMAPE values were less than 5 percent, indicating the accuracy of the models used.

Table.12c: Validation of models

Market	MAPE	RMSPE	RMAPE (%)
Jaipur	3.884	2.461	0.0895
Kishangarh	11.324	1.509	0.369
Chomu	28.488	1.167	0.997
Malpura	55.456	3.290	2.02

Forecasting

One step ahead out of sample forecast of wholesale prices of gram with 95% upper control limits (UCL) and Lower control limits (LCL) for all the markets during the period January, 2016 to December, 2015 were computed (Table 12d). The forecasted prices are the shadow prices, i.e true value of factor of production which will prevail under a perfect situation. Under imperfect market situation the prices will not exceed the UCL and will not go below LCL. All the price series observed a slight increase, likewise their corresponding standard errors, i.e, the standard error followed an increasing trend as the volatility increased. The forecasted prices were also depicted in Figure 4-7 to visualize the performance of fitted models.

Table.12d: Out of sample forecast of gram prices in selected markets

Months/Yr	**Jaipur market**			**Kishangarh market**		
	Forecast	**Upper CL**	**Lower CL**	**Forecast**	**Upper CL**	**Lower CL**
2016:01	2816.12	3220.89	2411.36	2979.16	3420.12	2538.19
2016:02	2827.99	3411.73	2244.25	2993.91	3593.75	2394.08
2016:03	2839.85	3559.35	2120.36	3008.67	3733.34	2283.99
2016:04	2851.72	3685.14	2018.30	3023.42	3854.39	2192.46
2016:05	2863.58	3797.13	1930.03	3038.18	3963.30	2113.06
2016:06	2875.45	3899.38	1851.52	3052.94	4063.48	2042.39
2016:07	2887.31	3994.27	1780.35	3067.69	4156.98	1978.40
2016:08	2899.18	4083.35	1715.00	3082.45	4245.16	1919.73
2016:09	2911.04	4167.70	1654.38	3097.20	4328.97	1865.43
2016:10	2922.91	4248.09	1597.72	3111.96	4409.11	1814.80
2016:11	2934.77	4325.11	1544.43	3126.71	4486.11	1767.32
2016:12	2946.63	4399.20	1494.07	3141.47	4560.38	1722.56
Months/Yr	**Chomu market**			**Malpura market**		
	Forecast	**Upper CL**	**Lower CL**	**Forecast**	**Upper CL**	**Lower CL**
2016:01	2962.88	3393.16	2532.61	2769.75	3281.79	2257.70
2016:02	2976.38	3559.23	2393.53	2781.90	3469.13	2094.67
2016:03	2990.25	3695.10	2285.41	2794.32	3623.53	1965.12
2016:04	3004.10	3812.61	2195.58	2806.72	3756.63	1856.81
2016:05	3017.94	3918.27	2117.61	2819.12	3876.06	1762.18
2016:06	3031.79	4015.40	2048.17	2831.52	3985.61	1677.43
2016:07	3045.63	4106.01	1985.25	2843.92	4087.59	1600.25
2016:08	3059.47	4191.42	1927.53	2856.32	4183.54	1529.09
2016:09	3073.32	4272.57	1874.07	2868.72	4274.53	1462.90
2016:10	3087.16	4350.14	1824.19	2881.12	4361.36	1400.87
2016:11	3101.01	4424.64	1777.37	2893.51	4444.61	1342.41
2016:12	3114.85	4496.48	1733.22	2905.91	4524.77	1287.05

Note: CL- Confidence Level

Diagnostic Checking

The model verification is concerned with checking the residuals of the model to see if they contained any systematic pattern which could be removed to improve the chosen ARIMA. For this purpose, autocorrelations of the residuals were computed and it was found that none of these autocorrelations were significantly different from zero at any reasonable level. This proved that the selected ARIMA models were the best fit and appropriate models for forecasting the series. Also, for checking normality and randomness of the residuals for all the selected markets, probability values were less than 5 percent; indicating residuals were distributed normally and independently (Table 12e).

Table.12e: Diagnostic checking for best ARIMA models

Market	ARIMA model	Autocorrelation test (Ljung-Box Q)	Normality Test (Chi^2)
Jaipur	0,1,1	10.52 (10.52)	202.29(0.000)
Kishangarh	0,1,1	7.96 (0.72)	51.78 (0.000)
Chomu	1,1,0	6.12 (0.87)	64.04 (0.000)
Malpura	1,1,0	10.52 (0.48)	67.53 (0.000)

IV. CONCLUSION AND RECOMMENDATION

The study investigated cointegration, causality and price transmission among selected gram markets in Rajasthan state of India. Stationarity tests showed that the entire price series were unit roots (non-stationary) at level, but became stationary after first difference, thus, integrated of order one. Multiple cointegration tests showed that the selected gram markets in the state were well-integrated and have long-run price association across them. Market pair-wise cointegration test confirmed pairs of Jaipur-Kishangarh; Jaipur-Chomu and jaipur-malpura markets not to have any price association between them. Findings indicated that prices of gram in Jaipur and Malpura markets converge to the long-run equilibrium at the speed of -1.9 percent and -12.9 percent respectively, per month if there is any distortion, i.e, they attain a long-run equilibrium relationship or converge in the long-run after restating and correcting prices at the speed of -1.9 percent and 12.9 percent respectively, per month in the state. For causality tests, two market pairs showed bidirectional causality, one market pair indicated unidirectional causality, and three market pairs depicted none causality. In the short- run, the markets were found to be integrated and price changes are transmitted contemporaneously, though not fully. This indicates that gram markets in the state have acquired competitive strength to certain extent in price formation after correcting short-run and long-run fluctuations. Results of impulse response functions showed that the speed as well as magnitude of a shock given to Malpura market is relatively less transmitted to other markets, thus showing Malpura market to be a trend follower and not trend setter. Comparatively, Kishangarh market was found competent, because price signals originating from this market is quickly transmitted to other markets. IMC results showed high short-run integration between the terminal market (Jaipur) and all the secondary whole sale markets. All the selected markets except Jaipur market observed persistent volatility, implying usefulness of gram marketing in the state. Findings further revealed that the selected ARIMA models could be used successfully for modeling as well as forecasting of monthly wholesale prices of gram for the selected markets, because the models demonstrated a good performance in terms of explained variability and predicting power. The researchers opined that findings of this study will serve as a pivot for the potential use of accurate forecasts in decision-making for the farmers, middlemen, consumers as well as government policy makers. Therefore, the researchers advocated that the network of gram wholesale markets should be well-designed so as to enhance their proximities, given that, it will boost a direct inter-market competition, and also control the wide marketing margins, so that, this produce can be moved to the deficit areas, thus, benefiting both consumers and producers. Furthermore, strengthening of physical infrastructure, use of information and communication technology, and well defined transparent agricultural policy or market measures will help in the development of single uniform economic market in the state and the country in general.

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APPENDIX

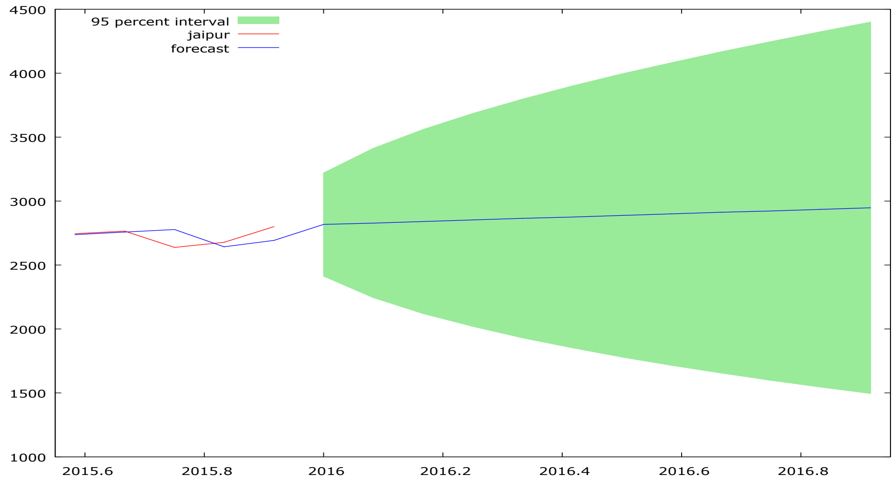

Figure 4: Price forecast of Jaipur

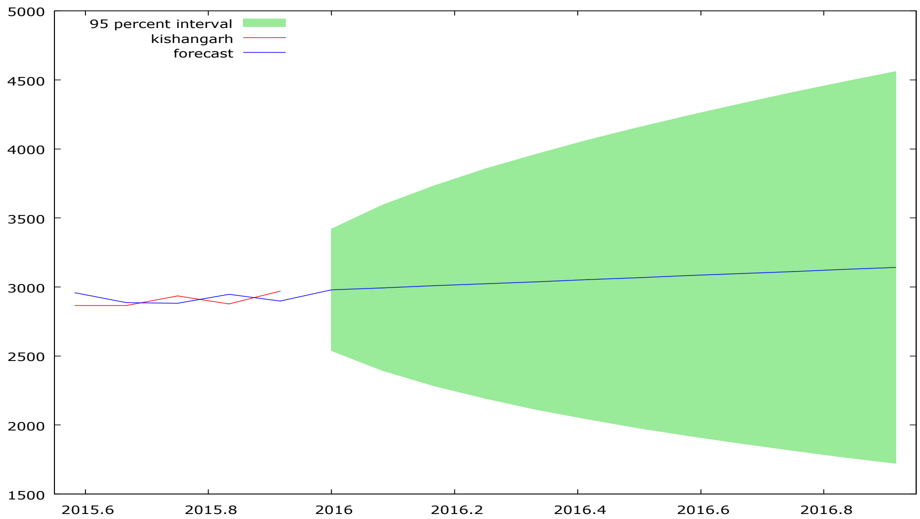

Figure 5: Price forecast of Kishangarh

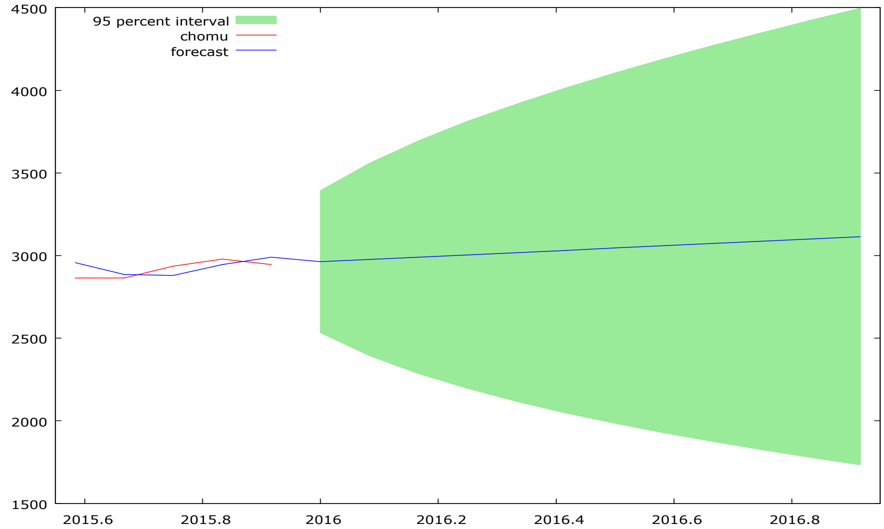

Figure 6: Price forecast of Chomu

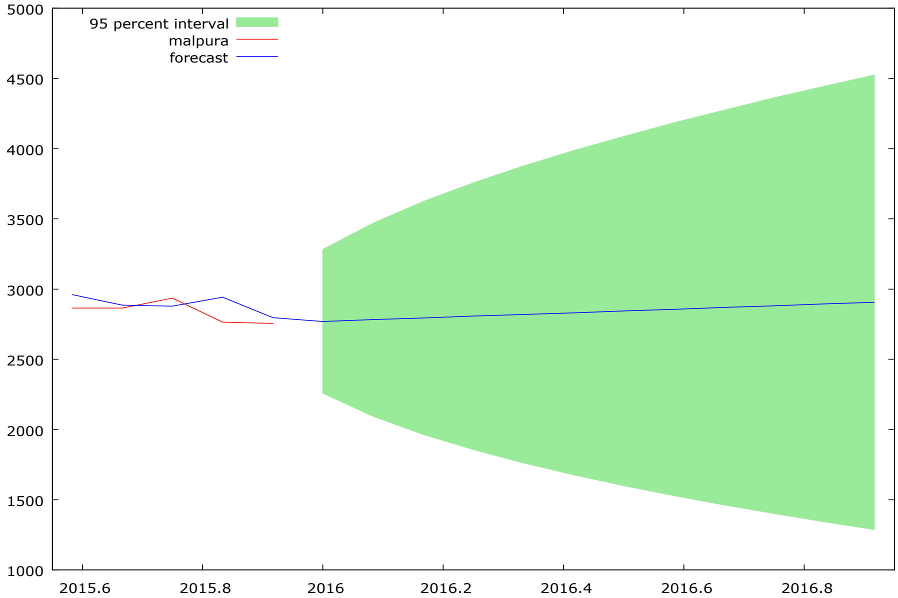

Figure 7: Price forecast of Malpura