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Time –Series Analyses of Food Commodity Prices in Jharkhand (July 2019 – June 2020)

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Abstract

Covid-19 pandemic in India has had a disastrous effect on the economy. There are sharp differences in the assessments of the impact on the agricultural sector. One of the main constraints is lack of detailed data. In an attempt to understand how food supply chains are impacted, we have undertaken detailed studies of three states: Maharashtra, Jharkhand and Meghalaya. Here the focus is on Jharkhand. An aspect of food supply chains is wholesale and retail food prices. We examine these in relation to pre-pandemic levels, the divergence between them and their time varying volatility. A set of time series models are estimated to throw light on prices of rice, potato, tomato and onion in one major market centre, Ranchi. Our analysis does not suggest food price stabilisation at the pre-pandemic level.

JEL Codes: E 31, E 61, E 65

Key Words: Covid 19, Food Supply Chains, Food Commodity Prices, Wholesale Prices, Retail Prices, Time-Series, Jharkhand.

Time-Series Analyses of Food Commodity Prices in Jharkhand (July 2019 – June 2020)

Nidhi Kaicker, Raghav Gaiha & Radhika Aggarwal[1]

Introduction:

When the first nation-wide lockdown was initiated on March 25, to curb the surge of covid-19 in India, the state of Jharkhand did not have a single case of the novel coronavirus. The state reported its first covid positive case on 31st March 2020 of a woman with a travel history to Malaysia[2] and recorded its first fatality due to the deadly virus on April 9 in Bokaro district[3]. The growth in infection was slow initially during the lockdowns but the state entered a turbulent stage of case explosion from June 2020 when the first phase of unlock began. In the wake of the increasing number of positive cases in the state, the government of Jharkhand announced an extension of the lockdown till July 31 with minor relaxations outside containment zones[4].

In this study, as part of a larger study of disruption in food supply chain, we analyse food commodities' price data in the Indian state of Jharkhand. The four commodities whose prices at the local *mandi* level and at the retail outlets are analysed include rice, tomato, potato and onion. The period of our study is July 2019 – June 2020 for which we assess the variability observed in these prices by employing various time –series techniques, and further investigate any changes that may have occurred- especially in the last quarter of our analysis period (i.e. Apr – Jun 2020)- that correspond with the nationwide lockdown and the subsequent partial opening up. We also analyse the gap between local *mandi* and retail prices (the price wedge) to see if the gap has widened or narrowed as a result of the pandemic.

The time series are tested for stationarity using unit root test by using Augmented Dicky Fuller (ADF) test. We further investigate the long-run relationships between retail and wholesale prices, if any, for each commodity using tests for co-integration on the level form of the variables. In order to analyse and ultimately forecast the time-varying behaviour of volatility of these prices, we use the Autoregressive Conditional Heteroscedasticity (ARCH), and its extension, Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models, which address time dependent volatility as a function of observed time volatility.

The focal point of this analysis is that food commodities' prices are the result of the interplay of supply-demand imbalances. These manifest themselves in wholesale/*mandi* prices and retail prices in varying degrees. Part of the wedge reflects transportation costs and traders' margins. Depending on the competition and the nature of the food commodity (whether cereals or perishables such as tomato and milk), the margins vary.

As a detailed literature review is given in our previous study of food commodities' prices in Maharashtra, it is unnecessary to repeat it here[5].

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[1]We are grateful to Rasha Omar, Country Director, IFAD, India, for her support and guidance. We also appreciate the advice of Katsushi Imai and RaghbendraJha on the econometric modeling, The views expressed are personal.

[2]Tewary, A. (2020, April 01). Jharkhand records first positive case. *The Hindu.*[Link]

[3] (2020, April 09). First Covid-19 death in Jharkhand.*The Times of India.*[Link]

[4](2020, June 26). Jharkhand extends lockdown till July 31 due to rising Covid-19 cases. *The Hindustan Times.*[Link]

[5]Kaicker, N., R. Gaiha & R. Aggarwal (2020) "Time –Series Analyses of Food Commodity Prices in Maharashtra (July 2019 – June 2020)", Draft.

Data

The daily retail and wholesale prices of four food commodities – namely – onion, rice, tomato, and potato, have been obtained from the Price Monitoring Division website of the Department of Consumer Affairs for a period of one year from 1st July 2019 to 30th June 2020. These prices have been collated and analysed for 108 centres from all over India. The daily prices have been converted to weekly to circumvent several missing daily values.

The following section analyses data for one centre in Jharkhand – Ranchi. District-wise breakup of covid-19 cases in Jharkhand showed that the capital city of the state – Ranchi -had the highest number of confirmed infections during the four lockdown phases. The cumulative severity ratio-severity measured as deaths during the pandemic relative to pre-pandemic period- in Jharkhand has shown a downward trend between April and May, and started rising after the completion of the fourth lockdown. The average cumulative severity ratio values were 0.17% during the first lockdown phase, decreasing to 0.06% during the second lockdown, and stable around 0.03% in the third, fourth lockdowns and unlock 1.0 phases.

Trends in Wholesale & Retail Prices

We first focus on the movements in food commodities' prices in Ranchi. Figure 1 shows the trends in retail and wholesale prices of the four food commodities in Ranchi. The vertical line in each of the graphs given below shows the time at which the first nation-wide lockdown was announced in India, that is, 25th March 2020, as a measure to contain the surge of the coronavirus (Covid-19) pandemic. Figure 2 shows the trends in price wedge (the difference between wholesale and retail price) of the four commodities in Ranchi.

Figure 1: Wholesale and Retail Prices in Jharkhand

Figure 1(a): Wholesale and Retail Onion Prices in Ranchi

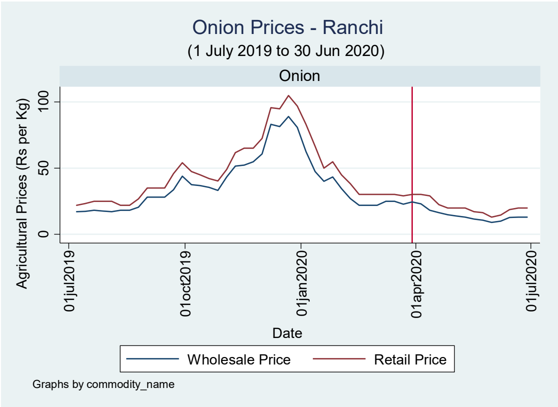


Figure 1(b): Wholesale and Retail Potato Prices in Ranchi

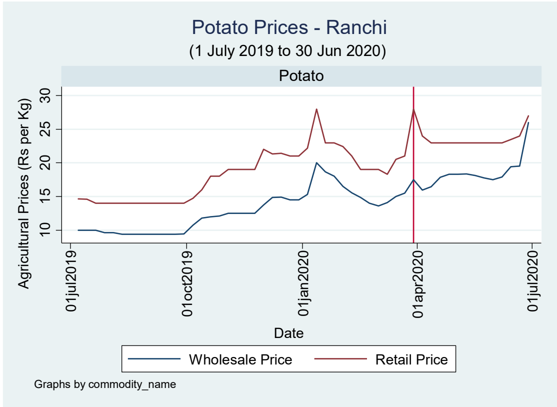


Figure 1(c): Wholesale and Retail Rice Prices in Ranchi

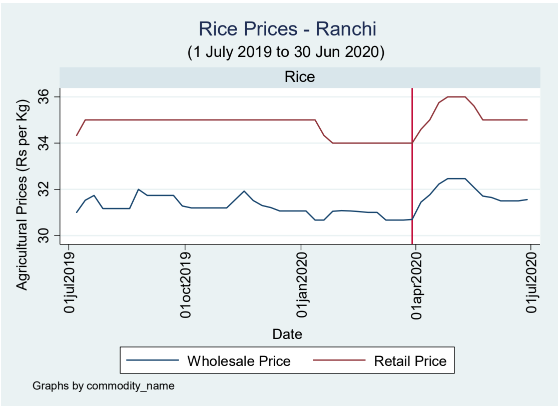
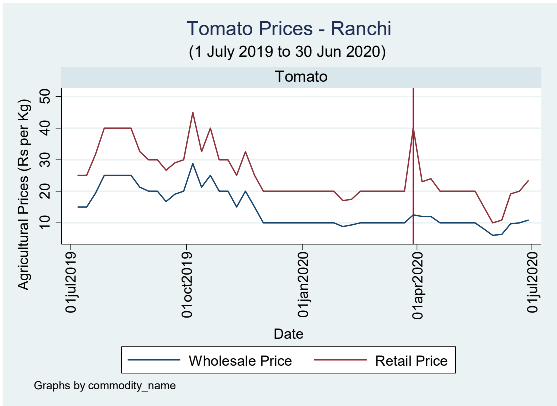


Figure 1(d): Wholesale and Retail Tomato Prices in Ranchi



Source: Authors' computations

Figure 1(a) shows that both retail and wholesale onion prices in Ranchi peaked at Rs. 105 per kg and Rs. 89.2 per kg, respectively, in the October-December quarter of 2019 and saw a steep fall since January 2020. The sharp spike in onion prices in the final quarter of 2019 was due to an estimated 25% fall in *kharif* crop production of that year as a result of late monsoon and eventual excess rains in major producing states. The government had resorted to several measures to control rising prices, such as ban on onion exports, imposing stock limits on traders and supplying buffer stock at lower prices[6].

However, in April-June 2020, both these prices crashed further below the July-Sept 2019 price levels, at Rs. 20 per kg in the former vis-à-vis Rs. 30.5 per kg in the latter in the case of retail and to Rs. 13.7 per kg from Rs. 23.5 per kg at the wholesale level. The prime reasons for this fall include lack of domestic demand due to closure of food outlets in the lockdown, limited inter-state movements of commodities, and a ban on exports.

The trend in price of potatoes in Ranchi is given in Figure 1(b). The figure shows that there has been an overall rise in the retail and wholesale prices of potatoes from July 2019 to June 2020. Particularly, in the case of average wholesale price per quarter, there has been an increase of 93.8%, from Rs. 9.6 per kg to Rs. 18.6 per kg. Thus, wholesale potato prices have nearly doubled in the last one year's time. Note that in the final quarter of the study, which coincides with the nation-wide covid lockdown, the variation in wholesale prices is the highest when compared with the other three quarters of the

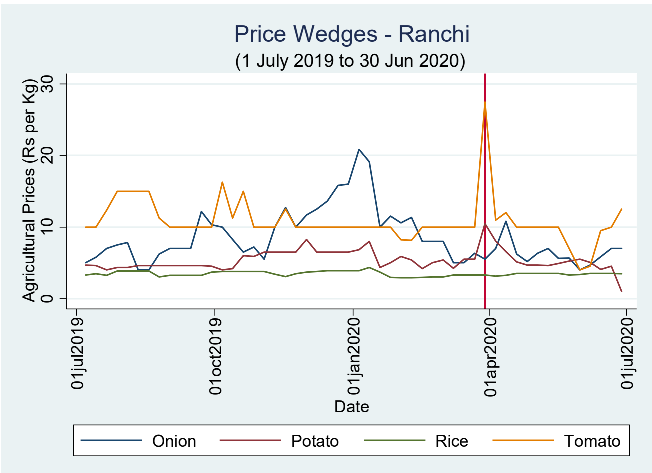
[6](2019, December 27). Onion prices remain higher at up to Rs. 150 per kg, imports underway. *LiveMint*[Link]

study. This can be attributed to the sudden spike in demand as people bought potatoes in bulk quantities and stored them fearing non-availability of supplies as the lockdown progressed. As potato perishes slowly compared to other food commodities, all states were demanding larger quantities of it than usual.

Figure 1(c) shows the trend in wholesale and retail price series of rice in Ranchi. It can be seen that the variation observed in the price series of rice is the lowest of all the four commodities. The retail price of rice remained mostly flat with no variation during the first half of the study period (July – December 2019), but displayed greater variability than the wholesale prices in the second half of the study (January – June 2020). A sudden increase in the prices is noted from the time of announcement of the covid induced lockdown, but the prices return to pre-lockdown levels in later half of the April-June quarter. This sudden surge in prices could possibly be on account of several black-marketing cases that were noted in the state of Jharkhand[7]. Many ration shops were charging higher rates for various commodities due to limited supplies from distributors.

The trend in price of tomatoes in Ranchi is given in Figure 1(d). A downward trend in the retail as well as wholesale price series of tomatoes is observed from July 2019-June 2020. The average wholesale price dropped by more than half, from Rs. 20.5 per kg in the first quarter of the study to Rs. 9.6 per kg in the final quarter. Similarly, the average retail price also fell by 40% approximately, from Rs. 32.3 per kg to Rs. 18.9 per kg during the last year. The retail price shot up for a very brief period just before the covid-19 lockdown was announced but plunged soon after which could be attributed to supply chain disruptions and sporadic release of limited supplies. Also, retail prices have exhibited more variability than the wholesale prices of tomatoes in every quarter of the study.

Figure 2: Price Wedges



The graph in Figure 2 depicts the trend in the wedge between wholesale and retail prices of all the four commodities in Ranchi. The price wedge of tomatoes fell by 5% from July-Sept quarter to the next quarter of 2019. There was, however, no change from the October-December quarter of 2019 to the January-March quarter of 2020, but a decline in the final quarter of our study (April-June 2020). The wedge between the retail and wholesale price series of rice has changed the least of all the four commodities under consideration over the last one year. The price wedges of all commodities, except tomatoes, have followed an increasing trend from the first to the second quarter of the study and a declining one in the January-March quarter of 2020.

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[7](2020, March 25). Coronavirus Outbreak: Jharkhand govt issues rate list in bid to prevent ration shops from overcharging, engaging in black marketing. *Firstpost.*[Link]

In the case of potatoes, the price wedge narrowed following the first covid lockdown. This process of narrowing has been much steeper for tomatoes where price wedge seems to be crashing for much of April-June quarter, but started following an upward trend in the month of June. The price wedge for rice is seen to remain unaffected during the lockdown. Finally, the gap between retail and wholesale prices of onions increased during the first lockdown period of 21 days and is seen dropping subsequently.

Descriptive Statistics

Table 1 given below summarizes the average, maximum and minimum retail and wholesale prices of the four food commodities as well as their respective average price wedges and standard deviations in the four quarters of our study (July 2019 to June 2020). These figures are for the Ranchi centre.

From the following table we infer that retail prices of the commodities are more variable than their wholesale prices. Rice prices show the least variation out of the four commodities under consideration. In the case of wholesale prices, onions and tomatoes display highest degrees of variation in the October-December quarter of 2019, while potatoes and rice show highest degree of variation in the April-June quarter of 2020. The same respective behaviour is observed in the case of retail prices of these commodities, except in the case of potatoes which exhibit greater variation in the third quarter of the study instead of the final quarter, as noted in the case of its wholesale price.

The maximum retail price of potatoes has increased over successive quarters of the last year. Note that there has been a record drop of more than 50% in the maximum wholesale price of tomatoes from the first half to the second half of the period of our study. The retail price of tomatoes has moved in tandem.

Across the four quarters, the price wedge of onions and tomatoes narrowed in the April-June quarter of 2020 which coincides with the country-wide covid-19 lockdowns. On the other hand, the price wedge of potatoes was the lowest in the first quarter of the study and that of rice was the lowest in January-March 2020. The price wedge of all commodities, except tomatoes, was the maximum in the October-December quarter of 2019.

Table 1: Mean, Maximum, Minimum and Standard Deviations of Retail and Wholesale Prices of Food Commodities in Ranchi

		July – September 2019				October to December 2019				January – March 2020				April – June 2020			
		Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato
July – September 2019	Average Wholesale Price	23.5	9.6	31.5	20.5	57.0	13.0	31.3	16.5	32.2	16.0	30.9	10.0	13.7	18.6	31.9	9.6
	SD - Wholesale Price	8.3	0.3	0.3	3.7	20.4	1.3	0.2	6.4	12.7	2.0	0.2	0.8	3.7	2.4	0.4	1.8
	Max - Wholesale Price	43.8	10.0	32.0	25.0	89.2	14.9	31.9	28.8	62.5	20.0	31.1	12.5	23.0	26.0	32.5	12.0
	Min - Wholesale Price	17.0	9.4	31.0	15.0	33.2	10.7	31.1	10.0	22.0	13.6	30.7	8.8	9.0	16.0	31.4	6.0
	Average Retail Price	30.5	14.1	34.9	32.3	67.8	19.2	35.0	27.7	42.1	21.9	34.2	21.1	20.1	23.5	35.3	18.9
	SD - Retail Price	10.1	0.2	0.2	5.8	23.3	2.2	-	8.3	17.3	3.1	0.4	5.8	4.9	1.1	0.5	4.4
	Max - Retail Price	54.2	14.7	35.0	40.0	105.0	22.0	35.0	45.0	83.3	28.0	35.0	40.0	30.0	27.0	36.0	24.0
	Min - Retail Price	22.0	14.0	34.3	25.0	40.4	14.8	35.0	20.0	29.2	18.3	34.0	17.0	13.0	23.0	34.6	10.0
	Average Price Wedge	7.0	4.5	3.5	11.8	10.8	6.2	3.7	11.2	9.9	5.8	3.3	11.1	6.3	4.9	3.4	9.3

Table 2: Tests of Stationarity for Prices in Ranchi

			WHOLESALE PRICES				RETAIL PRICES				PRICE WEDGE			
		5% Critical Value	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato
Actual Level of Price	Lag#		2	1	2	2	2	1	2	2	1	1	1	0
	ADF Test Statistic:													
	At Lag 0	-2.929												-5.257*
	At Lag 1	-2.930		0.453				-1.011			-2.281	-2.213	-3.233*	
	At Lag 2	-2.933	-1.673		-2.536	-1.653	-1.687		-2.778	-2.118				
First Difference of Prices	Lag #		1	0	0	1	1	0	1	1	0	0		
	ADF Test Statistic:													
	At Lag 0	-2.930		-4.761*	-6.066*			-8.731*			-7.633*	-8.382*		
	At Lag 1	-2.933	-3.601*			-4.458*	-3.497*		-3.502*	-5.206*				

Optimal Lag Length calculated based on the Bayesian Information Criterion (BIC)

* significant at 5% level

Time Series Analysis

So far, our analysis was focused on deterministic means, standard deviations and trends. The time series models/techniques are based on the notion that the series (say, wholesale food commodity prices during 2019-20) have been generated by a stochastic (or random) process with a structure that can be characterised or described. The description is given not in terms of a cause-and-effect relationship but in terms of how that randomness is embodied in the process[8]. We expect therefore new insights from this analysis.

Tests of Stationarity

We first examine the properties of our data by testing for stationarity. A stationary time series is one whose statistical properties such as mean, variance, and autocorrelation remain constant overtime. We examine the stationarity of the time series using unit root test – Augmented Dicky Fuller (ADF) test9 (Wooldridge, 2006). Thus, we are testing for the null hypothesis that the series follows a random walk without drift. The lag length k is determined using Schwartz/Bayesian Information Criterion (BIC). The results are shown in Table 2.

The null hypothesis of presence of unit root in the series is *not* rejected for all the series, except the price wedge of Rice and Tomato. Hence the prices are non-stationary, and we do a re-test taking their first differences. All the other price series (wholesale and retail prices of all commodities and the price wedge of onion and potato), are found to be stationary in the first differences.

Tests of Co-Integration between Retail and Wholesale Prices and Vector Error Correction Models (VECM)

As seen in the previous sub-section, the retail and wholesale prices of all commodities are found to be integrated of order 1, i.e. these series are non-stationary at their level, but stationary when the first differences are taken. A vector of variables, all that achieve stationarity after differencing, could have a linear combination which is stationary in level (or, has a lower degree of integration than the original series). This property, *Co-integration,* signifies co-movements among trending variables. A Co-integration test helps assess the long run relationship despite the fact that the series are drifting apart or trending either upward or downward. Co-integration test must be done on the level form of the variables – wholesale prices and retail prices.

Table 3 gives information on the co-integration test for the retail and wholesale prices (for 4 different commodities at Ranchi), based on Johansen's method (1995)[10]. The table gives the trace statistic and the 5% critical value. Johansen's testing procedure starts with the test for zero co-integrating equations (a maximum rank of zero) and then accepts the first null hypothesis that is not rejected.

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[8]For an exposition, see Greene (2012).

[9]The Augmented Dicky Fuller test fits the model of the form
$\Delta y_t = \alpha + \beta y_{t-1} + \delta t + \varsigma_1 \Delta y_{t-1} + \varsigma_2 \Delta y_{t-2} + \cdots + \varsigma_k \Delta y_{t-k} + \epsilon_t$, testing for the null hypothesis $\beta = 0$.

[10]Johansen, S.(1995), *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models* (New York: Oxford University Press).

Table 3: Tests of Co-Integration between Wholesale and Retail Prices at Ranchi

			RANCHI		
	Rank	5% Critical Value	Log Likelihood	Eigen-value	Trace Statistic
ONION	0	15.41	-270.213	.	36.33
	1	3.76	-253.468	0.49	2.83*
	2		-252.051	0.06	
POTATO	0	15.41	-164.364	.	5.23*
	1	3.76	-161.889	0.09	0.28
	2		-161.749	0.01	
RICE	0	15.41	4.511	.	15.22*
	1	3.76	10.401	0.21	3.44
	2		12.119	0.07	
TOMATO	0	15.41	-245.486	.	16.04
	1	3.76	-238.094	0.26	1.26*
	2		-237.466	0.02	

From this table, we infer the following:

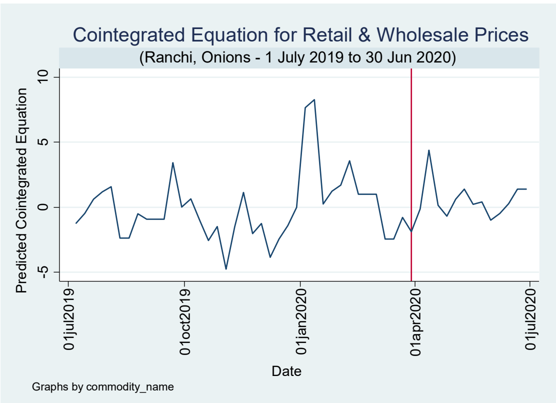
1. The null hypothesis of no co-integration between retail and wholesale prices is *not rejected* in case of Potatoes and Rice.
2. The null hypothesis of no co-integration between retail and wholesale prices is *rejected* in the case of Onions and Tomatoes. Thus, a long run relationship, based on co-integrating equations, can be estimated between wholesale and retail prices of Onions and of Tomatoes at the Ranchi centre. These cases have been highlighted in Table 3.

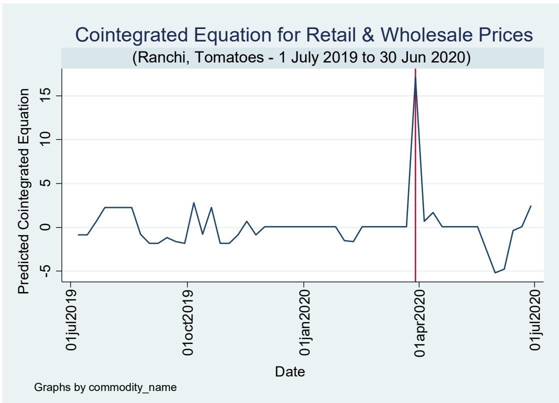
Since co-integration implies the existence of an error correction model (Engle and Granger, 1987), we estimate the co-integrating equation of the cases mentioned in (2) above.

Table 4 presents the parameters of the bivariate co-integrating Vector Error Correction Model (VECM) for retail and wholesale prices. The table comprises both short run adjustment factors and coefficients (retail and wholesale price equation) and the long run coefficients (co-integrating equation).

Table 4: Vector Error Correction Model for Retail and Wholesale Prices

	Onion			Tomato		
No. of Observations	50			50		
AIC | BIC | HQIC	10.50	10.84	10.63	9.88	10.23	10.01
Log Likelihood	-253.468			-238.094		
D_Retail Prices Equation						
RMSE | R-Squared | Chi2	5.84	0.36	25.37***	5.26	0.27	17.22***
Adjustment Factor	-1.68	(0.53)	***	-0.96	(0.34)	***
Retail Prices (LD)	0.31	(0.39)		-0.01	(0.27)	
Wholesale Prices (LD)	-0.25	(0.51)		-0.24	(0.49)	
Constant	0.02	(0.83)		0.02	(0.74)	
D_Wholesale Price Equation						
RMSE | R-Squared | Chi2	5.94	0.17	9.60**	2.77	0.09	4.55
Adjustment Factor	-0.73	(0.53)		-0.18	(0.18)	
Retail Prices (LD)	0.11	(0.40)		0.10	(0.14)	
Wholesale Prices (LD)	0.07	(0.51)		-0.36	(0.26)	
Constant	-0.04	(0.84)		-0.10	(0.39)	
Co-integrating Equation						
Chi2		9341.103***			154.1451***	
Retail Prices	1.00	.		1.00	.	
Wholesale Prices	-1.15	(0.01)	***	-1.19	(0.10)	***
Constant	-3.63	.		-8.07	.	
Post Estimation Diagnostics						
LM Test for Autocorrelation						
Chi2 at Lag 1		0.6121			7.7350	
Chi 2 at Lag 2		3.4992			8.2331*	
Jarque-Bera test for Normality						
Chi 2 for D_Retail Price		18.277***			50.738***	
Chi2 for D_Wholesale Price		0.661			193.471***	
Chi 2 for All		18.939***			244.209***	





Following are the key observations:

1. The adjustment factor in the retail prices equation for both Onion and Tomato is negative and significant. This implies a convergence in the long run, and the rate of convergence is faster for Onions compared to that of Tomatoes. The adjustment factor for wholesale prices for both Onions and Tomatoes is found to be insignificant.
2. For both the cases, the Chi^2 of the co-integrating equation indicates a good model fit. The coefficient of the Wholesale price in the co-integrating equation is negative and significant in both cases, implying presence of a *positive* long run relationship between Retail and Wholesale Prices.

3. The graphs of the predicted co-integrated equation are plotted and presented in the last row of Table 4. The co-integrating equation for both cases exhibits stationarity, as is confirmed by the statistical tests. In the case of Onions, a steep rise from the equilibrium is witnessed in the predicted values after the announcement of the lockdown, followed by a fall but the series mostly stayed above the equilibrium value. In the case of Tomatoes, a steep fall is witnessed immediately after the announcement of lockdown, followed by a deeper plunge, only to rise at the time of partial opening up of the economy after the strict nationwide lockdown.
4. We do post-estimation diagnostic tests to assess the validity of our model. Using the LM test, the null hypothesis for no autocorrelation is not rejected for both the series, implying absence of autocorrelation. The Jarque-Bera Normality test suggests that the null hypothesis that residuals are normally distributed is rejected for both models.

Vector Autoregression Model for Retail and Wholesale Prices (VAR)

In the previous section, we found that a long run relationship, based on co-integrating equations, can be estimated between wholesale and retail prices of Onions and of Tomatoes at Ranchi Centre. For Potatoes and Rice, since there is no co-integrating equation that can be estimated to establish a long-term relationship, we use a vector autoregression model to explain co-movements. A VAR model is a system of equations where each dependent variable (in the vector) is expressed as a function of its own lags and lags of other endogenous variables.

A prerequisite for the variables in a VAR framework is that they should be integrated of order 1, which has already been established for all our price series. Next, we estimate the appropriate lag length for the VAR model using the AIC (Akaike's Information Criterion), and using this lag length, estimate the parameters of the model. The results are given in Table 5. The model fit for both the commodities, as suggested by the Chi^{2}value, is good.

Table 5: Vector Auto Regression (VAR) Model for Retail and Wholesale Prices

	Potato			Rice		
Optimal Lag Length (AIC)	1			2		
No. of Observations	51			50		
AIC | BIC | HQIC	6.71	6.94	6.80	-0.60	-0.46	-0.22
Log Likelihood	-165.103			25.04		
Retail Prices Equation						
RMSE | R-Squared | Chi2	1.75	0.82	236.19***	0.18	0.90	438.02***
L1. Retail Price	0.59	(0.19)	***	1.24	(0.13)	***
L2. Retail Price				-0.43	(0.12)	***
L1. Wholesale Price	0.41	(0.22)	*	0.18	(0.11)	*
L2. Wholesale Price				-0.09	(0.11)	
Constant	2.619	(1.27)	**	3.54	(1.72)	**
Wholesale Price Equation						
RMSE | R-Squared | Chi2	1.33	0.88	377.89***	0.25	0.75	147.40***
L1. Retail Price	-0.08	(0.15)		0.32	(0.19)	*
L2. Retail Price				-0.19	(0.17)	
L1. Wholesale Price	1.12	(0.17)	***	0.91	(0.15)	***
L2. Wholesale Price				-0.25	(0.16)	
Constant	0.20	(0.96)		6.00	(2.43)	**

***, **, * denote significance at 1%, 5% and 10% levels, respectively.

The VAR model confirmed dependence of retail prices of potatoes and rice in Ranchi on the first lag of wholesale prices, with a positive coefficient. The dependence of wholesale prices on the lag of retail prices is found to be significant and positive in the case of rice, but not in the case of potatoes. In both retail and wholesale price equations for potatoes and rice, the coefficient of the own first lag of the dependent variable is significant and positive.

Measurement of Volatility in Prices

The volatility of many economic time series is not constant through time, but may exhibit clustering, i.e. large deviations from the mean tend to be followed by even larger deviations, and small deviations tend to be followed by small deviations. In other words, periods of relatively low volatility and periods of relatively high volatility tend to be grouped together.

The Autoregressive Conditional Heteroscedasticity (ARCH), and its extension, Generalised Autoregressive Conditional Heteroscedasticity (GARCH), address time dependent volatility as a function of observed time volatility. The ARCH models the variance of a regression model's disturbances as a linear function of lagged values of the squared regression disturbances. The GARCH model, in addition, includes lagged values of the conditional variance.

For the various price series, we test for the presence of conditional heteroscedasticity using the Lagrange's Multiplier (LM) Test. The LM test for ARCH effects is done on a stationary series. Since the price series were found to be integrated of order 1, we conduct the test on the first difference of the price series. The results are summarized in Table 6.

Table 6: LM Test for Autoregressive Conditional Heteroscedasticity

	Ranchi			
	Onion	Potato	Rice	Tomato
D. Wholesale Price chi^2	1.998	0.002	0.059	10.189***
D. Retail Price chi^2	2.488	5.625**	2.095	7.585***

D. refers to the first differencing of the time series to convert a non-stationary series to a stationary one.

***, **, * denote significance at 1%, 5% and 10%, respectively.

The results suggest presence of conditional heteroscedasticity in the wholesale and retail prices of Tomatoes, and retail price of Potatoes. These are highlighted in Table 6. Since these series exhibit non-constant volatility, they require further examination.

Table 7: GARCH Parameters for Ranchi Centre

	Retail Price	Wholesale Price	Retail Price
Commodity	Potato	Tomato	Tomato
No. of Obs	52	52	52
ARCH Coefficient (L1)	0.945 (11.20)	0.878 (2.37)	0.78 (2.00)
GARCH Coefficient (L1)	-0.016 (11.78)	0.038 (2.27)	0.06 (2.52)
Constant	31.324 (1396.5)	14.389 (134.55)	113.80 (678.90)

Table 7 shows the parameters for the Autoregressive Conditional Heteroscedasticity specification for these cases. The ARCH coefficient measures the extent to which the volatility reacts to shocks/ innovations. The coefficient is found to be positive (and less than 1) but insignificant for all the cases. The GARCH coefficient measures the persistence in conditional volatility. These are also found to be insignificant for all the cases.

Concluding Observations

A co-integration test helps assess the long run relationship regardless of whether the series are drifting apart or trending either upward or downward. A positive long- run relationship is observed between wholesale and retail prices of both Onions and Tomatoes in Ranchi. The adjustment factor in the retail prices equation for both Onion and Tomato is negative and significant implying convergence in the long run. The rate of convergence is faster for Onions compared to that of Tomatoes.

The volatility of many economic time series is not constant through time, but may exhibit clustering, i.e. large deviations from the mean tend to be followed by even larger deviations, and small deviations tend to be followed by small deviations. In other words, periods of relatively low volatility and periods of relatively high volatility tend to be grouped together.

Our analysis suggests (based on ARCH model) presence of conditional heteroscedasticity in retail price of Potatoes; and in both retail and wholesale prices of Tomatoes. These price-commodity pairs exhibit non-constant volatility.

Any generalisations about eventual convergence of food prices to pre-pandemic levels, resilience of the food system, and whether supply disruption dominated demand deficiency in explaining the food commodities' movements during the lockdown and unlock period are avoided, as the analysis is not sufficiently detailed to draw such inferences.

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