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

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Abstract

Meghalaya is a special case. The growth in the number of Covid-19 cases was very slow during all the lockdown phases. As on May 10, the total count of covid-19 cases in the state was 13, of which there was one death, two active cases and ten recoveries. Meghalaya did not see a second fatality due to the virus until July 7, and had reported a total of 89 cases by then. The state government extended night curfews and ban on inter-state movement of people till June 30. So unlike other states there was no pandemic. Using a long time –series of wholesale and retail prices of rice, potato, tomato and onion, covering the period year from 1st July 2019 to 30th June 2020, we use time series models to investigate co-movements between wholesale and retail prices over time and in three different market centres (Shillong, Jowai and Tura) and across them; and time varying volatility. It is not surprising that the results are not so striking (unlike Maharashtra or Jharkhand), as Covid-19 never turned into a pandemic. However, supply and demand disruptions cannot be ruled out given the stringency of the lockdown and weak market integration.

JEL Codes: E 31, E 61, E 65

Key Words: Covid 19, Food Supply Chains, Food Commodity Prices, Whole sale Prices, Retail Prices, Time-Series, Meghalaya

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

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Introduction:

The state of Meghalaya registered its first positive covid-19 case on 13th April 2020 when a doctor, who is believed to have contracted the virus from a silent carrier at Shillong's Bethany hospital tested positive for the virus[2]. He also accounts for the first Covid death that the state reported on 15th April 2020[3]. The growth in the number of Covid cases in Meghalaya was very slow during all the lockdown phases. As on May 10, the total count of covid-19 cases in the state was 13, of which there was one death, two active cases and ten recoveries[4]. Meghalaya did not see a second fatality due to the virus until July 7, and had reported a total of 89 cases by then[5]. The state government extended night curfews and ban on inter-state movement of people till June 30. However, there were conditional relaxations for operationalisation of over 400 shops including non-essentials in stringent adherence to social distancing norms and stipulated time limits.

In this study, as part of a larger study of disruption in food supply chain, we analyse food commodities' price data in Meghalaya. 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 corresponds 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 nationwide lockdown announced due to the spread of Covid-19 in the country.

The time series are tested for stationarity using unit root test – 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 central point of this analysis is that food commodities' prices are the outcome 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

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[2] (2020, April 14). Meghalaya registers first COVID-19 positive case. *The Hindu*. [Link]

[3] (2020, April 16). Covid-19 patient dies in Meghalaya. *The Economic Times*. [Link]

[4] (2020, May 10). Covid-19 lockdown relaxation: Shops, vehicles to operate in Meghalaya from May 11. *The New Indian Express*. [Link]

[5] (2020, July 7). Meghalaya: COVID-19 positive baby dies hours after travelling 400 kms for treatment. *Deccan Chronicle*. [Link]

the competition and the nature of the food commodity (whether cereals such as rice or perishables such as tomato and milk), the margins vary.

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 three centres in Meghalaya – Shillong, Jowai and Tura. These three centres have been selected with the aim of also conducting comparative analyses across centres within the same state.

Shillong is the capital city of Meghalaya and lies in the East Khasi Hills district of the state. It is the place where the first covid-19 positive case and associated death were reported in mid-April 2020. Till date, the district of East Khasi Hills has the highest number of active covid cases in the state. Jowai is the administrative headquarters of the West Jaintia Hills district of Meghalaya. The first positive case associated with the deadly virus in Jowai was reported on 3rd June 2020[6]. Among the three centres in our study, it has the lowest number of covid cases till date. Tura is a town in the West Garo Hills district of Meghalaya. This district has the second highest number of active covid cases in Meghalaya after Shillong in East Khasi Hills district[7].

Trends in Wholesale & Retail Prices

We first focus on the movements in food commodities' prices in three centres/cities – Shillong, Jowai and Tura. Figures 1 – 5 show the trends in retail and wholesale prices of the four commodities in the three centres. 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, on 25th March 2020, as a measure to contain the surge of the coronavirus (Covid-19) cases in the country. Figure 6 shows the trends in price wedge (the difference between wholesale and retail price) of the four commodities in each of the three centres.

[6] (2020, June 3). First COVID case reported in Jowai. *Syllad.* [Link]
[7] (2020, August 25). COVID-19 cases in Meghalaya cross total 2000 mark, 42 new positive cases. *Shillong Today.* [Link]

Figure 1: Prices of Onion in Meghalaya

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

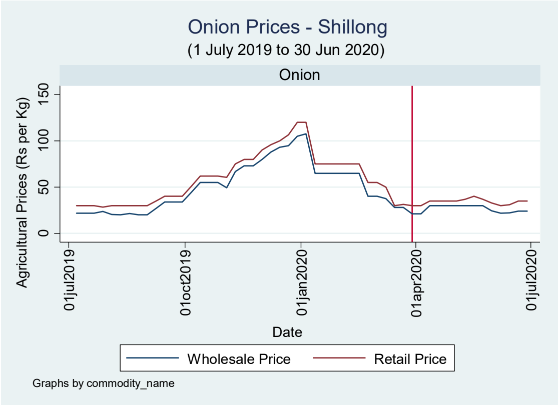


Figure 1(b): Wholesale & Retail Onion Prices in Jowai

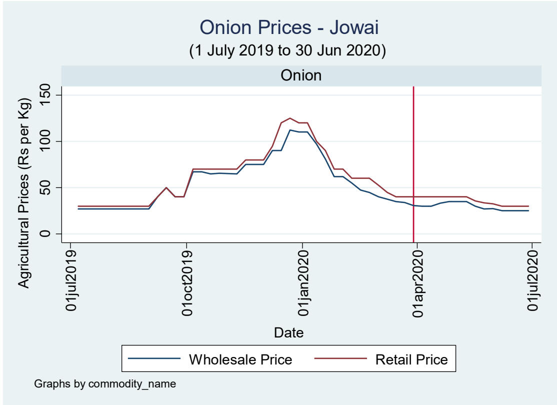
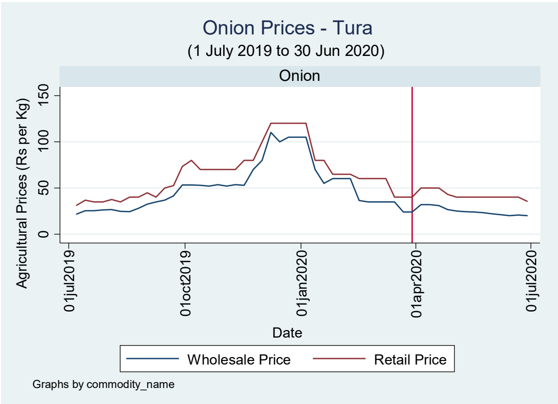


Figure 1(c): Wholesale & Retail Onion Prices in Tura



Source: Authors' computations

Figure 1 shows that, onion retail prices in all three centres peaked in the October-December quarter of 2019 and saw a steep fall since January 2020. The same is observed in the case of wholesale onion prices in Jowai and Tura centres. However, the maximum wholesale price of onion in the Shillong centre was found in the first quarter of 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.[8]

While the average wholesale price of onion peaked during the final quarter of 2019, greater variation in the wholesale prices is recorded in the following quarter (Jan-March 2020) at two centres – Shillong and Jowai.

In April-June 2020, the quarter coinciding with the country-wide coronavirus lockdown, onion prices displayed the maximum variability in the Tura centre at both wholesale and retail price levels.

[8](2019, December 27). Onion prices remain higher at up to Rs. 150 per kg, imports underway. *LiveMint*[Link]

Figure 2: Prices of Potato in Meghalaya

Figure 2(a): Wholesale and Retail Potato Prices in Shillong

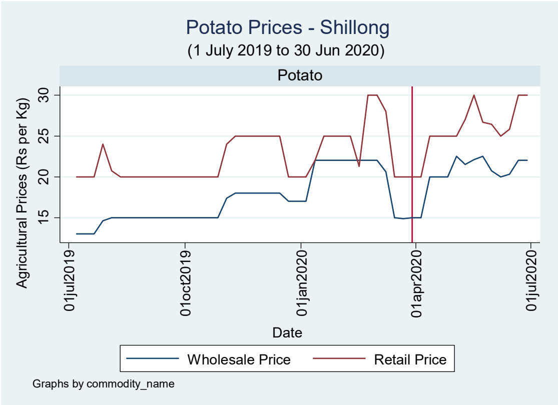


Figure 2(b): Wholesale & Retail Potato Prices in Jowai

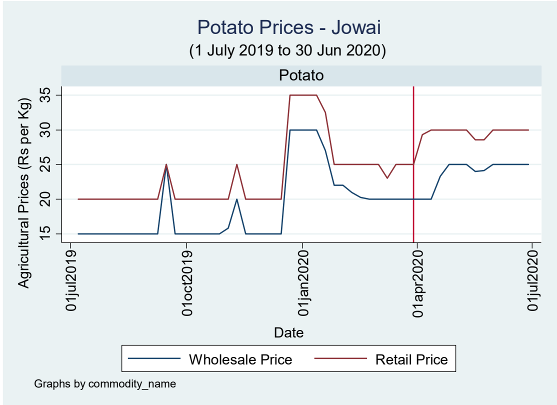
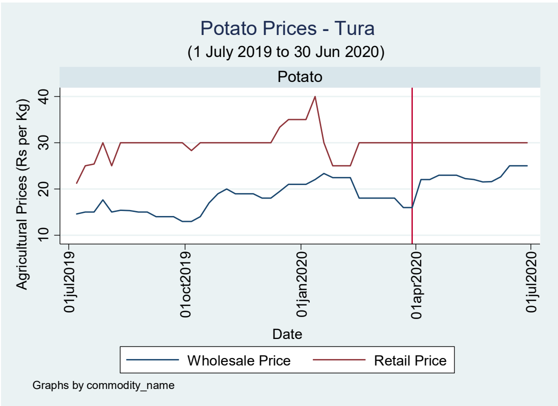


Figure 2(c): Wholesale & Retail Potato Prices in Tura



Source: Authors' computations

Figure 2(a) shows that retail and wholesale prices of potatoes in Shillong have moved parallel for most of the last year. The same is true for the prices in Jowai (Figure 2(b)). However, the two price series have shown a different trend in the Tura centre (Figure 2(c)).

It is worth noting that post the covid lockdown, the retail potato prices have exhibited no variability in April-June 2020. On the other hand, during the same period, wholesale potato prices have shown greater variation than retail prices in the same quarter. In relation to this point, it is also interesting to note that the average wholesale price of potatoes peaked at each centre during the final quarter of the study (April-June 2020) suggesting that with a low standard deviation, the prices remained at the higher end during most of this period.

This is further accompanied by an increase in the prices – both retail and wholesale at two of the three centres – Shillong and Jowai post the announcement of the covid lockdown on March 25th. This was because 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 vegetables, all states were demanding larger quantities of it than usual. As a consequence of the sudden hike in demand, potato prices soared.

Figure 3: Prices of Rice in Meghalaya

Figure 3(a): Wholesale and Retail Rice Prices in Shillong

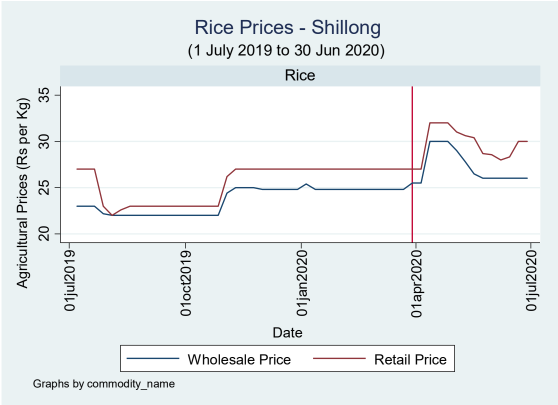


Figure 3(b): Wholesale & Retail Rice Prices in Jowai

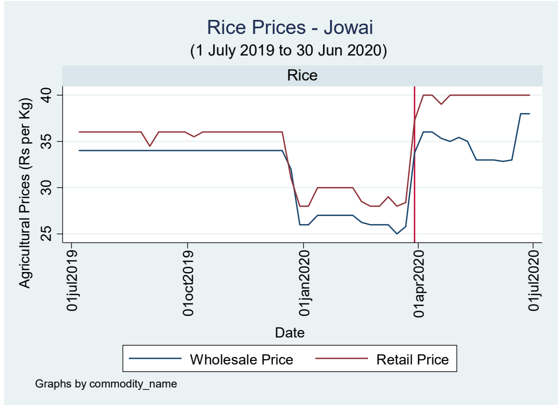
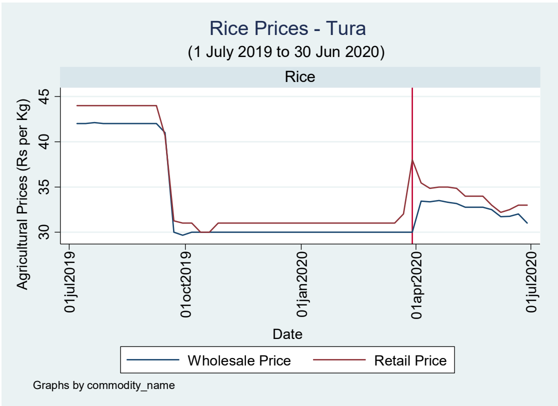


Figure 3(c): Wholesale & Retail Rice Prices in Tura



Source: Authors' computations

As depicted in Figure 3, both retail and wholesale prices of rice across the three centres move in tandem for most of the last one year during the period of the study (July 2019 to June 2020). There has been a sudden spike in prices in the April-June quarter of 2020 which coincides with the nation-wide coronavirus lockdown, at Shillong and Jowai. While there has been a drop in the retail price of rice post the lockdown announcement in Tura, the wholesale prices have exhibited a brief upward trend followed by a fall in line with the retail prices.

The maximum retail and wholesale prices of rice were recorded in the final quarter of the study (April-June 2020), with Tura centre being the only exception. Note that the prices of rice in Tura showed greater variation in the first quarter of the analysis period (July-September 2019) than any other quarter of the study. This behaviour is quite different from what we observe at the other two centres.

The reason for the sharp increase in price of rice in Meghalaya was the non-availability of stock in the godowns of wholesale dealers and surge in consumer demand. Also, rice is a staple food commodity in the state and thus observed sharp soaring of prices due to shortage of supplies during the covid lockdown.

Figure 4: Prices of Tomato in Meghalaya

Figure 4(a): Wholesale and Retail Tomato Prices in Shillong

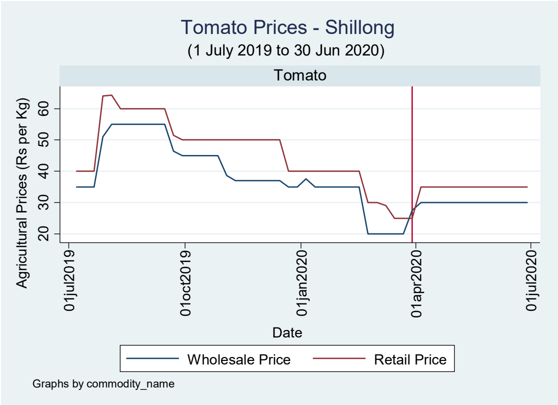


Figure 4(b): Wholesale and Retail Tomato Prices in Jowai

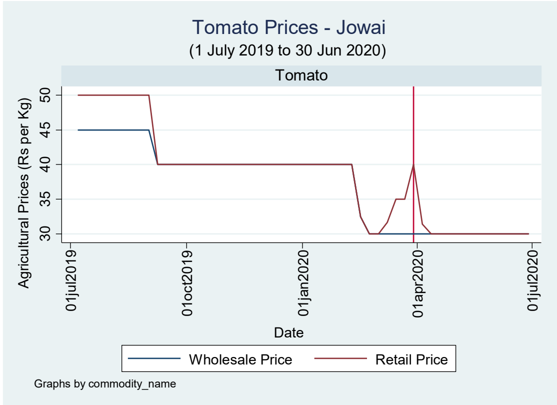
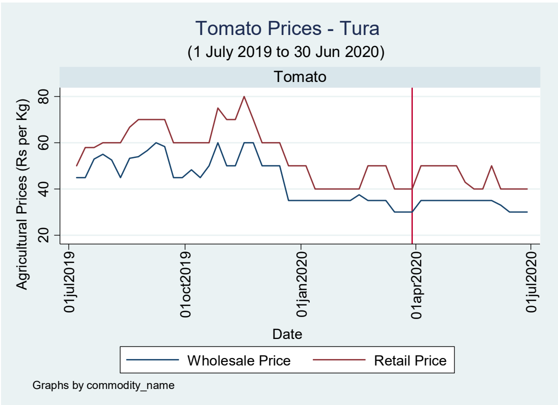


Figure 4(c): Wholesale and Retail Tomato Prices in Tura



Source: Authors' computations

Figure 4 (a) and (c) show similar trend in the retail and wholesale prices of tomatoes at Shillong and Tura, respectively. However, at Jowai as shown in figure 4(b), the retail and wholesale prices coincided during October-December 2019. While there has been an increase in the prices in Shilling and Tura post the covid lockdown announcement, a steep fall in the retail price of tomatoes is observed in Jowai.

The wholesale price of tomatoes peaked during the July-September quarter of 2019 in all the three centres. Similarly, the retail tomato prices peaked during the same quarter in Shillong and Jowai, but were the maximum at Rs. 80 per kg in the October-December quarter of 2019 in Tura. Retail prices have exhibited more variability than the wholesale prices of tomatoes in every quarter of the study in the Tura centre.

In Jowai, the retail price of tomatoes shot up drastically ahead of the lockdown. This was the result of pre-lockdown panic driven rush in the markets accompanied by fluctuations in fuel prices and short supplies. Post the covid lockdown, the retail tomato prices have exhibited no variability in April-June 2020 in Shillong and Jowai which is surprising due to the change in the demand-supply dynamics during this period.

Figure 5 depicts the trend in the wedge between wholesale and retail prices of the four food commodities – onion, potato, rice, and tomato in the three centres, namely Shillong, Jowai and Tura over the four quarters of the last one year (July 2019 – June 2020).

In Shillong and Jowai, the price wedge of onion expanded the maximum in the first quarter of 2020. The maximum wedge between retail and wholesale prices of potatoes occurred in the July-September quarter of 2019 in Shillong and Tura, while it was maximum in Jowai in the April-June quarter of 2020. In Tura, the price wedge of potato has followed a downward trend from July 2019 to June 2020. In Jowai, the price wedge of rice rose by 85% from Jan-March quarter to April-June quarter. The price wedge of onion has displayed huge variations from one quarter over the other in all the three centres.

It is interesting to note that tomato prices in Jowai displayed no variation at both retail and wholesale levels from October-December 2019. The price wedge is seen to rise ahead of the coronavirus lockdown, followed by a decline after the lockdown till it was restored to its late 2019 level. The price wedge of rice has shown the least variation across the three centres and across the four quarters with the April-June 2020 quarter in Jowai being the only exception.

Figure 6: Price Wedges

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 given for the three centres of our study.

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
SHILLONG	Average Wholesale Price	24.7	14.5	22.2	48.6	71.7	16.9	24.0	39.3	53.2	19.9	24.9	28.8	26.7	20.7	27.3	30.0
	SD - Wholesale Price	5.6	0.9	0.4	8.5	19.4	1.4	1.4	4.1	23.6	3.1	0.2	7.6	3.8	2.0	1.8	-
	Max - Wholesale Price	34.0	15.0	23.0	55.0	105.0	18.0	25.0	45.0	107.5	22.0	25.5	37.5	30.0	22.5	30.0	30.0
	Min - Wholesale Price	20.0	13.0	22.0	35.0	44.5	15.0	22.0	35.0	21.0	14.9	24.8	20.0	21.0	15.0	25.5	30.0
	Average Retail Price	32.5	20.4	23.8	54.6	80.4	22.6	25.7	48.5	63.2	23.9	27.0	34.2	34.4	26.2	29.9	35.0
	SD - Retail Price	4.5	1.1	1.8	9.3	21.0	2.5	1.9	3.8	25.1	3.7	-	6.8	2.9	2.7	1.7	-
	Max - Retail Price	40.0	24.0	27.0	64.3	120.0	25.0	27.0	50.0	120.0	30.0	27.0	40.0	40.0	30.0	32.0	35.0
	Min - Retail Price	28.4	20.0	22.0	40.0	51.0	20.0	23.0	40.0	30.0	20.0	27.0	25.0	30.0	20.0	27.0	35.0
	Average Price Wedge	7.9	5.9	1.6	5.9	8.7	5.7	1.8	9.2	9.9	4.1	2.1	5.3	7.7	5.6	2.6	5.0
JOWAI	Average Wholesale Price	31.8	15.8	34.0	43.5	78.6	17.8	33.2	40.0	56.6	22.5	26.9	34.8	29.4	24.0	34.9	30.0
	SD - Wholesale Price	7.9	2.8	-	2.4	16.9	5.6	2.2	-	25.3	3.9	2.1	5.0	4.1	1.8	1.8	-
	Max - Wholesale Price	50.0	25.0	34.0	45.0	112.5	30.0	34.0	40.0	110.0	30.0	33.8	40.0	35.0	25.0	38.0	30.0
	Min - Wholesale Price	27.0	15.0	34.0	40.0	65.0	15.0	26.0	40.0	30.5	20.0	25.0	30.0	25.0	20.0	32.8	30.0
	Average Retail Price	33.8	20.4	35.9	46.9	86.2	22.7	35.0	40.0	65.2	27.0	29.6	36.5	35.5	29.7	39.9	30.1
	SD - Retail Price	6.5	1.4	0.4	4.8	21.5	5.6	2.5	-	24.9	4.2	2.5	4.2	4.6	0.5	0.3	0.4
	Max - Retail Price	50.0	25.0	36.0	50.0	125.0	35.0	36.0	40.0	120.0	35.0	37.3	40.0	40.0	30.0	40.0	31.4
	Min - Retail Price	30.0	20.0	34.5	40.0	70.0	20.0	28.0	40.0	40.0	23.0	28.0	30.0	30.0	28.6	39.0	30.0
	Average Price Wedge	2.1	4.6	1.9	3.5	7.5	4.9	1.7	-	8.6	4.5	2.7	1.7	6.1	5.8	5.0	0.1
TURA	Average Wholesale Price	30.9	14.8	40.1	51.4	72.3	18.3	30.0	49.5	48.8	19.7	30.0	34.0	24.8	22.9	32.6	33.7
	SD - Wholesale Price	8.9	1.1	4.5	5.6	24.2	2.4	-	8.0	22.7	2.7	-	2.4	4.4	1.3	0.8	2.2
	Max - Wholesale Price	53.3	17.6	42.1	60.0	110.0	21.0	30.0	60.0	105.0	23.3	30.0	37.5	32.0	25.0	33.5	35.0
	Min - Wholesale Price	21.8	13.0	29.7	45.0	52.0	13.0	30.0	35.0	24.0	16.0	30.0	30.0	20.0	21.5	31.0	30.0
	Average Retail Price	42.4	28.2	41.8	62.5	90.0	30.9	30.8	63.5	64.2	30.0	31.6	43.1	42.2	30.0	33.9	44.8
	SD - Retail Price	11.1	3.0	4.8	6.3	22.4	2.1	0.4	9.0	21.3	4.1	1.9	4.8	4.7	-	1.1	5.0
	Max - Retail Price	73.3	30.0	44.0	70.0	120.0	35.0	31.0	80.0	120.0	40.0	38.0	50.0	50.0	30.0	35.4	50.0
	Min - Retail Price	31.3	21.3	31.0	50.0	70.0	28.3	30.0	50.0	40.0	25.0	31.0	40.0	35.8	30.0	32.2	40.0
	Average Price Wedge	11.6	13.4	1.7	11.1	17.7	12.6	0.8	14.0	15.4	10.3	1.6	9.0	17.4	7.1	1.3	11.1

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[9]. 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) test[10] (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 retail price of Rice in Tura centre. Hence the prices are non-stationary, and we do a re-test taking their first differences. All the price series are found to be stationary in the first differences.

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

[10]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 $\beta = 0$.

Table 2: Tests of Stationarity for Prices in Meghalaya

				WHOLESALE PRICES				RETAIL PRICES			
			5% Critical Value	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato
SHILLONG	Actual Level of Price	Lag#		1	1	1	1	1	1	1	1
		ADF Test Statistic:									
		At Lag 1	-2.930	-1.355	-2.033	-1.566	-1.460	-1.425	-2.530	-1.430	-1.448
	First Difference of Prices	Lag #		0	0	0	0	0	0	0	0
		ADF Test Statistic:									
		At Lag 0	-2.930	-6.478*	-6.479*	-6.033*	-6.066*	-6.108*	-7.398*	-6.125*	-6.780*
JOWAI	Actual Level of Price	Lag#		1	1	2	1	2	1	2	1
		ADF Test Statistic:									
		At Lag 1	-2.930	-1.296	-2.041		-1.098		-1.982		-1.536
		At Lag 2	-2.933			-1.628		-1.463		-1.350	
	First Difference of Prices	Lag #		0	0	0	0	1	0	1	0
		ADF Test Statistic:									
		At Lag 0	-2.930	-5.612*	-8.395*	-5.303*	-5.825*		-7.522*		-7.307*
		At Lag 1	-2.933					-4.022*		-5.096*	
TURA	Actual Level of Price	Lag#		1	1	1	1	1	1	1	1
		ADF Test Statistic:									
		At Lag 1	-2.930	-1.435	-1.375	-2.089	-1.431	-1.393	-3.616*	-2.155	-1.346
	First Difference of Prices	Lag #		0	0	0	0	0	0	0	0
		ADF Test Statistic:									
		At Lag 0	-2.930	-5.781*	-6.597*	-6.309*	-7.447*	-6.197*	-8.290*	-5.865*	-7.750*

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

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

As seen in the previous sub-section, the prices (wholesale and retail) for all commodities, except retail price of Rice in Tura, were 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 are stationary in levels (or have 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 presents information on the co-integration test for the retail and wholesale prices (for 4 different commodities at the 3 centres) based on Johansen's method (1995)[11]. 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.

From the table, we infer the following:

1. The null hypothesis of no co-integration between retail and wholesale prices is *not rejected* in the case of Onion in Tura, Potatoes in Shillong and Jowai, Rice in Jowai and Tomatoes in Shillong, Jowai and Tura.
2. The null hypothesis of no co-integration between retail and wholesale prices is *rejected* in the case of Onions and Rice in Shillong, and Potatoes and Tomatoes in Tura.
3. Thus, a long run relationship, based on co-integrating equations, exists between wholesale and retail prices of Onions and Rice in Shillong, and Potatoes and Tomatoes in Tura. These cases have been highlighted in Table 3. For all other commodity-centre pairs, there is no co-integrating equation that can be estimated to establish a long-term relationship.

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 (3) above. Table 4 presents the parameters of the bivariate co-integrating Vector Error Correction Model (VECM) for retail and wholesale prices. The results include both short run adjustment factors and coefficients (retail and wholesale price equation) and the long run coefficients (co-integrating equation). Following are key observations:

1. The adjustment factor in the retail prices of both Onion and Rice at Shillong is negative and significant. This implies convergence in the long run, and the rate of convergence is faster for retail price of Onions than Rice at the Shillong centre. The adjustment factor for Potato retail price at Tura is also found to be negative and significant, implying convergence in the long run.
2. In the case of Tomato wholesale price at Tura, the adjustment factor is positive and significant. This implies instabilities and is likely to be an indication of a structural change. The adjustment factor for the wholesale price of all other centre-commodity pairs is found to be insignificant.
3. The Chi^2 of the co-integrating equation indicates a good model fit for three of the four cases – Shillong-Onion, Shillong-Rice and Tura-Tomato.

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

4. The coefficient of the Wholesale price in the co-integrating equation is negative and significant for the same three centre-commodity pairs mentioned in (3), implying presence of a *positive* long run relationship between Retail and Wholesale Prices for these pairs.

5. The graphs of the predicted co-integrated equation are plotted and presented in the last row of Table 4. We do post-estimation diagnostic tests to assess the validity of our model. Using the LM test, the null hypothesis of no autocorrelation is rejected for the Tura-Tomato series, implying presence of autocorrelation. For the Shillong-Onion, Shillong-Rice and Tura-Potato series, the null hypothesis is not rejected, implying absence of autocorrelation in the co-integrated equation. The Jarque-Bera Normality test suggests that the null hypothesis that residuals are normally distributed can be rejected for most 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 Rice in Shillong, and Potatoes and Tomatoes in Tura. For all other commodity-centre pairs, 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 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 all the commodity-centre pairs, as suggested by the Chi^2 value- is good.

The VAR model confirmed dependence of retail prices of potatoes in Shillong on the first lag of wholesale prices, making it the only significant case. The dependence of retail prices on wholesale prices is found to be insignificant in case of all three commodities – potato, rice and tomato in Jowai in the first lag; in case of onions in Tura in the first lag; and, finally, in the case of tomato in Shillong also in the first lag.

In Shillong, the dependence of wholesale prices on retail prices is found in the first lag of both potato and tomato. This relationship is also confirmed in the first lag of both rice and tomato in Jowai and for onion in Tura also in the first lag. However, this relationship is found to be insignificant in the case of potato in Jowai.

Table 3: Tests of Co-Integration between Wholesale and Retail Prices at various centres for all commodities

			SHILLONG			JOWAI			TURA		
	Rank	5% Critical Value	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic
ONION	0	15.41	-296.17	.	32.02				-336.43	.	15.348*
	1	3.76	-281.25	0.45	2.189*				-329.86	0.23	2.21
	2		-280.16	0.04					-328.76	0.04	
POTATO	0	15.41	-172.74	.	13.915*	-184.65	.	11.321*	-200.63	.	15.64
	1	3.76	-167.78	0.19	4.00	-179.82	0.19	1.65	-194.06	0.23	2.508*
	2		-165.78	0.08		-178.99	0.04		-192.81	0.05	
RICE	0	15.41	-107.02	.	25.02	-163.87	.	9.464*			
	1	3.76	-96.04	0.36	3.055*	-160.86	0.11	3.44			
	2		-94.51	0.06		-159.14	0.07				
TOMATO	0	15.41	-256.31	.	10.639*	-177.18	.	8.056*	-289.75	.	15.89
	1	3.76	-252.09	0.16	2.20	-173.77	0.13	1.24	-282.65	0.25	1.697*
	2		-250.99	0.04		-173.15	0.02		-281.80	0.03	

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

	Shillong – Onion			Shillong – Rice			Tura – Potato			Tura - Tomato		
No. of Observations	50			50			50			50		
AIC | BIC | HQIC	11.61	11.95	11.74	4.20	4.55	4.33	8.12	8.47	8.25	11.67	12.01	11.80
Log Likelihood	-281.255			-96.0421			-194.063			-282.653		
D_Retail Prices Equation												
RMSE | R-Squared | Chi2	8.19	0.20	11.45**	1.05	0.17	9.39*	2.08	0.25	15.36***	5.53	0.04	2.00
Adjustment Factor	-1.56	(0.54)	***	-0.61	(0.21)	***	-0.41	(0.13)	***	-0.24	(0.20)	
Retail Prices (LD)	1.50	(0.51)	***	0.30	(0.25)		0.01	(0.13)		0.00	(0.21)	
Wholesale Prices (LD)	-1.53	(0.54)	***	-0.32	(0.35)		-0.25	(0.20)		-0.09	(0.24)	
Constant	0.01	(1.16)		-0.01	(0.15)		0.06	(0.30)		-0.38	(0.78)	
D_Wholesale Price Equation												
RMSE | R-Squared | Chi2	8.46	0.10	4.99	0.83	0.03	1.38	1.50	0.05	2.59	4.81	0.07	3.67
Adjustment Factor	-0.79	(0.56)		-0.07	(0.17)		0.11	(0.09)		0.30	(0.18)	*
Retail Prices (LD)	1.14	(0.53)	**	-0.01	(0.20)		-0.01	(0.10)		-0.05	(0.18)	
Wholesale Prices (LD)	-1.11	(0.56)	**	0.13	(0.28)		0.02	(0.15)		0.03	(0.21)	
Constant	-0.03	(1.20)		0.04	(0.12)		0.22	(0.22)		-0.30	(0.68)	
Co-integrating Equation												
Chi2		5181.808***			357.2905***			0.2571			127.6136***	
Retail Prices	1.00	.		1.00	.		1.00	.		1.00	.	
Wholesale Prices	-1.04	(0.01)	***	-1.26	(0.07)	***	-0.10	(0.20)		-1.20	(0.11)	***
Constant	-6.84	.		4.32	.		-28.27	.		-3.15	.	
Post Estimation Diagnostics												
LM Test for Autocorrelation												
Chi2 at Lag 1		4.6097			7.7123			1.6078			13.6994***	
Chi 2 at Lag 2		4.6919			2.9123			1.2945			9.2322*	
Jarque-Bera test for Normality												
Chi 2 for D_Retail Price		248.56***			172.396***			20.956***			2.920	
Chi2 for D_Wholesale Price		1.923			16.903***			63.733***			0.248	
Chi 2 for All		250.480***			189.298***			84.690***			3.168	

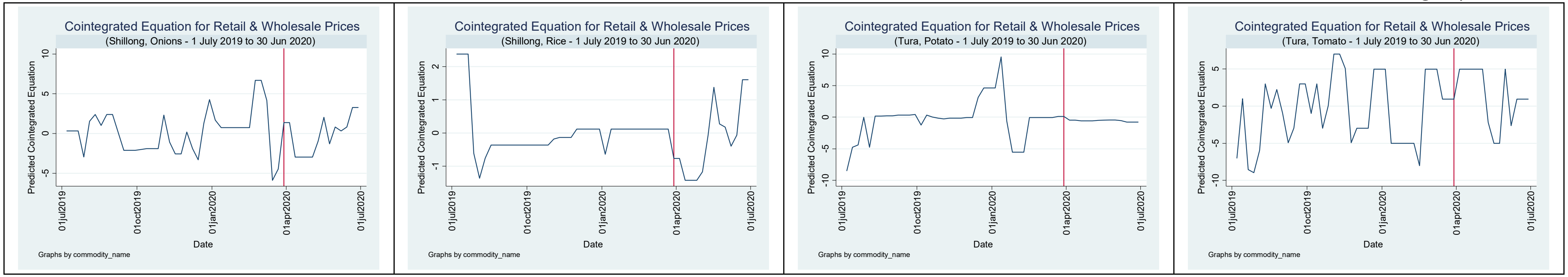


Table 5: Vector Auto Regression (VAR) Model for Retail and Wholesale Prices

	SHILLONG		JOWAI			TURA
	Potato	Tomato	Potato	Rice	Tomato	Onion
Optimal Lag Length (AIC)	1	1	1	1	1	1
No. of Observations	51	51	51	51	51	51
Log Likelihood	-187.71	-256.08	-203.775	-165.66	-177.02	-338.39
Retail Price Equation						
Chi2	77.38***	270.18***	123.05***	289.22***	420.89***	384.32***
L1. Retail Price	0.334 (0.16) **	0.660 (0.18) ***	1.133 (0.29) ***	1.084 (0.13) ***	0.736 (0.13) ***	0.607 (0.21) ***
L1. Wholesale Price	0.528 (0.16) ***	0.287 (0.19)	-0.310 (0.30)	-0.190 (0.15)	0.241 (0.16)	0.340 (0.21)
Constant	6.161 (2.13) ***	4.008 (2.52)	3.056 (2.23)	3.247 (2.04)	0.811 (2.05)	8.509 (4.15) **
Wholesale Price Equation						
Chi2	209.28***	334.02***	100.10***	221.72***	991.26***	410.49***
L1. Retail Price	-0.159 (0.10)	0.006 (0.16)	0.718 (0.31) **	0.282 (0.13) **	0.001 (0.08)	0.405 (0.20) **
L1. Wholesale Price	1.019 (0.11) ***	0.930 (0.17) ***	0.089 (0.32)	0.621 (0.15) ***	0.970 (0.09) ***	0.538 (0.20) ***
Constant	3.515 (1.37) **	2.248 (2.17)	0.482 (2.36)	2.374 (2.02)	0.774 (1.18)	-3.783 (3.98)

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

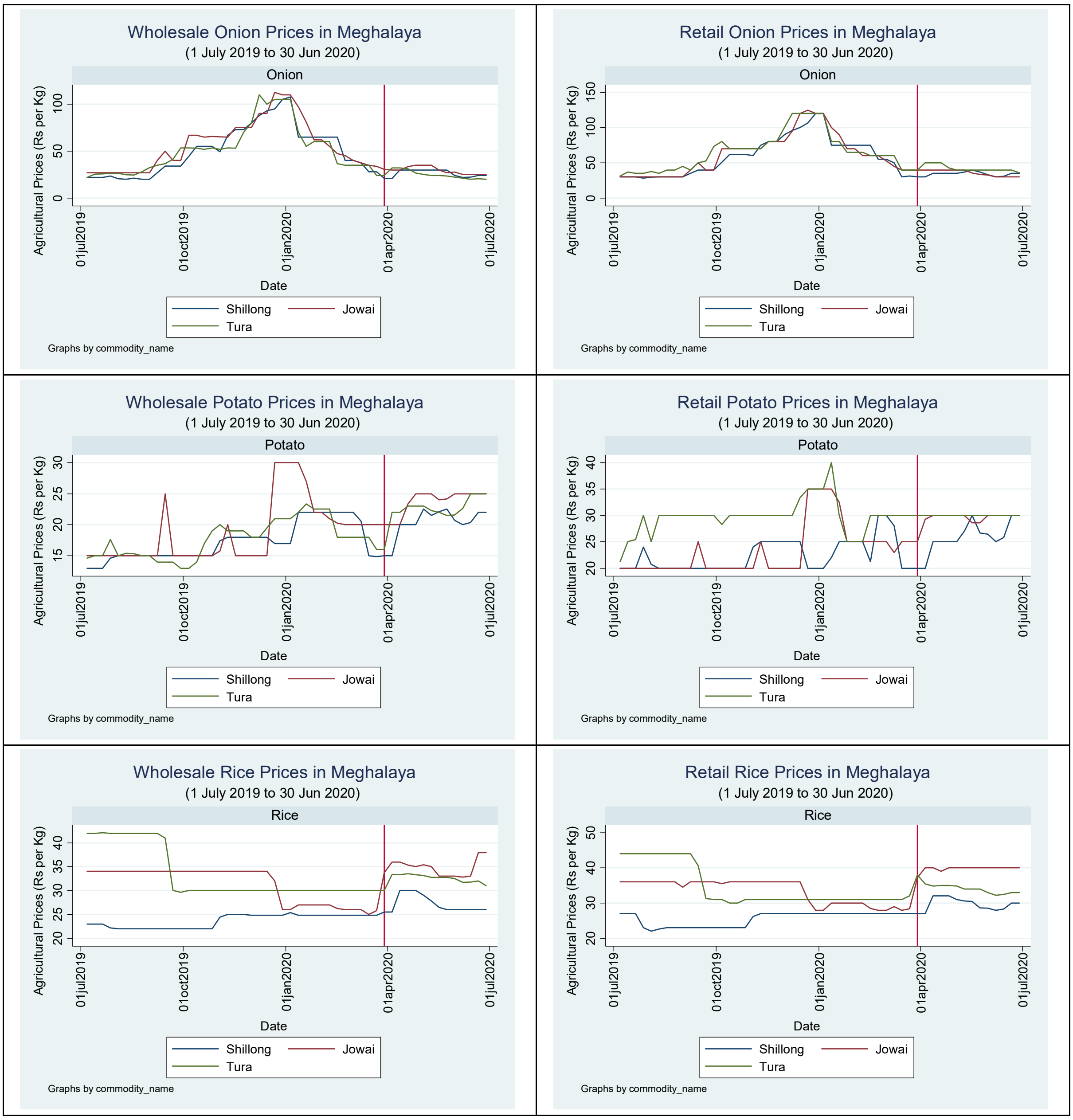
Co-integration between Prices at Different Markets

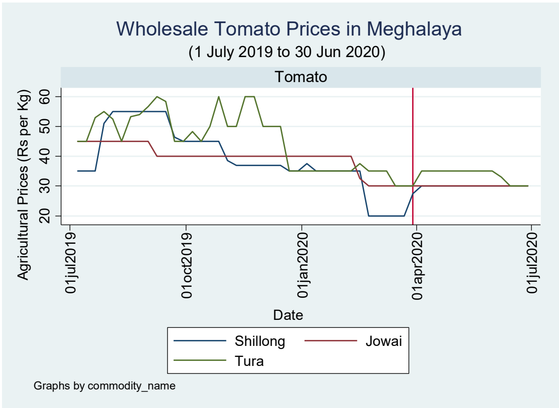
Next, we see the data on food prices of the same commodity in different centres. We first focus on a multivariate analysis, examining the three centres together.

Figure 7 below shows the prices of various commodities in different centres. While the prices of Onion, Potato and Tomato do appear to move together, the relationship is not very clear. There are periods where price spikes happen in one particular centre, and other periods, where the spike is in another. As done previously, we first test for co-integration, followed by estimation of the co-integration equation. Table 6 shows the results of the Johansen's co-integration test.

The test results confirm presence of one co-integrating equations between the three centres for both wholesale and retail prices of Onions, one co-integrating equation for wholesale price of Potatoes and two co-integrating equations for retail price of potatoes. The null hypothesis of zero co-integrating equations is not rejected for retail and wholesale price of rice and tomatoes between the three centres.

Figure 7: Co-movements in Prices at various centres





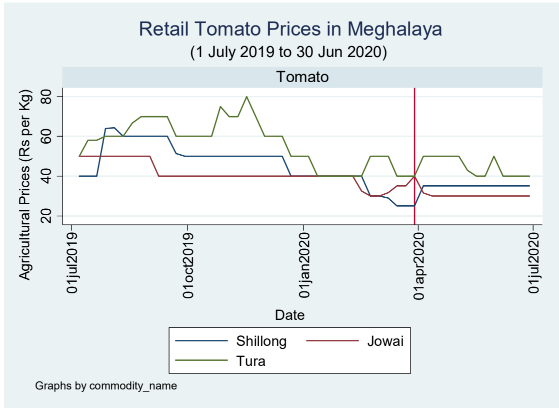


Table 6: Johansen's Co-integration Test for prices at Various Centres

			Wholesale Prices			Retail Prices		
	Rank	5% Critical Value	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic
ONION	0	29.68	-507.43	.	47.33			
	1	15.4	-491.15	0.48	14.785*			
	2	3.76	-484.72	0.23	1.92			
	3		-483.76	0.04				
POTATO	0	29.68	-303.77	.	35.91	-340.54	.	32.59
	1	15.4	-293.09	0.35	14.554*	-332.25	0.28	16.00
	2	3.76	-287.01	0.22	2.39	-324.98	0.25	1.4688*
	3		-285.82	0.05		-324.25	0.03	
RICE	0	29.68	-247.27	.	17.920*	-258.43	.	14.959*
	1	15.4	-242.53	0.17	8.45	-254.19	0.16	6.49
	2	3.76	-239.87	0.10	3.13	-251.95	0.09	2.01
	3		-238.31	0.06		-250.95	0.04	
TOMATO	0	29.68	-357.75	.	19.722*	-408.16	.	29.625*
	1	15.4	-352.07	0.20	8.37	-398.08	0.33	9.46
	2	3.76	-348.16	0.14	0.54	-393.75	0.16	0.79
	3		-347.89	0.01		-393.35	0.02	

We now turn to estimation of the co-integrating equations for the cases mentioned above using the Vector Error Correction Model (VECM). Table 7 reports the coefficients of the co-integrating equations. The predicted co-integrating equations for the Prices are given in Figure 8.

Table 7: Vector Error Correction Model between prices at various Centres

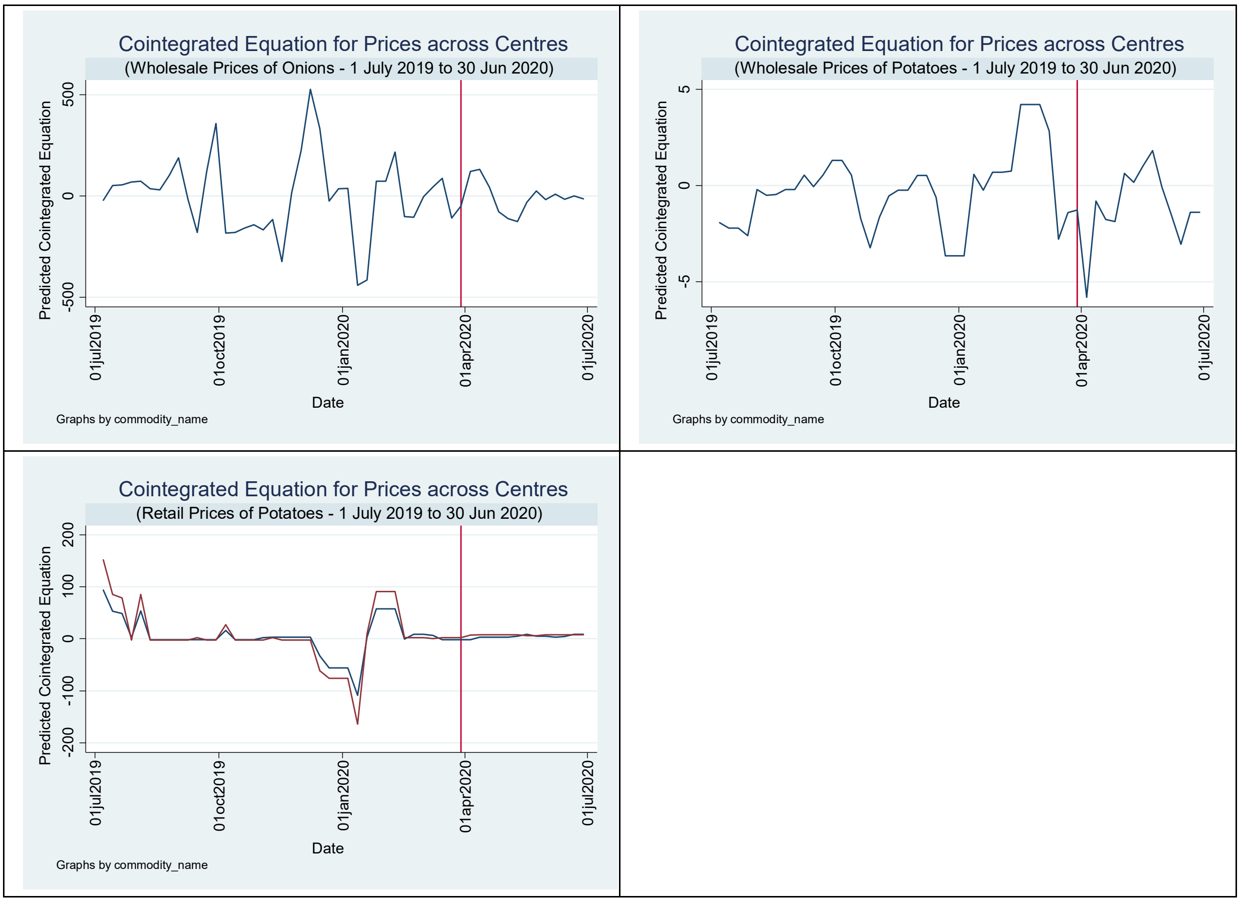
	Wholesale Prices		Retail Prices
	Onion	Potato	Potato
No. of Co-integrating Equations	1	1	2
No. of Observations	50	50	50
Log Likelihood	-491.154	-293.09	-324.98
Co-integrating Equation 1			
Chi2	42.311***	67.177***	16.775***
Shillong	1	1	1
Jowai	-20.43 (3.14) ***	-0.06 (0.10)	Omitted
Tura	20.05 (3.21) ***	-0.76 (0.15) ***	-10.89 (2.66) ***
Constant	72.07	-2.95	305.11
Co-integrating Equation 2			
Chi2			19.256***
Shillong			Omitted
Jowai			1
Tura			-17.64 (4.02) ***
Constant			506.72

The short run adjustment parameters, and coefficients of the short run equations are not reported, and are available on request.

Table 7 presents the coefficients of the co-integrating Vector Error Correction Model (VECM) for wholesale prices of Onions and Potatoes and Retail price of Potatoes. Following are key observations:

1. The Chi^2 value of the co-integrating equation 1 indicates a good model fit for all commodity-price series pairs. In the case of Jowai, the coefficients of co-integrating equation 1 are negative for both Onions and Potatoes; while being significant for Onion and insignificant for Potatoes. This implies that wholesale price of onions in the Jowai centre has a *positive* long run relationship with the wholesale price of onions in Shillong.
2. Similarly, in the case of Tura, the coefficient of co-integrating equation 1 is negative and significant for both wholesale and retail price of Potatoes, implying a *positive* long run relationship between wholesale and retail price of potatoes, respectively, in Tura and Shillong. The coefficient for wholesale price of onions in Tura is, however, positive and significant implying divergence in the long run.
3. The Chi^2 of the co-integrating equation 2 indicates a good model fit for retail price of potatoes. The coefficient of retail potato price in Tura is negative and significant which implies a *positive* long run relationship with the retail price of potatoes in Shillong.

Figure 8: Predicted Co-integrated Equations for Prices across Centres



The graphs of the predicted co-integrated equations for the cases mentioned in Table 7 are plotted and presented in Figure 8.

We also test for co-integration between prices at different pairs of centres for all the commodities. The results are given in Table 8. The key findings are shown in Table 10.

Table 8: Tests of Co-Integration between Prices at Different Centres (Pair-wise) for all commodities

		Shillong & Jowai			Shillong & Tura			Jowai & Tura		
	Rank	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat
WHOLESALE PRICES										
ONION	0	-340.84	.	16.31	-345.91	.	15.29*	-344.24	.	32.04
	1	-333.65	0.25	1.92*	-339.34	0.23	2.16	-329.03	0.46	1.62*
	2	-332.69	0.04		-338.26	0.04		-328.22	0.03	
POTATO	0	-217.94	.	18.40	-176.24	.	21.12	-217.98	.	13.56*
	1	-210.21	0.27	2.93*	-166.98	0.31	2.61*	-212.08	0.21	1.76
	2	-208.75	0.06		-165.68	0.05		-211.20	0.03	
RICE	0	-154.37	.	6.76*	-153.20	.	11.55*	-189.74	.	9.10*
	1	-152.29	0.08	2.60	-149.43	0.14	4.01	-187.11	0.10	3.83
	2	-150.99	0.05		-147.42	0.08		-185.19	0.07	
TOMATO	0	-213.21	.	9.64*	-282.28	.	10.18*	-231.29	.	11.02*
	1	-208.92	0.16	1.07	-277.96	0.16	1.55	-226.06	0.19	0.56
	2	-208.39	0.02		-277.19	0.03		-225.78	0.01	
RETAIL PRICES										
ONION	0	A			-346.66	.	17.46	a		
	1				-338.97	0.26	2.09*			
	2				-337.93	0.04				
POTATO	0	-237.91	.	14.33*	-211.27	.	15.55	-228.86	.	20.56
	1	-231.94	0.21	2.39	-204.45	0.25	1.89*	-220.34	0.29	3.51*
	2	-230.74	0.05		-203.50	0.04		-218.58	0.07	
RICE	0	-168.50	.	5.92*	-172.23	.	9.67*	-184.39	.	7.77*
	1	-166.40	0.08	1.73	-168.93	0.12	3.07	-182.04	0.09	3.06
	2	-165.54	0.03		-167.40	0.06		-180.51	0.06	
TOMATO	0	-256.49	.	18.22	-299.28	.	11.90*	-266.11	.	9.29*
	1	-248.11	0.28	1.47*	-293.93	0.19	1.20	-261.88	0.16	0.84
	2	-247.38	0.03		-293.33	0.02		-261.46	0.02	

The 5% critical values are 15.41 at Rank 0 and 3.76 at Rank 1; a-dropped due to collinearity

Table 9: Summary – Presence of Co-integration between Prices at various centre-pairs.

Presence of Co-integration	Shillong & Jowai	Shillong & Tura	Jowai & Tura
WHOLESALE PRICES			
Onion	YES	NO	YES
Potato	YES	YES	NO
Rice	NO	NO	NO
Tomato	NO	NO	NO

RETAIL PRICES			
Onion		YES	
Potato	NO	YES	YES
Rice	NO	NO	NO
Tomato	YES	NO	NO

Table 9 summarises the presence of co-integration between prices at various centre-pairs for wholesale and retail prices of four food commodities. In the case of Onions, we note the presence of co-integration between Wholesale prices of Onions in Shillong and Jowai centres and between those in Jowai and Tura centres. This implies that wholesale price of onions in Shillong and Tura, respectively, show presence of a long run relationship with the wholesale price of onions in Jowai. Similarly, in the case of wholesale price of Potatoes, co-integration is found to be present between Shillong and Jowai centre-pair; as well as between Shillong and Tura centre-pair. However, co-integration is found to be absent for all centre-pairs in the case of wholesale price of both Rice and Tomato.

On the other hand, retail price of onions exhibit presence of co-integration in only one centre-pair, i.e. Shillong-Tura. Retail price of potatoes exhibited the presence of co-integration at two centre-pairs, i.e. Shillong-Tura and Jowai-Tura. For retail price of tomatoes, co-integration is present at only in the centre pair of Shillong-Jowai, while no co-integration was found between retail price of tomatoes at Shillong-Tura and Jowai-Tura centre pairs. In the case of rice, retail price does not show presence of co-integration at any centre-pair.

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 10.

The results suggest presence of conditional heteroscedasticity in the retail prices of potatoes in Tura only. Table 11 shows the parameters for the Autoregressive Conditional Heteroscedasticity Specification for retail Prices of Potatoes at the Tura centre.

Table 11: LM Test for Autoregressive Conditional Heteroscedasticity

	Shillong				Jowai				Tura			
	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato
D. Wholesale Price chi2	0.181	0.177	0.058	0.078	0.001	0.349	0.013	0.081	0.305	0.630	0.022	0.256
D. Retail Price chi2	0.174	0.002	0.140	0.148	0.030	0.059	0.241	0.175	0.126	7.199 ***	0.320	0.278

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

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

The ARCH coefficient measures the extent to which the volatility reacts to shocks/innovation. The coefficient is found to be positive (and less than 1) but insignificant.

The GARCH coefficient measures the persistence in conditional volatility. The sum of ARCH and GARCH coefficients must be equal to one to ensure a mean reverting variance process. The GARCH coefficient is also found to be insignificant in our case.

Table 11: GARCH Parameters for Tura

	Retail Price
Commodity	Potato
No. of Obs	52
ARCH Coefficient (L1)	0.553 (7.29)
GARCH Coefficient (L1)	-0.807 (6.86)
Constant	1128.83 (4548.88)

Concluding Observations

In this study, we have examined and analysed the wholesale and retail prices of select agricultural commodities in Meghalaya, over the period July 2019 – June 2020. Descriptive statistics suggest that the Onion prices peaked in the October-December quarter of 2019 and have seen a steep fall since January 2020. In the case of Potatoes, a significant finding is that the average prices peaked during the final quarter of the study (April-June 2020) coinciding with the nationwide lockdown and the partial opening up. This was because 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 vegetables, all states were demanding larger quantities of it than usual. As a consequence of the sudden hike in demand, Potato prices soared. The state also witnessed a sharp increase in price of rice in during the period April – June 2020. The reason for the sharp increase in price of rice in Meghalaya was the non-availability of stock in the godowns of wholesale dealers and surge in consumer demand. Also, Rice is a staple food commodity in the state and thus observed sharp soaring of prices due to shortage of supplies during the covid lockdown. In the case of Tomatoes, some parts of the state saw the retail price shoot up drastically ahead of the lockdown. This was the result of pre-lockdown panic driven rush in the markets accompanied by fluctuations in fuel prices and short supplies.

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 price of Onions in Jowai and Shillong; wholesale prices of potatoes in Tura and Shillong; and retail prices of potatoes in Tura and Shillong. The adjustment factor in the retail price of both Onion and Rice at Shillong is negative and significant. This implies convergence in the long run, and the rate of convergence is faster for retail price of Onions than Rice at the Shillong centre. The adjustment factor for Potato retail price at Tura is also found to be negative and significant implying convergence in the long run

On market integration, our analysis suggests that there is a long run convergence in the wholesale price of Onions, and that of Potatoes, and the retail price of Potatoes, across the three centres that are studied here – namely, Shillong, Jowai and Tura. When considering only one centre-pair at a time, a long run convergence is found in the following cases – wholesale price of onions and potatoes and retail price of tomatoes in the Shillong-Jowai pair, wholesale price of potaoes, retail price of onions and potatoes in Shillong – Tura pair, and wholesale price of onions, and retail price of potatoes in Jowai-Tura pair.

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 for Tura centre. There is limited evidence of persistence of volatility.

Our analysis raises the concern that, despite low severity of Covid-19 in Meghalaya, supply-demand disruptions occurred, due to limited market integration and transport disruptions.

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