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

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Abstract

The outbreak of Covid-19 in March and subsequent draconian lockdowns that resulted in disruption of supply of most commodities except "essential commodities and services", widespread closure of factories, marginal, small and medium enterprises, massive unemployment and return migration, and deceleration of economic growth are intensely debated. Even though agriculture's share of GDP has declined, it continues to be the largest employer in India. Analyses of the impact of the Covid pandemic on this sector-especially food supply chains-are still few and far between. Views range from resilience of this sector to substantial losses of output and livelihoods. Focusing on an important aspect of food supply chains in Maharashtra, which witnessed highest severity of the Covid pandemic, we conduct a detailed empirical analysis of movements of wholesale and retail food commodities' prices, the gaps between them (or the price wedge) and market integration in this state during July, 2019-June 2020. One section of this study is devoted to deterministic means and standard deviations that throw light on these movements during different phases of lockdowns. This in itself goes well beyond what we know from the extant literature. Another significant contribution is the time-series analyses of the food commodities' price series and price wedges in which the focus shifts to the stochastic process, with a structure that can be characterised and described. Some of the issues addressed are whether the wholesale and retail food prices are cointegrated, whether their wedges have narrowed, whether volatilities have accentuated and whether markets are spatially integrated. The insights are useful for policy purposes.

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, Maharashtra.

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

Nidhi Kaicker, Raghav Gaiha & Radhika Aggarwal [1]

Introduction:

The first positive Covid-19 case was registered in India on 30 January 2020 in Kerala of a student who had returned from China[2]. While there were only three cases in India till the end of February 2020, the number of cases started increasing rapidly in early March. India reported its first death due to Covid-19 on 13 March 2020[3], soon after which the Indian government sealed its international borders, suspended all visas to India, banned domestic travel by rail as well as air, and eventually announced a complete lockdown of the country to prevent community spread of the virus.

The first lockdown spanned a period of 21 days from 25 March 2020 to 14 April 2020, where nearly all factories and services were suspended, barring "essential services". The second lockdown started on 15 April 2020 and continued till 3 May 2020, with conditional relaxations for regions where the Covid-19 spread had been contained. With additional relaxations, the phase three of the lockdown was from 4 May 2020 to 17 May 2020, and the fourth phase was from 18 May 2020 to 21 June 2020. Phase 5 of the lockdown (1 June 2020 to 30 June 2020), also known as Unlock 1.0, was the first phase of the reopening in stages, aiming to revive the economy.

The coronavirus outbreak has affected populations across the world posing new medical, economic and social challenges. The shutting down of international as well as state borders and the resultant bottlenecks in farm labour, processing, transport and logistics, as well as sharp drop in demand have had a huge disruptive impact on supply chains, including that of food. The agriculture value chain in India witnessed several unforeseen challenges. These include acute shortage of labour resulting from massive reverse migration, affecting loading-unloading and sorting of commodities*, sharp increase in transportation costs as the government raised excise duty on petrol and diesel on May 6[4] and large drops in *mandi* arrivals during the lockdown period in the country. For instance, in Nashik's Lasalgaon, which is Asia's biggest onion market, arrival quantities were down by 80% from March to April 2020[5].

The *mandis* where farmers sell their produce were sporadically closed. Wholesale prices of several essential food commodities such as fruits and vegetables have fallen remarkably due to reduced supplies to *mandis,* led by lack of demand from commercial buyers. On the other hand, retail prices of commodities inflated owing to panic buying by consumers who feared indefinite extension of the countrywide covid lockdown. This was soon followed by a drastic slowdown in consumer demand due to loss of income and rising food prices.

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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 Raghbendra Jha on the econometric modeling, The views are personal and not necessarily of IFAD which funded this study.

[2]Perapaddan, B. S. (2020, January 30). India's first coronavirus infection confirmed in Kerala.*The Hindu*.[Link]

[3] Based on data available on MoHFW website

[4] Mondal D. (2020, June 18). Why petrol, diesel prices are rising? There's a lockdown connection. *Business Today*. [Link]

*[5] Haq Z & Dutta A. (2020, April 10). Covid-19 in India: Food prices surge three times when a supply chain takes a hit. *Hindustan Times*. [Link]

Under a new central law on inter-state trade, farmers have the freedom to sell their produce in any market within and outside the state of their residence, without being hamstrung by the APMCs. Via another Ordinance on contract farming, farmers would get share of post-contract price surge, after they sign agreements of contract farming with private players. Also, they will have the cover of minimum guaranteed price if open market/mandi rates fall drastically. These ordinances, along with another one through which the Essential Commodities Act has been amended easing stock holding restrictions on commodities, are associated with substantial reductions in mandi arrivals[6] . In fact, during the June 6-August 31 period, mandi arrivals of crops –- from fruits and vegetables to cereals and pulses – have dropped dramatically. The fall was up to 49% for fruits, 57% for vegetables and 45% for grains.

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 Maharashtra. The five commodities whose prices are analysed include rice, tomato, potato, onion and milk at the local *mandi* level and at the retail outlets. Using various time –series techniques, we assess the variability observed in these prices during the period July 2019 – June 2020, and 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 pandemic.

We examine the stationarity of the time series using unit root test – Augmented Dicky Fuller (ADF) test. Further, using tests for co-integration on the level form of the variables, we try to identify stable, long-run relationships between retail and wholesale prices, if any, for each commodity of the study. Finally, to analyse and eventually 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 main 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 the competition and the nature of the food commodity (whether cereals or perishables such as tomato and milk), the margins vary.

Literature Review

As most of the comments on the Covid pandemic impact are journalistic in nature, we review a few important studies of food value chains that inform our own analysis.

Jhajhria et al. (2020) offer a detailed but somewhat optimistic account based on deterministic means for a range of food commodities[7].They draw attention to the marketing of farm produce in the wake of lockdown. The Government has now exempted marketing from the lockdown but still there are not many buyers in the market and there are transport bottlenecks. This is partly due to non-availability of

[6] Kasabe N & Jainani D. (2020, September 7). APMCs losing trade share post reforms; crop arrivals fall as traders, farmers kick middlemen out. *Financial Express*. [Link]

[7]Jhajhria, A., A. Kandpal, S. J. Balaji, J. Jumrani, I.Kingsly, K.Kumar, N. P. Singh, P.S. Birthal, P. Sharma, R. Saxena, S. Srivastava, S.P.Subash, S. Pal, V. Nikam (2020) "COVID-19 LOCKDOWN AND INDIAN AGRICULTURE: OPTIONS TO REDUCE THE IMPACT", ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi-12.

buyers but largely due to market uncertainty. Some illustrative evidence is given but it precedes the pandemic.

The supply of foodgrains and other important commodities is likely to be normal because of a good agricultural year. There is not much change in the demand except lower demand from the bottom income group primarily because of loss of income during the lockdown. Hence domestic prices of essential food commodities are likely to be stable during the lockdown and after. The wholesale and retail prices of cereals and edible oil in the four metros have risen moderately (less than 10 percent) and for pulses, the price increase was 10-20 percent. It was only in case of vegetables, potato in Chennai and Kolkata and tomato in Delhi, the price increase was 30 percent or more. The same might be true for other vegetables. Partly the price increase could be attributed to the disruption of supply chains and a large part due to the off-season for vegetables such as tomato.

The trend in the wholesale price until February 2020 is moderate, except for meat, egg and fish which are rising. If this trend continues during the lockdown, there may not be much change in wholesale prices of essential commodities, except for milk and meat which otherwise also show some increase in their prices during this period. The international prices of agricultural commodities have been moderate because of near-normal production. In fact, the prices show a declining trend in the last few years, which should have continued in the absence of the lockdown.

This study does not expect a major long-term impact of the lockdown or lower economic growth on Indian agriculture. A normal agricultural growth in 2019-20 and exemption of farm operations during the lockdown period are likely to contribute to better farm income. For marketing of agricultural produce also, special efforts are made to ensure smooth functioning of supply chains of the perishable commodities. These direct interventions are further strengthened by a positive forecast of IMD for a normal monsoon in 2020 which is extremely important for the coming *kharif* season.

In brief, it is an optimistic assessment but largely conjectural.

In an admirably comprehensive and insightful survey of impact of Covid-19 pandemic on food supply chains (FSCs)- drawing upon their substantial contribution to the growing literature on FSCs in India and elsewhere-Reardon et al. (2020) draw attention to the salient features of FSCs in India and delineate the mechanisms through which the rural economy is likely to be impacted. One is dominance of purchased food. Of all the food consumed, 92% is purchased. This illustrates the great importance of FSCs for India’s food security. Essentially, all the food consumed in urban areas is purchased, since almost all urban households are net buyers of food. And, of the 40% of India’s food that is consumed in rural areas, 80% (in value terms) is purchased (while the rest is home-produced on own farms).

Thus, India’s FSC in terms of the purchased food market is enormous.COVID-19’s most important effect will be on national food security via its effects on the FSCs, as 92% of food consumed in India is purchased from FSCs. It will have other system-wide effects such as food price inflation and related social unrest that will undermine FSC and, thus, food security in the short term and productivity investments in the medium run. Higher food prices are, in turn, likely to signal impending shortages.

Most of its effects will be on the post-farmgate FSC—the firms and workers in the midstream wholesale, processing, and logistics segments, and downstream in retail and food service—and much less on farms and farm workers.

The direct effect of COVID-19 on farms is likely to be limited. Since farms are relatively spread out, the human density driven COVID-19 spread will be less than in the cities. However, the indirect effect of COVID- 19 on farms is likely to be substantial, through several channels. First, COVID-19’s main effect on farmers will be through deficient effective demand from consumers via the constraints on the midstream and downstream of the FSC and because of reduction in consumers’ real incomes in the crisis. The effect will be strongest on perishable products such as milk, fruits and vegetables, and fish and chicken, which require more handling and are more income-elastic in demand. Second, its effects on the midstream of input supply chains such as fertiliser and seed will hurt farmers. Third, COVID-19 could limit farmers' access to labour. While most farm labour (70%) is own labour, but 30% of farm labour is hired. The flow of hired workers from towns to villages or across villages will be constrained by mobility restrictions. That could accelerate a long-term trend of farm wage increase, inducing accelerated mechanisation, which would affect the landless.

In brief, while informative and the mechanisms identified are plausible, some of the long-term effects are largely conjectural.

In yet another significant contribution, Andrle and Blagrave (2020) use a large monthly dataset on agricultural price movements for 21 different commodities and 60 different markets (mandis) in India[8]. The measure of market integration is the cross-market price differential across each market pair in the sample. Two exercises are conducted. First, they consider the evolution of this market-integration variable over time and across commodities. The second exercise examines the determinants of agricultural market integration in India. This is done for a group of 5 agricultural commodities: onions; potatoes; rice; tomatoes; and wheat.

Results from the cross-section regression show a strong relationship between cross-market price markups and (i) distance between the market pairs; (ii) density of transportation infrastructure (average value of road and rail densities, between market pairs); and (iii) urbanization.

A comparison of the distribution of markups across mandis, for each commodity, for two sub-samples—before and after the beginning of 2017—suggests considerable similarity. If market integration had improved, this would have led to a narrower distribution in the more recent period, after the reforms. Hence there is little evidence of increased integration over time.

In a policy brief prepared by Asian Development Bank economists (2020), a summary of food price movements in India during the pandemic is given[9]. The salient points are: food prices rose sharply across the country as transportation services stopped and fresh supplies became scarce during lockdown. This hurt the bumper harvest of wheat in northern India, while the western city of Pune, where grapes are produced in abundance, had to seek student volunteers for harvest. In Maharashtra, Asia's largest onion trading market, transporting onion harvests stopped as the fear of the virus made drivers and workers flee to their homes. Despite high demand for processed food, such as instant noodles, biscuits and snacks, food processing activities halted. Major producers such as Nestle and PepsiCo could not raise production as labourers moved back to their villages.

Another rich and insightful study (Narayana, 2020)[10] outlines five key features of the lockdown's consequences for the Indian agrifood system, noting that these are broad patterns that mask large variations.

Two broad impacts on prices are noted. The overall decline in demand, especially in cities—driven in part by the fall in hotel, restaurant, and catering demand and in part by the large exodus of migrants—has moved upstream, leading to a substantial fall in producer prices. One producer price index suggests that after a brief rise, prices crashed to almost a third of the pre-lockdown prices by the end

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[8]Andrle, M. and P. Blagrave (2020)"Agricultural Market Integration in India", IMF Working Paper WP/20/115, Washington DC.

[9]Asian Development Bank (2020) *Food Security in Asia and the Pacific amid the COVID-19 Pandemic*, Policy Brief, Manila.

[10] Narayanan, S. (2020) "How India's agrifood supply chains fared during the COVID-19 lockdown, from farm to fork", Blog IFPRI, Washington DC.

of May. This is consistent with findings from farmer telephone surveys as well, where many report a dramatic collapse in prices, especially for perishables.

At the same time, consumer food prices in most urban areas have risen, driven by increased frictions in the supply chain in the form of limited availability of labour, higher transport costs (in some cases, double pre-lockdown costs) and uncertainties around logistics. This gap between wholesale and retail prices increased sharply during the first phase of the lockdown (March 24-April 14) and remains wide.

These disruptions fragmented markets across rural and urban areas. In some large cities, average retail prices did fall, with increases for just a few commodities; but in smaller cities and towns for which data are available, retail prices rose an average of more than 20% in the two months following the lockdown. In addition, the range of prices across urban centers increased significantly during the lockdown, signifying a lack of spatial integration; wide variations persist even after two months, suggesting continuing challenges.

The price trends of different commodities have varied as well. Producer prices for perishables collapsed, and retail prices for fruits and vegetables have fluctuated widely over time and space—increasing substantially in some areas, declining in others; and rising since the lockdown in some cities. In contrast, producer prices have stayed high for major cereals, likely because of active government procurement, and retail prices in urban markets did not rise-due to the dampening role of Public Distribution System (PDS) that supplies grains to consumers, and also because of large scale grain distributions to vulnerable populations by civil society organizations. Retail prices for pulses and edible oils, and for processed goods such as biscuits and flour, however, rose sharply.

Street vendors of fresh produce have also been instrumental in the functioning of supply chains. A survey of over 50 retailers in 14 locations across India suggests that some people who lost jobs in cities and could not return to their home villages, or had shops closed due to lockdown restrictions, switched to vending fresh produce and groceries. The low entry barriers to informal retail led to an expansion in the number of informal retailers of food during the lockdown.

Most online food retailers suspended operations; several struggled to meet the surge in consumer demand. Modern format retail stores, meanwhile, many located in shopping malls, have remained shut for most of the lockdown.

Under the national lockdown, people in urban areas were likely more vulnerable to food insecurity than those in rural areas, especially those dependent on wage employment. In one survey of 11,159 workers conducted during the lockdown, an estimated 96% said they were not receiving rations from the government due to eligibility or implementation problems, 72% said that their rations would run out in two days, and 90% were not receiving wages. In rural areas, meanwhile, the collapse in producer prices and farmers' difficulty selling their produce imply lower prices and greater availability of a variety of foods. Yet, in many regions, food insecurity remains high, mainly because of a large loss in incomes, according to several telephone surveys of rural workers and farmers.

In a more detailed analysis (Naraynan and Saha, 2020)[11] offer a plausible conjecture. In the near term, supply shocks more than counterbalance the collapse of demand leading to increase in food prices. It may well be that food prices will increase first before they go down. It also justifies a sharp focus on emergency measures that expand food availability and feeding arrangements for a sustained period until processing and transportation attain pre-lockdown levels.

[11] Narayanan,S. & S. Saha (2020)"Urban food markets and the lockdown in India", IGIDR WP-2020-017,Mumbai.

Although insightful, most these analyses rely entirely on descriptive means and standard deviations. Without rigorous econometric validation, it is difficult to take their findings at face value. Moreover, the period analysed is much too short for a comprehensive assessment of the impact of lockdowns on food supply chains. Our analyses-both descriptive and econometric-overcome these limitations.

Perhaps the only detailed study of the impact of Covid-19 pandemic on agriculture prices in India during March-May 2020 is by Seth et al. (2020)[12]. Its merits are that it analyses producer and consumer price changes in a large number agricultural commodities in 11 cities, from March 1, 2020 to May 31, 2020, relative to the same period in 2019. The comparisons are based on the means /medians. So the comparisons of prices are essentially between the pre-pandemic period and during the pandemic, which are bolstered by journalistic reports. Besides, the price wedges between producer and consumer prices are largely neglected.

The assessment of impact of the price changes on nutrition is sketchy. It rests on the premise that a disproportionate rise in prices of non-cereals may divert consumer spending toward staples (that is, wheat and rice), resulting in inadequate intakes of protein-rich food groups, like pulses. Unemployment and income loss from the decline in remittances to rural areas will further exacerbate the problem. The nutritional implications are not directly analysed. Instead, heavy reliance on journalistic accounts is far from credible as isolated evidence without systematic measures of nutrition is dicey.

In brief, it is a descriptive study with a modicum of analytical content.

An exceptionally rich and analytically rigorous study (Varshney et al.2020)[13] assesses the impact of the spread of COVID-19 and the lockdown on wholesale prices and quantities traded in agricultural markets. It compares whether these impacts differ across non-perishable (wheat) and perishable commodities (tomato and onion), and the extent to which any adverse impacts are mitigated by the adoption of a greater number of agricultural market reform measures. It uses granular data set comprising daily observations for 3 months (i.e April-June 2020relative to the same period in 2019) from nearly 1000 markets across five states and use a double- and triple- difference estimation strategy. Indeed, as the authors rightly claim, this study is probably one of the first to estimate the causal impacts of COVID-19 on food prices.

COVID-19 and its associated disruptions had a differentiated impact—both across commodities and over time. Wheat saw a decrease in price differentials in June, but the overall impact across the 3 months was insignificant. This is likely because government procurement operations helped anchor wheat prices at the MSP. Prices for tomatoes fell in May, but there was no statistically robust impact otherwise. Also, onion prices were unaffected—this may reflect the concentrated nature of its supply, and the relatively dispersed nature of its demand.

In comparison, all the market arrival impact magnitudes were positive and significant, especially for the two perishable goods. That the magnitudes of differentials in market arrivals were much higher than those in prices suggests that supply constraints began easing beginning in May. In the case of the perishables, the positive coefficients on market arrivals may well be a reflection of distress sales and/or the need to address cash flow constraints. Together, these results suggest that while there were undoubtedly short-term disruptions in agricultural markets, they were also relatively resilient, in the

[12]Seth, P., B. Mittra, & P. Pingali. "Pandemic Prices: Covid-19 Price Shocks and Their Implications for Nutrition Security in India, March – May 2020", Tata-Cornell Institute for Agriculture and Nutrition, Ithaca.

[13] Varshney, D., D. Roy, & J. V. Meenakshi (2020) "Impact of COVID‐19 on agricultural markets: assessing the roles of commodity characteristics, disease caseload and market reforms", *Indian Economic Review*, https://doi.org/10.1007/s41775-020-00095-1.

sense that market arrivals were quick to recover after the initial month, and that possible distress sales did not result in a disproportionate fall in prices.

The methodology used is, however, debatable. Running double and triple differences on wholesale prices and mandi arrivals, respectively, raises the concern whether the results on the prices might be different if instrumented mandi arrivals are used as an explanatory variable.

Data

The daily retail and wholesale prices of five food commodities – namely – onion, rice, tomato, potato and milk, 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. To analyse the supply side situation we collated the *mandi* arrivals data for each centre from AGMARKNET website.

The following section analyses data for four centres in Maharashtra – Mumbai, Nagpur, Pune and Nashik. Maharashtra has so far been the hardest hit state by the novel coronavirus pandemic in India, with its capital city, Mumbai, emerging as the initial epicentre. The state accounted for one-fifth of covid-19 infections when the first countrywide lockdown was imposed on March 25. The number of infections grew unabated making Maharashtra's share more than one-third by the end of May 2020[14]. The average cumulative severity ratio values for Maharashtra were 0.11% during the first lockdown phase, increasing to 0.43% during the second lockdown, 0.82% during the third lockdown, 1.33% during the fourth and 2.41% in the first three weeks of the unlock 1.0 phases (Nidhi et al. 2020). It is also noted that Maharashtra alone contributes to 14 percent of India's national GDP[15].

Mumbai is one of India's major cities and has seen the highest number of Covid-19 cases as well as deaths (Nidhi et al. 2020)[16].Nagpur, Pune and Nashik are also important cities within the state of Maharashtra from an economic perspective. These four centres have been selected with the aim of also conducting comparative analyses across centres within the same state.

Trends in Wholesale & Retail Prices

We first focus on the movements in food commodities' prices in four centres/cities – Mumbai, Nagpur, Pune and Nashik. Figures 1 – 5 show the trends in retail and wholesale prices of the five commodities in the four 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) pandemic. Figure 6 shows the trends in price wedge (the difference between wholesale and retail price) of the five commodities in each of the four centres.

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[14] Sinha A. (2020, May 25). Maharashtra accounts for a third of all cases, shapes Covid map. *Indian Express*.
[15] Mudgill A. (2020, March 25). How will India lockdown play out for economy & markets: 4 scenarios. *The Economic Times*. [Link]
[16]Kaicker, N., K. Imai and R. Gaiha (2020) "Severity of the Covid-19 Pandemic in India The case of 3 states: Maharashtra, Jharkhand & Meghalaya", Draft submitted to IFAD**.**

Figure 1: Prices of Onion in Maharashtra

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

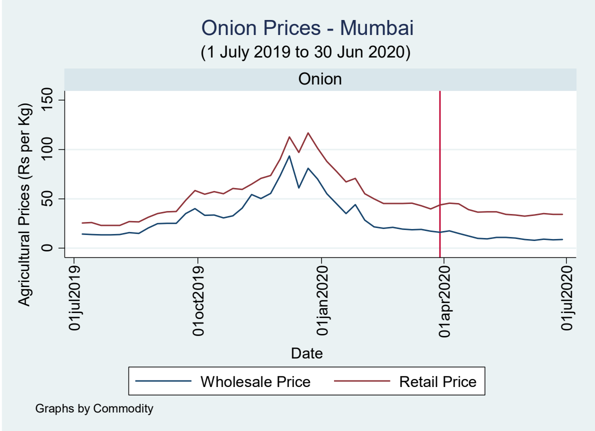


Figure 1(b): Wholesale & Retail Onion Prices in Nagpur

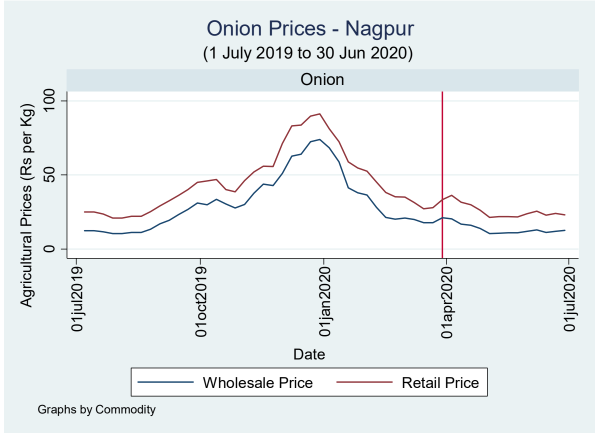


Figure 1(c): Wholesale & Retail Onion Prices in Pune

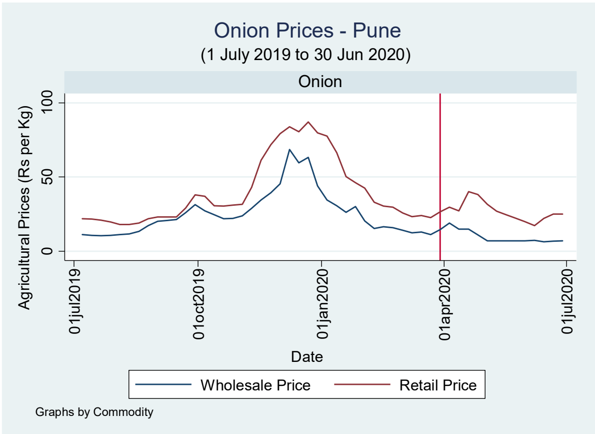
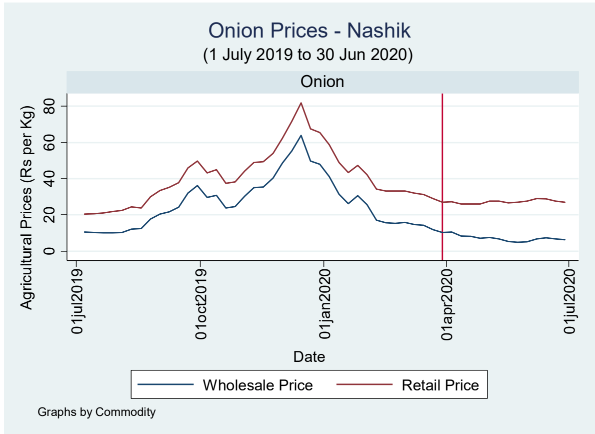


Figure 1(d): Wholesale & Retail Onion Prices in Nashik



Source: Authors' computations

Figure 1(a) shows that, onion prices in Mumbai peaked at Rs. 116.7 per kg in the October-December quarter of 2019 and have seen a steep fall since January 2020. This trend has been observed in both retail and wholesale price levels. However, wholesale prices in the April-June 2020 quarter plunged further below the July-Sept 2019 price levels, at Rs. 8 per kg in the former vis-à-vis Rs. 13.40 per kg in the latter. A very similar trend in the prices has been observed in Nagpur and Nashik as well (figure 1(b) and Figure 1(c) respectively). However, in Pune, the retail and wholesale prices of onion climbed marginally post the first nation-wide lockdown and dropped again towards the end of the last quarter of the study.

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.[17]

[17](2019, December 27). Onion prices remain higher at up to Rs. 150 per kg, imports underway. *LiveMint*[Link]

Figure 2: Prices of Potato in Maharashtra

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

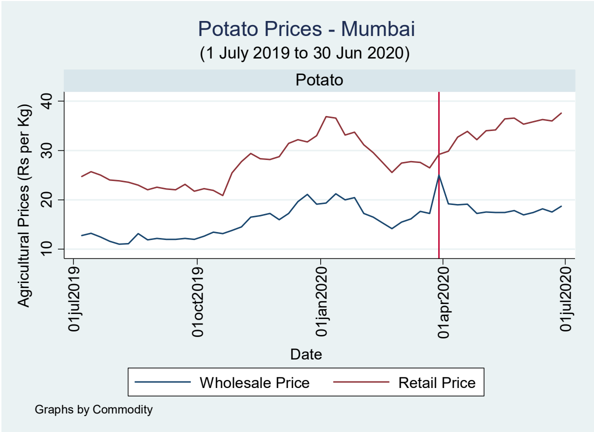


Figure 2(b): Wholesale & Retail Potato Prices in Nagpur

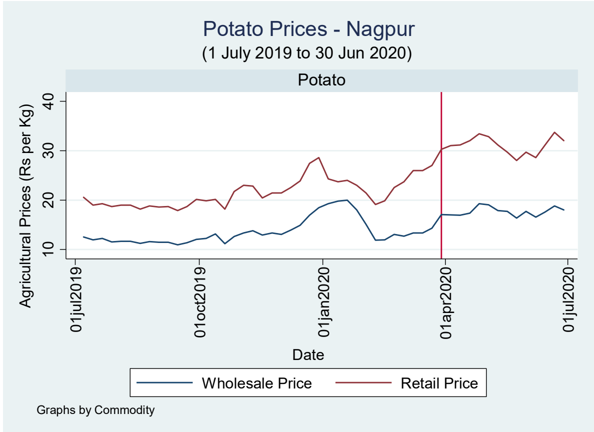


Figure 2(c): Wholesale & Retail Potato Prices in Pune

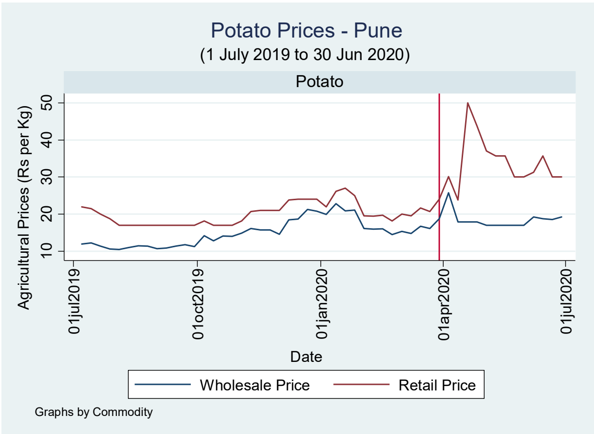
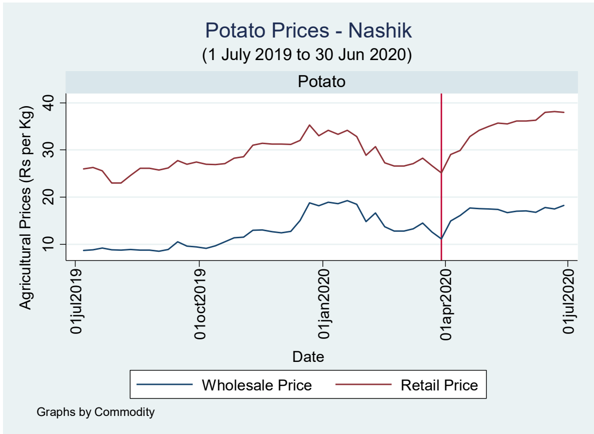


Figure 2(d): Wholesale & Retail Potato Prices in Nashik



Source: Authors' computations

Figure 2(a) shows that, while there has been an overall increase in average retail price of potatoes in Mumbai, the average wholesale price per quarter decreased in April-June 2020, after rising for three consecutive quarters of our study. However, the retail price of potatoes in Pune has shown a sudden and significant spike during the first Covid-19 lockdown in India. The retail price in Nashik has shown an upward trend (Figure 2(d)) in the period following the lockdown announcement.

Note that the wholesale prices of potatoes have exhibited different behaviour in all the four cities. While in Mumbai there was a sudden rise in wholesale prices of potatoes just before and after the announcement of the first nation-wide lockdown, the wholesale price in Nagpur became flat for much of the first lockdown. The wholesale price in Nashik has followed an upward trend post the announcement and in Pune the prices increased marginally but dropped soon after.

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, after which the retail prices continued to follow an upward trend while the wholesale prices fell.

Figure 3: Prices of Rice in Maharashtra

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

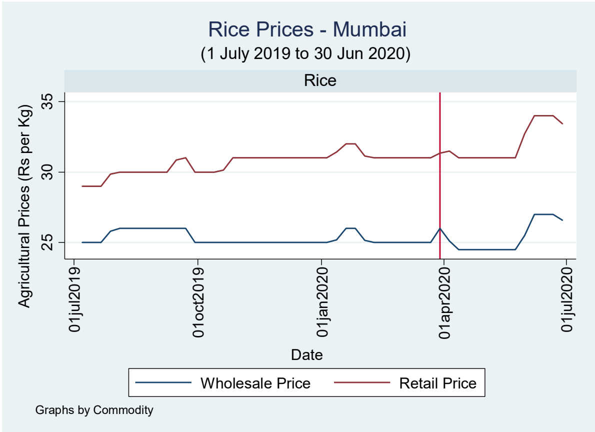


Figure 3(b): Wholesale & Retail Rice Prices in Nagpur

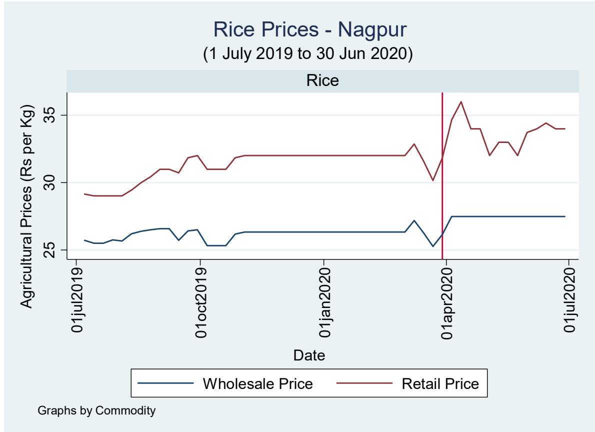


Figure 3(c): Wholesale & Retail Rice Prices in Pune

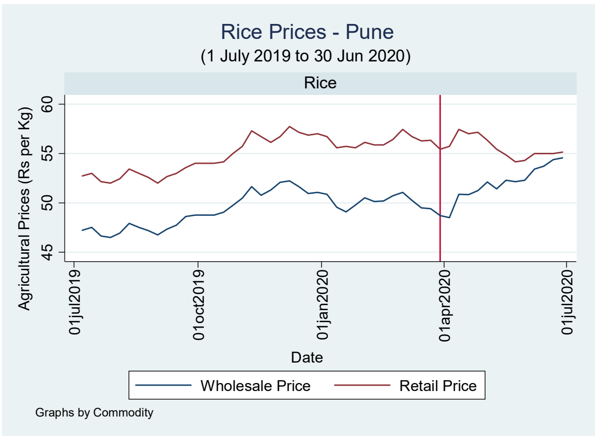
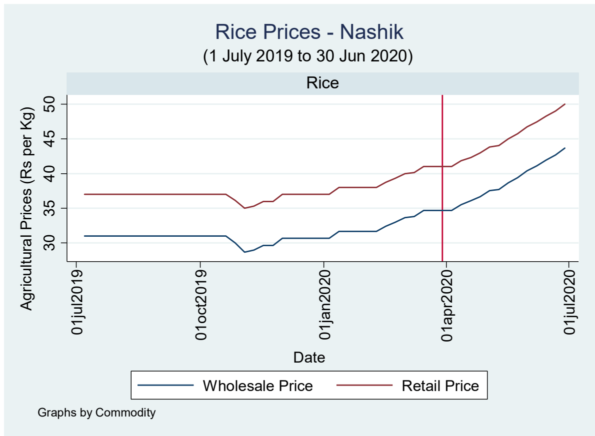


Figure 3(d): Wholesale & Retail Rice Prices in Nashik



Source: Authors' computations

As depicted in Figure 3(a), in Mumbai, the price of rice has been relatively stable compared to other food commodities and has exhibited very little to no variability within each quarter. On the other hand, in figure 3(c) these prices have shown the most variation in Pune. The wholesale price of rice has shown an upward trend in both Nashik and Pune while it has remained flat in Nagpur. The retail price in Nashik has consistently increased post the announcement of the first Covid lockdown in India.

It is worth noting that the retail and wholesale prices of rice in Pune nearly converge towards the end of June 2020 while they run parallel in Mumbai and Nashik. In Nagpur, while there is a sudden increase in the variability of retail price of rice in lockdown period, the wholesale prices have not displayed any variation.

Figure 4: Prices of Tomato in Maharashtra

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

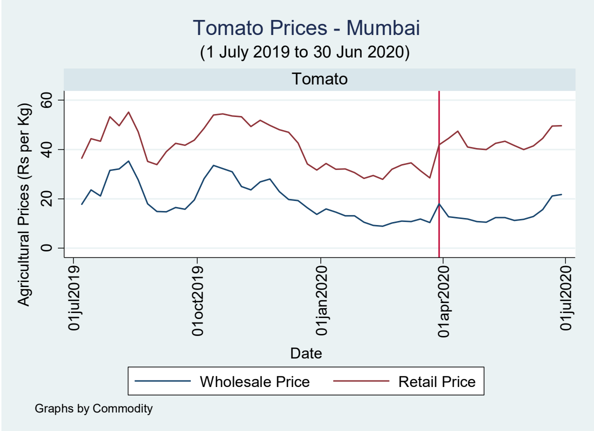


Figure 4(b): Wholesale and Retail Tomato Prices in Nagpur

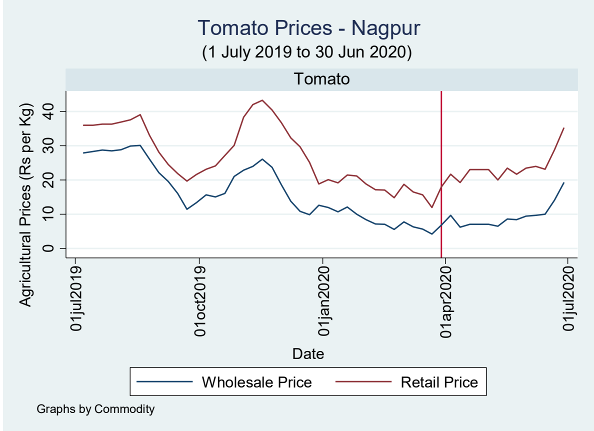


Figure 4(c): Wholesale and Retail Tomato Prices in Pune

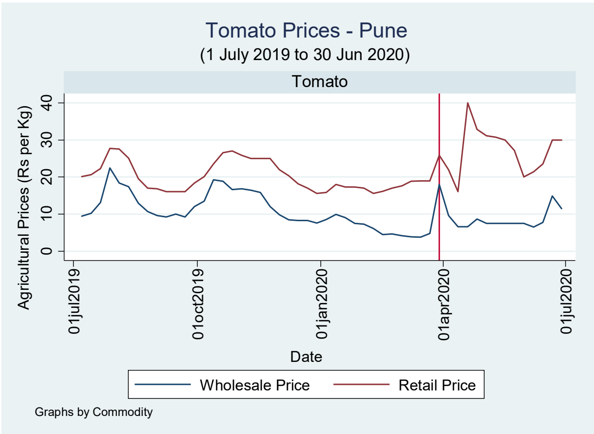
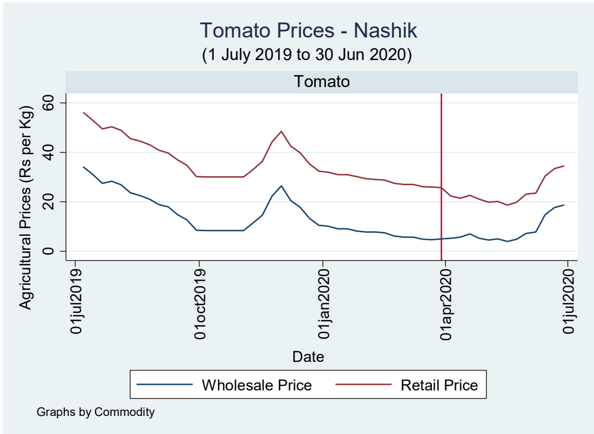


Figure 4(d): Wholesale and Retail Tomato Prices in Nashik



Source: Authors' computations

As expected, tomato prices have shown high variability in the last one year (Figure 4). The retail and wholesale prices were observed to decline steadily from the last quarter of 2019 to much of the first quarter of 2020 in all the four cities. The prices started rising around the first Covid-19 lockdown in Mumbai and Nagpur but continued to drop in Nashik until the second half of the ultimate quarter of our study. In Pune, there was sudden drop in prices after the first lockdown was imposed. From thereon, the retail price shot up substantially for a brief period but plunged soon after and the wholesale price remained low and did not much variation (Figure 4(c)).

This surge in prices accompanied by high variability, particularly in retail prices can be attributed to supply chain disruptions and sporadic release of limited supplies. The widening of the gap between retail and wholesale tomato prices during much of the last quarter is presumably indicative of tardy supplies to rising consumer demand, as transfers to retail outlets were constrained by weak logistical support (eg, transportation facilities).

Figure 5: Prices of Milk in Maharashtra

Figure 5(a): Wholesale and Retail Milk Prices in Mumbai

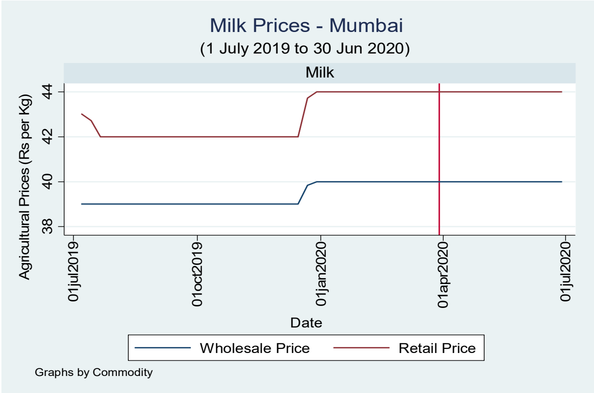


Figure 5(b): Wholesale and Retail Milk Prices in Nagpur

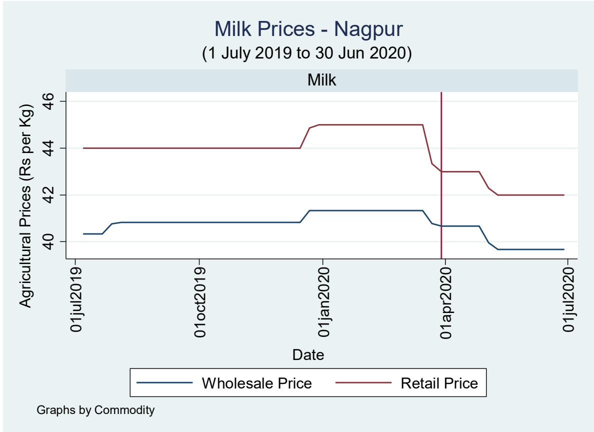


Figure 5(c): Wholesale and Retail Milk Prices in Pune

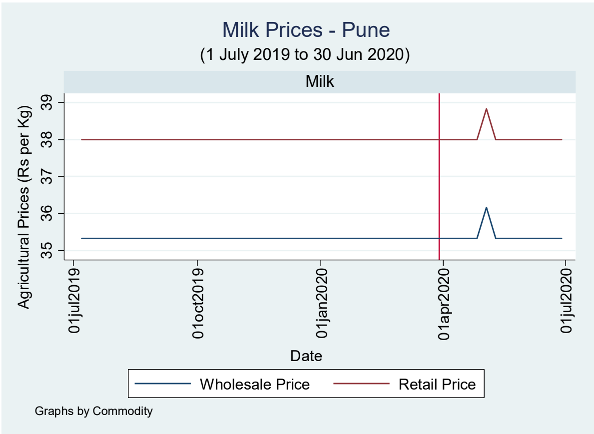
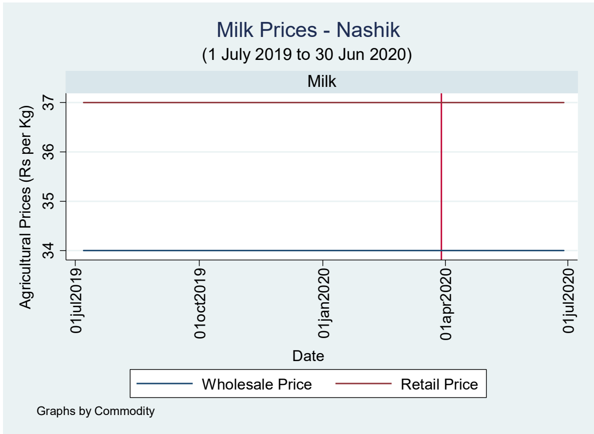


Figure 5(d): Wholesale and Retail Milk Prices in Nashik



Source: Authors' computations

As shown in Figure 5, milk prices show very little to no variation within each quarter of the last year. Both retail and wholesale prices have shown similar trajectories with a sudden increase in prices since December 2019 in Mumbai and Nagpur. This sudden rise in price of milk has been due to climatic conditions such as unseasonal rainfall which has affected the milch animals and resulted in low milk production even during what is usually called the flush period of October to January. [18] However, in the case of Nagpur, the prices of milk, both retail and wholesale, have fallen substantially below the pre-lockdown prices in the April-June quarter of 2020. This can be attributed to the collapse in demand from commercial buyers[19].

In the case of Nashik, there has been no variation in both retail and wholesale prices of milk during the last one year represented by the flat line in figure 5(d). As shown in Figure 5(c), the milk price in Pune spiked for a brief period in the final quarter of our study. This could possibly be because of the milk producers in Maharashtra requesting the government to buy excess milk supplies which helped in bringing the prices back to their pre-lockdown levels. We also infer from the graphs above that the nation-wide lockdown to curb the coronavirus outbreak has not affected the wholesale and retail

[18]Srivastava, A. (2020, January 19). Climate change directly affecting prices of milk. *Sakal Times*. [Link]
[19]Damodaran, H. (2020, April 6). Covid-19 lockdown effect: From deficit, dairies suddenly grappling with excess milk supplies. [Link]

prices of milk in three of the four cities, namely, Mumbai, Pune and Nashik. This is not surprising given milk's perishability and limited transport facilities.

Figure 6 depicts the trend in the wedge between wholesale and retail prices of each of the five food commodities – onion, potato, rice, tomato and milk in each of the four cities. In the case of onions, the price wedge showed an increasing trend in the latter half of the October-December quarter of 2019. This rising trend has been similar in Mumbai, Nagpur and Pune. This can be attributed to the stock limits imposed to control the rising price of onions. In Nashik, the price wedge of onion widened as the nation-wide lockdown progressed. For milk and rice, the price wedges have remained mostly flat, particularly in Mumbai and Nashik. In the case of Nagpur and Pune, the price wedge showed variability only after the Covid-19 lockdown was imposed.

For two centres – Mumbai and Nagpur- the wedge between retail and wholesale prices of tomato has seen a sharp rise only from around the time immediately preceding the first lockdown up to the beginning of the second lockdown. For the remaining two centres, the price wedge rose shortly after the implementation of the lockdown, while in Nashik it plummeted immediately.

In Mumbai, a sudden short-lived decline in the price wedge is observed in the price wedge of potato coinciding with the announcement of the first nation-wide lockdown, followed by a steady rising trend thereafter. In Nagpur, the price wedge of potato increased for a short while but soon exhibited a downward trend since the second Covid-19 lockdown. In the case of Pune, a steep rise in the price wedge of potato was noted in the beginning of the final quarter of the study followed by a sharp drop in the latter half of the same quarter. Finally, in the case of Nashik, price wedge of potato displayed a gradual increasing trend since the initiation of the covid lockdown in India.

Figure 6: Price Wedges

Descriptive Statistics

Table 1 below summarizes the average, maximum and minimum retail and wholesale prices of the five 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 have been provided for the four centres of our study – Mumbai, Nagpur, Pune and Nashik.

From the following table we infer that retail prices of the commodities are more variable than their wholesale prices. Milk prices show the least variation out of the five commodities under consideration. In Nashik, particularly, milk prices showed absolutely no variation. The same is noted in Pune as well except for the final quarter of the analysis period where very little variation is seen. The average retail price of onion and tomato peaked in the October-December quarter of 2019, while those of potato and rice in the April-June quarter of 2020.

In Mumbai, the average price wedge of all commodities except onion was the maximum in the last quarter of our study. In the case of Nagpur, the average price wedge for onion and milk peaked in the second and third quarter of the study, respectively; while those of potato, rice and tomato peaked in April-June 2020.The average price wedge of milk remained flat in Pune and Nashik during the last one year. It was only in Nashik that average price wedge of tomato widened to Rs. 22 per kg in the first quarter of the study and has decreased in the remaining three quarters of the analysis.

The variation in wholesale prices of milk unerringly mirrors the variation in its retail prices in the ultimate quarter of the analysis period. This observation is true for all the four centres. In both quarters of 2019, average wholesale and retail price of tomato was the lowest in Pune when compared with the other three centres.

The soaring price in Mumbai of four out of the five commodities (except rice) in our study, when compared to the other three centres is associated with higher cost of living index. The other three centres have considerable land under cultivation. Maharashtra's major tomato growing belts are Nashik, Pune, Nagpur and Gadchiroli. The district of Nashik is also a major contributor to the state's onion production and is one of Asia's largest onion markets.

An important observation from the following table is that the price of rice – both wholesale and retail- in Mumbai is much lower than that in Pune, Nashik and Nagpur throughout the four quarter of our study. This is despite Mumbai having a higher cost of living index compared to its peer centres. This is likely because of its closer proximity to Thane district, which is the largest rice producer in Maharashtra.

It is surprising to note that from the first quarter of 2020 to the second quarter of the same year, variability in retail price of onion has dropped sharply while the opposite (sharp increase) was true for variability in retail onion prices from July-September 2019 to October-December 2019, and is seen in all the four centres under consideration. This behaviour is also reflected in retail price of potatoes with the fourth quarter of the study being the only exception for one of the four centres, i.e. Pune.

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

		Mumbai					Nagpur					Pune					Nashik				
		Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk
July – September 2019	Average Wholesale Price	20.8	12.1	25.7	22.2	39.0	16.2	11.7	26.1	23.9	40.7	16.6	11.2	47.4	12.7	35.3	17.6	9.0	31.0	22.1	34.0
	SD - Wholesale Price	8.8	0.7	0.5	7.2	-	6.9	0.4	0.4	6.7	0.2	6.8	0.5	0.7	4.2	-	8.9	0.5	-	7.5	-
	Max - Wholesale Price	40.1	13.2	26.0	35.3	39.0	31.0	12.6	26.6	30.1	40.8	31.3	12.2	48.8	22.5	35.3	36.3	10.5	31.0	34.0	34.0
	Min - Wholesale Price	13.4	11.0	25.0	14.8	39.0	10.4	10.9	25.5	11.5	40.3	10.5	10.5	46.5	9.2	35.3	10.2	8.5	31.0	8.4	34.0
	Average Retail Price	32.4	23.3	29.9	43.5	42.1	28.3	19.0	30.1	31.3	44.0	22.9	18.1	52.8	20.3	38.0	29.8	25.7	37.0	44.1	37.0
	SD - Retail Price	10.8	1.3	0.6	6.6	0.3	7.8	0.7	1.1	7.1	-	5.4	1.9	0.6	4.3	-	10.0	1.5	-	7.5	-
	Max - Retail Price	58.3	25.7	31.0	55.1	43.0	45.0	20.6	32.0	39.0	44.0	38.0	22.0	54.0	27.7	38.0	49.7	27.7	37.0	56.0	37.0
	Min - Retail Price	22.9	21.7	29.0	33.9	42.0	21.0	17.9	29.0	19.7	44.0	18.0	17.0	52.0	16.0	38.0	20.4	23.0	37.0	30.1	37.0
	Average Price Wedge	11.6	11.2	4.2	21.3	3.1	12.1	7.3	4.0	7.4	3.3	6.2	6.8	5.4	7.6	2.7	12.2	16.7	6.0	22.0	3.0
October – December 2019	Average Wholesale Price	54.6	16.2	25.0	24.7	39.1	46.2	13.8	26.1	17.7	40.9	38.7	16.3	50.6	13.2	35.3	39.7	12.9	30.3	13.7	34.0
	SD - Wholesale Price	20.4	2.7	-	6.1	0.3	16.9	2.0	0.4	5.4	0.2	16.4	2.7	1.2	4.4	-	12.5	2.9	0.8	6.2	-
	Max - Wholesale Price	93.3	21.1	25.0	33.6	40.0	73.9	18.5	26.3	26.1	41.3	68.7	21.3	52.2	19.2	35.3	64.0	18.8	31.0	26.4	34.0
	Min - Wholesale Price	30.7	12.7	25.0	13.8	39.0	27.8	11.1	25.3	9.9	40.8	21.9	12.8	48.8	7.6	35.3	24.0	9.1	28.7	8.3	34.0
	Average Retail Price	78.0	27.8	30.8	47.5	42.3	61.5	22.4	31.8	31.6	44.1	57.5	20.5	56.0	22.4	38.0	54.6	30.3	36.5	35.5	37.0
	SD - Retail Price	22.7	4.1	0.4	7.3	0.7	19.5	2.9	0.4	7.9	0.3	23.7	2.8	1.3	3.8	-	13.9	2.6	0.7	6.3	-
	Max - Retail Price	116.7	33.0	31.0	54.4	44.0	91.1	28.6	32.0	43.3	45.0	87.1	24.0	57.7	27.0	38.0	81.9	35.3	37.0	48.4	37.0
	Min - Retail Price	54.6	20.9	30.0	31.7	42.0	38.6	18.1	31.0	18.9	44.0	30.4	17.0	54.0	15.6	38.0	37.4	26.9	35.0	30.0	37.0

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

		Mumbai					Nagpur					Pune					Nashik				
		Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk
	Average Price Wedge	23.4	11.5	5.8	22.9	3.1	15.4	8.6	5.7	13.9	3.2	18.8	4.3	5.4	9.2	2.7	14.9	17.4	6.2	21.8	3.0
January - March 2020	Average Wholesale Price	27.7	18.1	25.3	12.1	40.0	31.5	15.4	26.3	8.0	41.2	19.6	17.6	50.0	7.1	35.3	20.8	15.2	32.8	7.0	34.0
	SD - Wholesale Price	12.8	3.0	0.4	2.7	-	16.5	3.0	0.4	2.5	0.2	8.0	2.7	0.7	3.9	-	9.3	2.8	1.4	1.8	-
	Max - Wholesale Price	55.0	25.0	26.0	18.0	40.0	68.4	20.0	27.2	12.1	41.3	34.5	22.8	51.1	17.9	35.3	41.2	19.2	34.7	10.0	34.0
	Min - Wholesale Price	16.0	14.2	25.0	8.9	40.0	17.6	11.9	25.3	4.2	40.7	11.1	14.5	48.7	3.8	35.3	10.4	11.1	30.7	4.7	34.0
	Average Retail Price	55.1	30.2	31.2	32.0	44.0	45.6	23.9	31.9	17.7	44.7	38.3	21.8	56.2	18.0	38.0	38.0	29.4	39.1	28.5	37.0
	SD - Retail Price	15.6	3.8	0.4	3.7	-	17.3	3.0	0.6	2.6	0.7	17.5	2.9	0.6	2.6	-	9.3	3.2	1.4	2.1	-
	Max - Retail Price	87.9	36.9	32.0	41.8	44.0	81.3	30.3	32.9	21.4	45.0	77.6	27.0	57.4	25.9	38.0	58.7	34.1	41.0	32.0	37.0
	Min - Retail Price	39.7	25.6	31.0	27.9	44.0	27.3	19.1	30.2	12.0	43.0	22.7	18.1	55.4	15.6	38.0	27.1	25.1	37.0	25.7	37.0
	Average Price Wedge	27.4	12.1	6.0	19.9	4.0	14.1	8.6	5.6	9.8	3.5	18.8	4.2	6.2	11.0	2.7	17.2	14.2	6.3	21.5	3.0
April – June 2020	Average Wholesale Price	10.7	18.0	25.4	13.6	40.0	13.2	17.7	27.5	9.5	40.0	9.4	18.5	52.1	8.4	35.4	7.0	17.1	38.9	8.3	34.0
	SD - Wholesale Price	2.7	0.8	1.1	3.7	-	3.0	0.9	-	3.6	0.5	4.2	2.3	1.7	2.4	0.2	1.5	0.9	2.9	5.2	-
	Max - Wholesale Price	17.4	19.2	27.0	21.8	40.0	20.5	19.2	27.5	19.1	40.7	18.8	25.8	54.6	14.9	36.2	10.5	18.3	43.7	18.7	34.0
	Min - Wholesale Price	8.0	16.9	24.5	10.5	40.0	10.5	16.3	27.5	6.2	39.7	6.4	17.0	48.5	6.5	35.3	5.0	14.9	34.7	4.0	34.0
	Average Retail Price	36.7	34.7	32.0	43.5	44.0	25.4	31.1	33.8	23.8	42.3	26.9	34.1	55.6	27.3	38.1	27.3	35.0	45.2	23.9	37.0
	SD - Retail Price	4.2	2.2	1.3	3.4	-	4.6	1.8	1.1	4.1	0.5	6.6	6.8	1.1	6.4	0.2	1.0	2.9	2.9	5.3	-

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

		Mumbai					Nagpur					Pune					Nashik				
		Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk
	Max - Retail Price	45.5	37.6	34.0	49.6	44.0	36.3	33.7	36.0	35.1	43.0	40.0	50.0	57.4	40.0	38.8	29.0	38.1	50.0	34.4	37.0
	Min - Retail Price	32.3	29.8	31.0	40.0	44.0	21.4	28.0	32.0	19.3	42.0	17.1	23.9	54.1	16.0	38.0	26.0	29.0	41.0	18.7	37.0
	Average Price Wedge	26.0	16.7	6.7	29.9	4.0	12.2	13.4	6.3	14.4	2.3	17.5	15.6	3.4	18.9	2.7	20.3	17.9	6.3	15.6	3.0

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[20]. 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[21] (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. Hence the prices are non-stationary, and we do a re-test taking their first differences. All the price series, except for those of Milk, are found to be stationary in the first differences. In case of Milk, there is no, or little variation in prices as seen from Figure 5. We therefore restrict the further analysis to the other four commodities only.

[20]For an exposition, see Greene (2012).
[21]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

				WHOLESALE PRICES					RETAIL PRICES					PRICE WEDGE				
			5% Critical Value	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk
Mumbai	Actual Level of Price	Lag#		1	1	2	2	1	1	1	2	1	1	1	1	1	1	1
		ADF Test Statistic:																
		At Lag 1	-2.930	-1.141	-1.541				-1.320	-0.750		-2.151	-1.010	-2.128	-1.810	-1.345	-2.593	-1.320
		At Lag 2	-2.933			-2.385	-2.493	-1.092			-1.426							
	First Difference of Prices	Lag #		0	1	0	0	0	1	0	2	0	0	0	0	0	0	0
		ADF Test Statistic:																
		At Lag 0	-2.930	-8.326*		-5.696*	-5.957*	-5.840*		-6.184*		-6.498*	-5.820*	-6.974*	-6.783*	-8.475*	-6.148*	-5.703*
		At Lag 1	-2.933		-5.581*				-3.499*									
		At Lag 2	-2.936								-4.401*							
Nagpur	Actual Level of Price	Lag #		2	2	1	2	1	2	1	1	2	1	2	2	1	1	1
		ADF Test Statistic:																
		At Lag 1	-2.930			-2.387		-0.742		-1.095	-2.422		-0.615			-2.321	-2.078	-1.400
		At Lag 2	-2.933	-1.751	-2.019		-2.105		-1.635			-2.484		-2.254	-1.129			
	First	Lag #		1	0	2	1	0	1	0	0	1	0	2	2	0	0	0
		ADF Test Statistic:																
		At Lag 0	-2.930		-5.514*			-5.573*		-6.179*	-6.745*		-5.698*			-7.980*	-6.716*	-5.747*

				WHOLESALE PRICES					RETAIL PRICES					PRICE WEDGE				
			5% Critical Value	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk
		At Lag 1	-2.933	-3.293*			-3.479*		-3.433*			-2.851[a]						
		At Lag 2	-2.936			-5.370*								-5.414*	-4.108*			
Pune	Actual Level of Price	Lag #		1	1	1	1	0	2	1	1	1	0	2	1	1	1	
		ADF Test Statistic:						-7.141*					-7.141*					
		At Lag 1	-2.930	-1.506	-1.621	-0.603	-2.563			-1.553	-1.867	-2.332			-2.307	0.707	-1.774	
		At Lag 2	-2.933						-2.089					-2.271				
	First Difference of Prices	Lag #		0	1	0	0		1	1	0	0		0	0	0	1	
		ADF Test Statistic:																
		At Lag 0	-2.930	-6.100*		-6.614*	-7.544*				-6.157*	-8.583*		-5.544*	-7.856*	-6.159*		
		At Lag 1	-2.933		-5.933*				-3.154*	-6.060*							-5.585*	
		At Lag 2	-2.936															
Nashik	Actual Level of Price	Lag #		2	1	1	2		2	1	1	2		2	2	1	2	
		ADF Test Statistic:																
		At Lag 1	-2.930		-1.295	2.997				-0.645	3.330					-1.465		
		At Lag 2	-2.933	-1.465			-2.303		-1.804			-2.135		-1.198	-1.710		-0.376	
	First Diff	Lag #		0	0	1	1		0	0	1	1		1	1	0	1	
		ADF Test Statistic:																
		At Lag 0	-2.930	-5.282*	-7.010*				-5.189*	-7.363*						-6.920*		

				WHOLESALE PRICES					RETAIL PRICES					PRICE WEDGE				
			5% Critical Value	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk	Onion	Potato	Rice	Tomato	Milk
		At Lag 1	-2.933			-2.853*	-3.540*	[redacted]			-2.723[a]	-3.584*	[redacted]	-4.475*	-4.182*		-4.509*	[redacted]
		At Lag 2	-2.936															

Optimal Lag Length calculated based on the Bayesian Information Criterion (BIC)
a: significant at 10% level

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, retail and the price wedge) for all commodities, except Milk, 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 4 centres) based on Johansen's method (1995)[22]. 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 case of Tomatoes and Potatoes across the 4 centres. The same is also the case with Rice, except in the Nashik Centre.
2. The null hypothesis of no co-integration between retail and wholesale prices is *rejected* in the case of Onions for all centres, except Nashik.
3. Thus, a long run relationship, based on co-integrating equations can be estimated between wholesale and retail prices of Onion at the Mumbai, Nagpur and Pune Centres, and of Rice at the Nashik centre. 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 table comprises 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 Onion retail prices at both Mumbai and Pune is negative and significant. This implies a convergence in the long run, and the rate of convergence is faster for prices at the Mumbai centre compared to the Pune centre. The adjustment factor for Onion wholesale prices at Mumbai, Nagpur and Pune and for Onion retail prices at Nagpur is found to be insignificant.
2. In the case of Rice prices at Nashik, the adjustment factor for both retail and wholesale prices is positive and significant. This implies instabilities and is likely to be an indication of a structural change.
3. For all the 4 cases on commodity-centre pairs, 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 all four cases, implying presence of a *positive* long run relationship between Retail and Wholesale Prices.

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

4. The graphs of the predicted co-integrated equation are plotted and presented in the last row of Table 4. While the co-integrating equation for Mumbai-Onion and Nashik-Rice series does not exhibit stationarity, the graphs for Nagpur-Onion and Pune-Onion series, and the statistical tests confirm that the co-integrating equation exhibits stationarity. For both these cases, there is a steep rise from the equilibrium witnessed in the predicted values followed by a fall post the announcement of the lockdown.
5. We do post-estimation diagnostic tests to assess the validity of our model. Using the LM test, the null hypothesis for no autocorrelation is rejected for the Mumbai-Onion series, implying presence of autocorrelation. For the Nagpur-Onion, Pune-Onion and Nashik-Rice 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 Onion at the Mumbai, and Pune Centres, and of Rice at the Nashik centre. 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^2value, is good.

The VAR model confirmed dependence of retail prices of potatoes in Mumbai on the second lag of wholesale prices, and in Nagpur and Pune on the first lag of wholesale prices. In case of Rice, dependence of retail prices on wholesale prices is found in second and third lags in Nagpur. And in case of Tomatoes, dependence of retail prices on wholesale prices is found in the first lag in case of Nagpur, and second and third lags in Pune. These relationships are found to be insignificant in case of Nashik. The dependence of wholesale prices on retail prices is found to be significant in case of rice in Mumbai in both the first and second lags, and in case of potatoes in Nagpur in the second lag. In both retail and wholesale price equations, the coefficient of the own first lag of the dependent variable is significant and positive.

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

			MUMBAI			NAGPUR			PUNE			NASHIK		
	Rank	5% Critical Value	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic
ONION	0	15.41	-307.22	.	18.67	-241.03	.	27.48	-300.34	.	16.85	-187.17	.	7.31*
	1	3.76	-299.34	0.270	2.91*	-228.89	0.385	3.20*	-293.36	0.244	2.89*	-183.82	0.125	0.61
	2		-297.89	0.056		-227.29	0.062		-291.92	0.056		-183.51	0.012	
POTATO	0	15.41	-184.30	.	12.23*	-144.55	.	14.19*	-241.41	.	14.15*	-133.26	.	7.45*
	1	3.76	-178.94	0.193	1.51	-138.19	0.225	1.47	-235.61	0.207	2.55	-129.83	0.128	0.59
	2		-178.18	0.030		-137.46	0.029		-234.33	0.050		-129.53	0.012	
RICE	0	15.41	-27.51	.	12.08*	-71.17	.	11.72*	-78.51	.	4.56*	63.28	.	23.81
	1	3.76	-22.47	0.182	2.01	-67.86	0.124	5.10	-76.68	0.071	0.90	74.60	0.364	1.16*
	2		-21.47	0.039		-65.31	0.097		-76.23	0.018		75.19	0.023	
TOMATO	0	15.41	-256.82	.	12.64*	-217.58	.	9.18*	-267.29	.	11.06*	-149.34	.	8.82*
	1	3.76	-252.95	0.143	4.91	-215.24	0.089	4.51	-263.38	0.145	3.24	-145.72	0.135	1.58
	2		-250.50	0.093		-212.99	0.086		-261.76	0.063		-144.93	0.031	

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

		MUMBAI – Onion			NAGPUR – Onion			PUNE – Onion			NASHIK – Rice	
No. of Observations	50			50			50			50		
AIC | BIC | HQIC	12.33	12.46	12.68	9.52	9.65	9.86	12.09	12.23	12.44	-2.62	-2.49	-2.28
Log Likelihood	-299.35			-228.89			-293.36			74.60		
D_Retail Prices Equation												
RMSE | R-Squared | Chi2	7.09	0.20	11.35**	4.31	0.35	25.16***	5.02	0.35	25.17***	0.37	0.56	59.51***
Adjustment Factor	-0.47	(-3.05)	***	-0.52	(-1.5)		-0.25	(-2.75)	***	0.99	(4.47)	***
Retail Prices (LD)	0.33	(1.12)		1.15	(3.25)	***	0.55	(3.8)	***	-1.46	(-1.03)	
Wholesale Prices (LD)	-0.53	(-1.99)	**	-0.66	(-1.75)	*	-0.23	(-1.34)		1.40	(1.05)	
Constant	0.10	(0.1)		0.00	(0.01)		-0.01	(-0.02)		0.01	(0.1)	
D_Wholesale Price Equation												
RMSE | R-Squared | Chi2	8.47	0.09	4.70	3.76	0.40	30.99***	5.75	0.04	1.88	0.39	0.54	53.86***
Adjustment Factor	-0.29	(-1.6)		0.18	(0.58)		0.04	(0.37)		0.98	(4.2)	***
Retail Prices (LD)	0.21	(0.59)		0.67	(2.16)	**	0.16	(0.94)		-1.26	(-0.84)	
Wholesale Prices (LD)	-0.48	(-1.49)		-0.14	(-0.42)		0.06	(0.31)		1.24	(0.88)	
Constant	-0.16	(-0.14)		0.01	(0.02)		-0.07	(-0.09)		-0.01	(-0.1)	
Co-integrating Equation												
Chi2		196.91***			3618.89***			84.70***			3161.38***	
Retail Prices	1			1			1			1		
Wholesale Prices	-1.14	(-14.03)	***	-1.11	(-60.16)	***	-1.34	(-9.2)	***	-0.94	(-56.23)	***
Constant	-18.18			-0.49			-8.09			-8.03		
Post Estimation Diagnostics												
LM Test for Autocorrelation												
Chi2 at Lag 1		11.26**			0.91			5.99			1.72	
Chi 2 at Lag 2		12.48**			2.28			7.52			1.76	
Jarque-Bera test for Normality												
Chi 2 for D_Retail Price		4.253			16.338***			1.797			1.046	
Chi2 for D_Wholesale Price		6.919**			1.823			65.995***			53.760***	
Chi 2 for All		11.172**			18.161***			67.792***			54.806***	

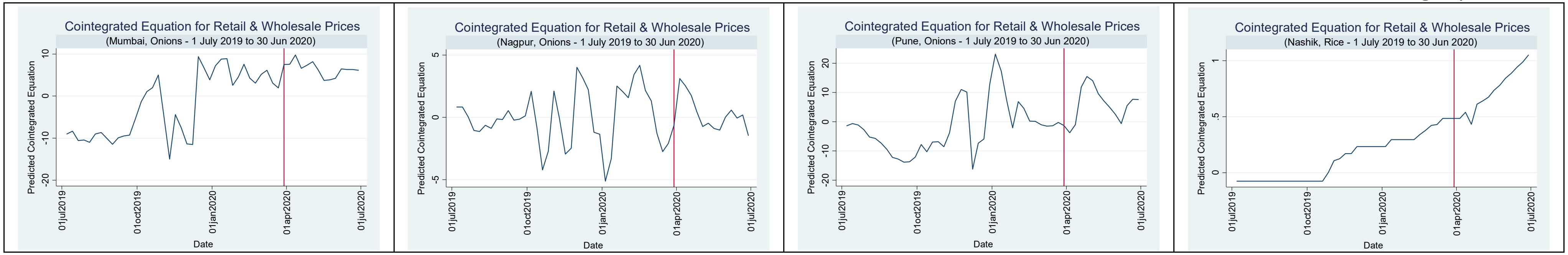


Table 5: Vector Auto Regression (VAR) Model for Retail and Wholesale Prices

	MUMBAI			NAGPUR			PUNE			NASHIK		
	Potato	Rice	Tomato	Potato	Rice	Tomato	Potato	Rice	Tomato	Onion	Potato	Tomato
Optimal Lag Length												
AIC	2	2	2	2	3	2	2	1	4	2	3	2
No. of Observations	50	50	50	50	49	50	50	51	48	50	49	50
Log Likelihood	-178.2	-21.5	-250.5	-137.5	-59.1	-213.0	-234.3	-77.6	-233.2	-183.5	-122.7	-144.9
Retail Price Equation												
Chi2	587.3***	314.8***	141.8***	512.7***	143.2***	353.8***	168.6***	304.2***	102.2***	510.8***	348.8***	736.2***
L1. Retail Price	1.15***	1.16***	0.91***	1.25***	0.90***	1.01***	0.72***	0.91***	0.84***	1.13	1.23***	1.23***
L2. Retail Price	-0.32**	-0.24	-0.06	-0.12	0.04	-0.20	0.01		-0.01	-0.58	-0.34	-0.37
L3. Retail Price					-0.14				-0.01		0.13	
L4. Retail Price									-0.06			
L1. Wholesale Price	-0.22	0.04	0.16	-0.51*	0.28	0.52**	-0.78***	-0.01	-0.01	0.04	-0.39	0.10
L2. Wholesale Price	0.47***	-0.26	-0.19	0.17	-1.09***	-0.41	1.23***		-0.48**	0.34	0.62	-0.06
L3. Wholesale Price					0.93**				1.03***		-0.32	
L4. Wholesale Price									-0.74***			
Constant	1.17	8.23***	6.89*	2.18*	3.49	3.63**	-0.28	5.31*	7.38***	9.08**	0.92	2.99
Wholesale Price Equation												
Chi2	142.8***	121.5***	193.8	364.7***	114.6***	618.7***	123.3***	432.6***	74.68***	614.7***	349.3***	561.7***
L1. Retail Price	0.20	0.39*	-0.10	-0.08	0.14	0.06	0.02	-0.12	0.09	-0.17	-0.28	-0.08
L2. Retail Price	-0.15	-0.41**	0.18	0.25*	-0.12	-0.09	-0.03		-0.10	-0.24	0.37	0.00
L3. Retail Price					0.02				-0.06		0.02	
L4. Retail Price									0.01			
L1. Wholesale Price	0.52***	0.78***	1.18***	1.10***	0.74***	1.30***	0.61***	1.04***	0.64***	1.33	1.22***	1.43***
L2. Wholesale Price	0.28*	-0.04	-0.41*	-0.46**	-0.30	-0.36*	0.27*		0.08	0.01	-0.37	-0.44

L3. Wholesale Price					0.38**				0.04		-0.02	
L4. Wholesale Price									-0.04			
Constant	1.75	7.12***	0.60	1.27	3.88	1.40	2.35*	4.47	3.70*	8.31**	-0.79	2.47

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

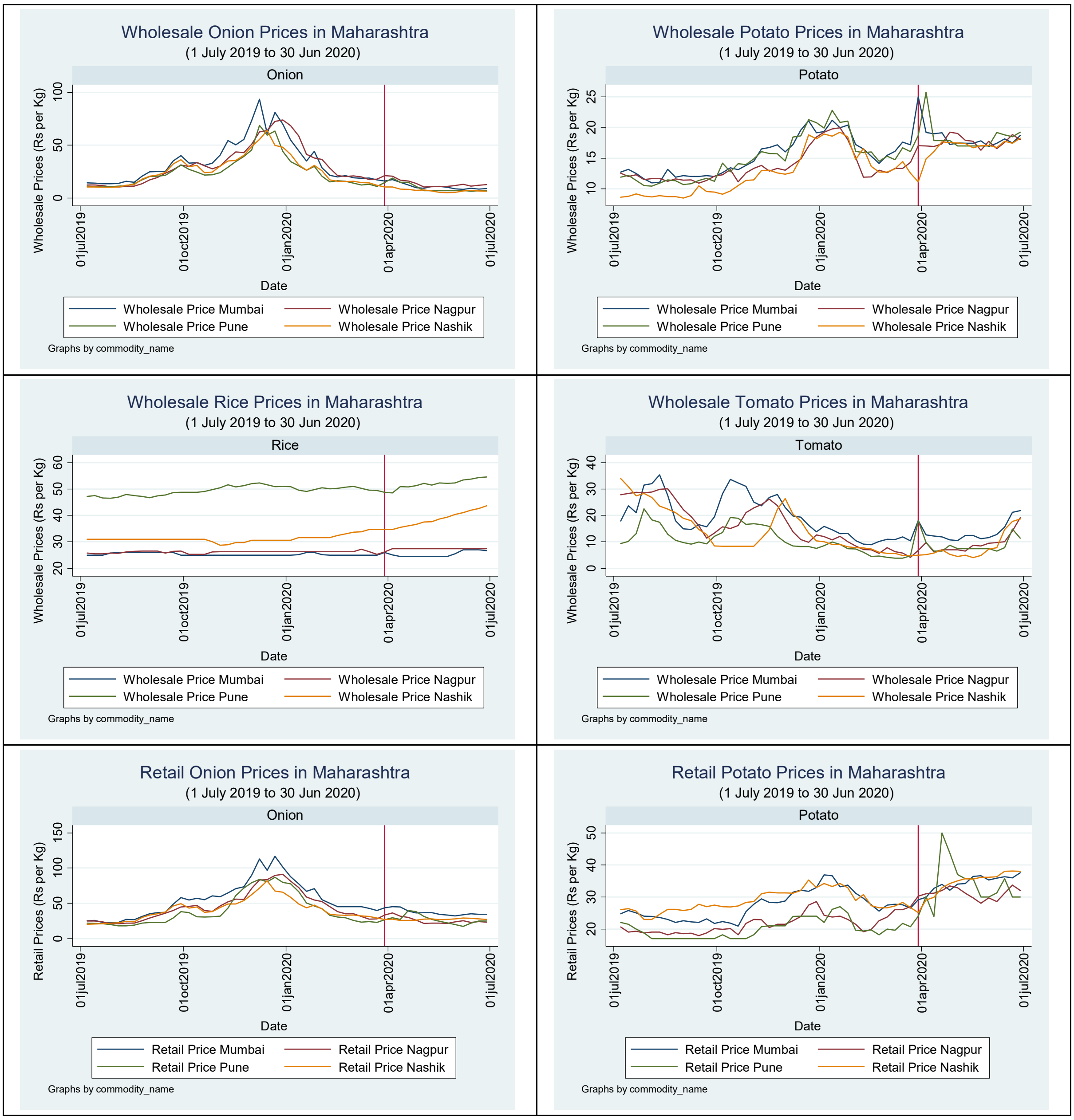
Co-integration between Prices at Different Markets

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

The 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, but 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 two co-integrating equations for both wholesale and retail prices of Onions and Tomatoes. It also confirms presence of one co-integrating equation for the wholesale and retail prices of rice, and wholesale price of potatoes. The null hypothesis of zero co-integrating equations is not rejected for retail prices of potatoes in various centres.

Figure 7: Co-movements in Prices at various centres



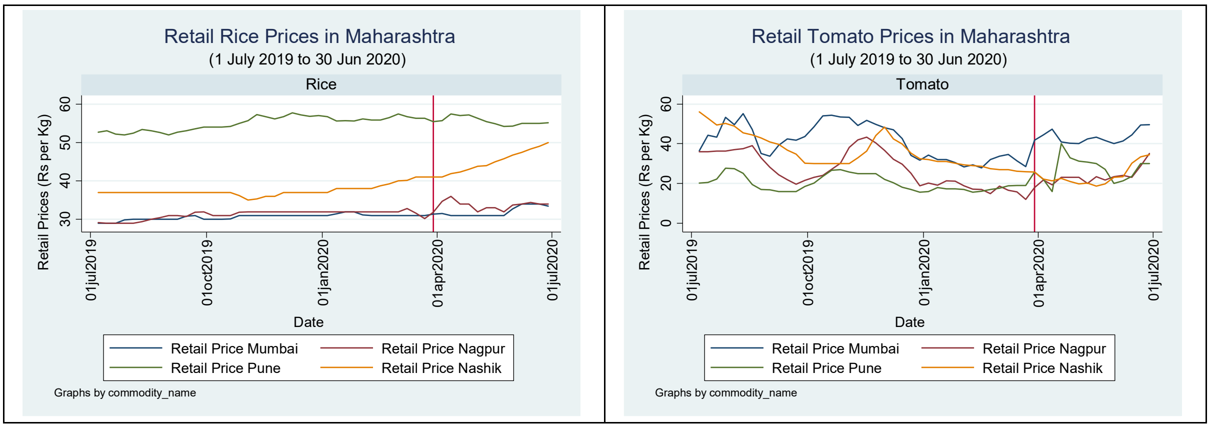


Table 6: Johansen's Co-integration Test for prices at Various Centres

			Wholesale Prices			Retail Prices		
	Rank	5% Critical Value	Log Likelihood	Eigen-value	Trace Statistic	Log Likelihood	Eigen-value	Trace Statistic
ONION	0	47.21	-533.80	.	85.45	-561.07	.	62.89
	1	29.68	-514.13	0.54	46.12	-545.52	0.46	31.79
	2	15.4	-496.98	0.50	11.83*	-535.46	0.33	11.66*
	3	3.76	-491.81	0.19	1.48	-531.63	0.14	4.01
	4		-491.07	0.03		-529.63	0.08	
POTATO	0	47.21	-325.71	.	64.75	-406.16	.	43.27*
	1	29.68	-307.17	0.52	27.68*	-394.96	0.36	20.87
	2	15.4	-298.15	0.30	9.63	-387.87	0.25	6.70
	3	3.76	-294.67	0.13	2.68	-385.12	0.10	1.20
	4		-293.33	0.05		-384.52	0.02	
RICE	0	47.21	-122.32	.	47.44	-150.94	.	50.17
	1	29.68	-108.32	0.43	19.44*	-140.51	0.34	29.32*
	2	15.4	-102.58	0.21	7.96	-131.75	0.30	11.81
	3	3.76	-100.40	0.08	3.62	-126.69	0.18	1.68
	4		-98.60	0.07		-125.85	0.03	
TOMATO	0	47.21	-454.21	.	69.66	-508.81	.	69.05
	1	29.68	-437.05	0.50	35.35	-489.37	0.54	30.17
	2	15.4	-426.77	0.34	14.79*	-481.31	0.28	14.05*
	3	3.76	-421.32	0.20	3.88	-476.55	0.17	4.53
	4		-419.38	0.07		-474.28	0.09	

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 for Wholesale Prices. The predicted co-integrating equations for Wholesale Prices are given in Figure 8.

Table 8 reports the coefficients of the co-integrating equations of Retail Prices. The predicted co-integrating equations for Retail Prices are given in Figure 9.

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

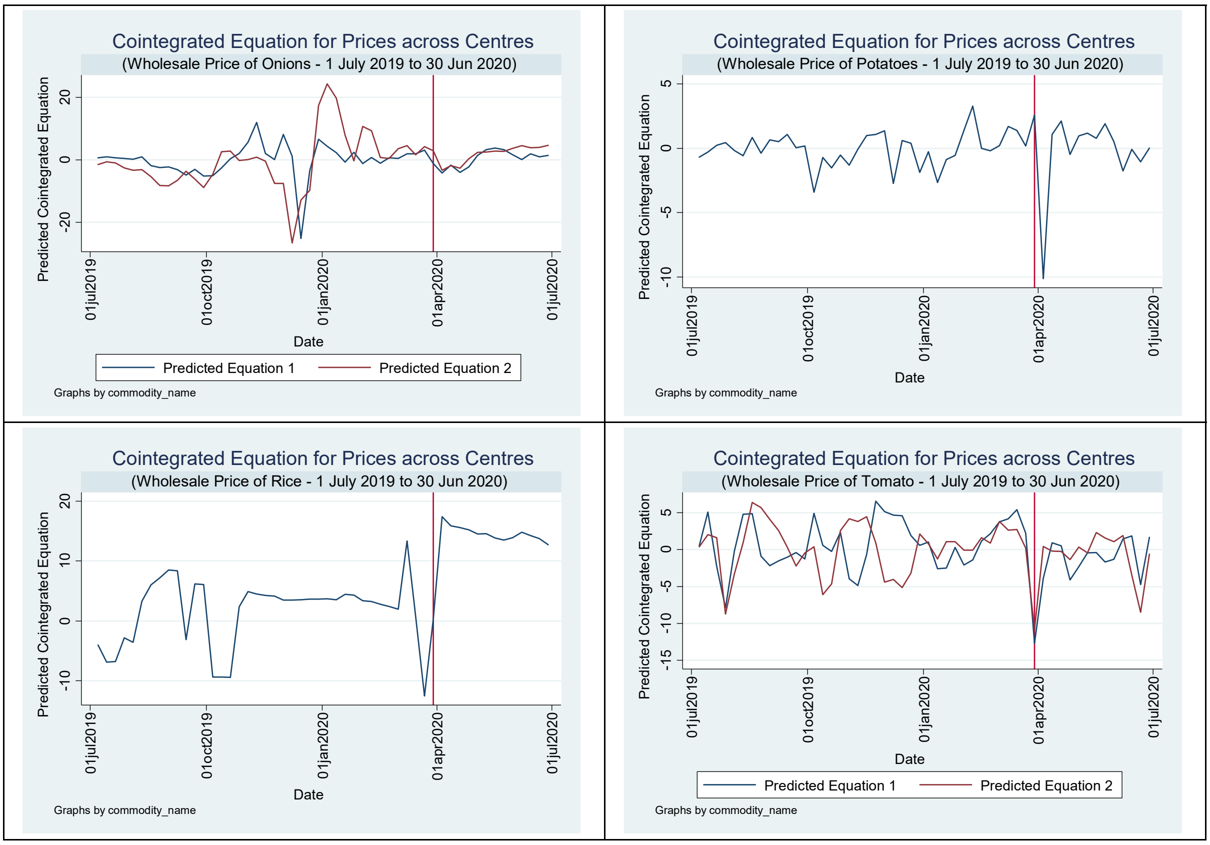
	Wholesale Prices			
	Onion	Potato	Rice	Tomato
No. of Co-integrating Equations	2	1	1	2
No. of Observations	50	50	50	50
Log Likelihood	-496.98	-307.17	-108.32	-426.77
Co-integrating Equation 1				
Chi2	1301.954***	374.65***	33.050***	210.76***
Mumbai	1.00	1.00	1.00	1.00
Nagpur	(omitted)	-0.34**	13.21 ***	(omitted)
Pune	-1.04 ***	-1.34***	-0.17	-1.71***
Nashik	-0.42 **	0.67***	-0.57	-0.04
Constant	2.40	1.03	-343.04	0.20
Co-integrating Equation 2				
Chi2	561.2153***			231.84***
Mumbai	(omitted)			(omitted)
Nagpur	1.00			1.00
Pune	-1.33***			-1.03***
Nashik	0.02			-0.64 ***
Constant	0.96			3.94

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 the four commodities in various centres. Following are key observations:

1. For all the 4 commodities, the Chi^2 value of the co-integrating equation 1 indicates a good model fit. In the case of Onions, the coefficients of co-integrating equation 1 are negative and significant for both Pune and Nashik centres. This implies that wholesale price of onions in these two centres have a *positive* long run relationship with the wholesale price of onions in Mumbai centre.
2. Similarly, the coefficients of Pune-Potato and Pune-Tomato combinations are negative and significant implying presence of a *positive* long run relationship between Wholesale Prices of Potatoes and Tomatoes respectively, in Pune and Mumbai centres.
3. The coefficients of co-integrating equation 1 for Nagpur-Rice and Nashik-Potato combinations are positive and significant, implying presence of a *negative* long run relationship with wholesale prices in Mumbai centre of these commodities. The coefficients of the remaining combinations in co-integrating equation 1 are negative but insignificant.
4. The Chi^2 of the co-integrating equation 2 indicates a good model fit for both Onions and Tomatoes. The coefficients of Pune-Onion, Pune-Tomato and Nashik-Tomato are negative and significant, implying presence of a *positive* long run relationship between Wholesale Prices of these respective centre-commodity combinations with those at the Mumbai centre. However, the coefficient of Nashik-Onion is positive and insignificant.

Figure 8: Predicted Co-integrated Equation for Wholesale Prices across Centres



The graphs of the predicted co-integrated equation for Wholesale prices across centres is plotted and presented in Figure 8. It is interesting to note that in the case of Potatoes, there is a steep fall from the equilibrium witnessed in the predicted values post the announcement of the lockdown.

Table 8: Vector Error Correction Model between prices at various Centres – Retail Prices

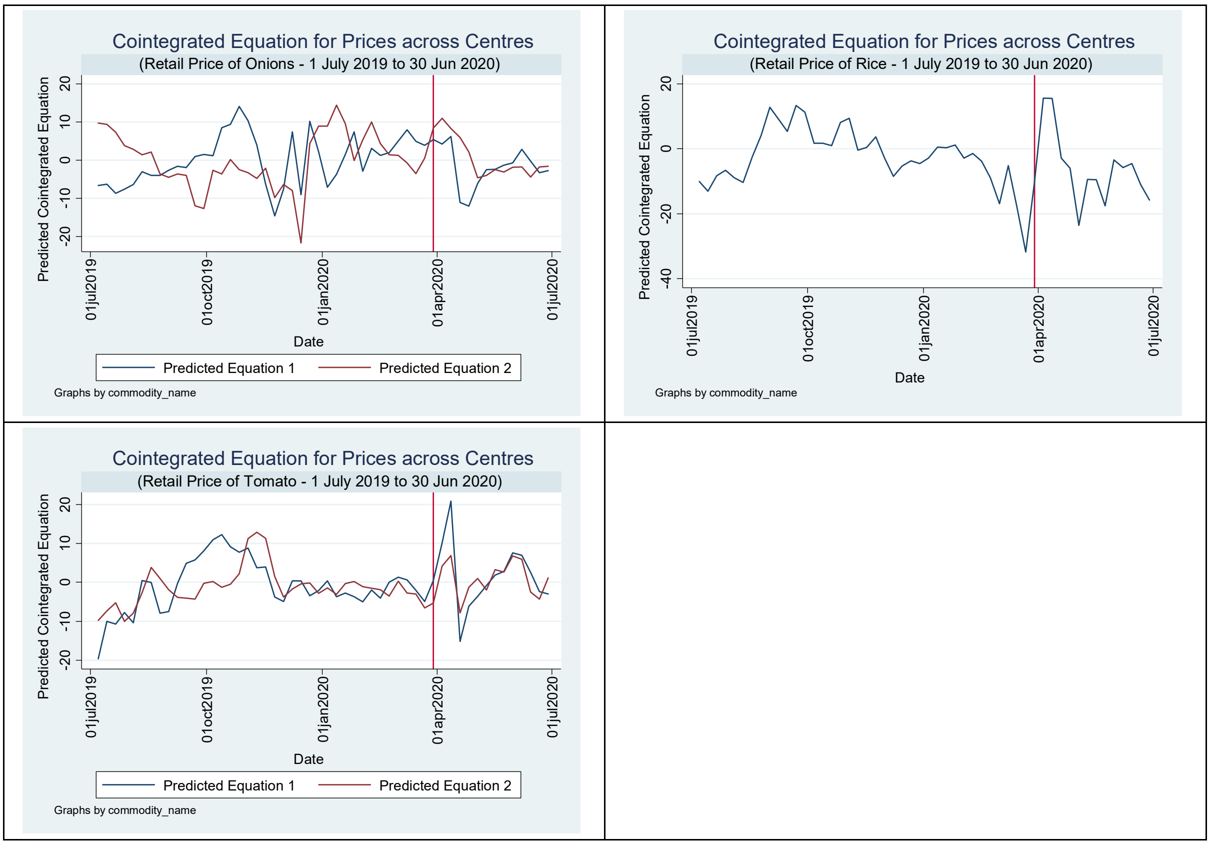
	Retail Prices			
	Onion	Potato	Rice	Tomato
No. of Co-integrating Equations	2	0	1	2
No. of Observations	50		50	50
Log Likelihood	-535.46		-140.51	-481.31
Co-integrating Equation 1				
Chi2	404.82***		23.15***	31.85***
Mumbai	1.00		1.00	1.00
Nagpur	(omitted)		9.65***	(omitted)
Pune	-0.88***		-5.60***	-1.20***
Nashik	-0.36*		-3.33***	-0.71***
Constant	-5.42		98.11	7.91
Co-integrating Equation 2				
Chi2	469.96***			231.00***
Mumbai	(omitted)			(omitted)
Nagpur	1.00			1.00
Pune	-0.05			-0.73***
Nashik	-1.42***			-0.88***
Constant	14.79			18.17

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

Table 8 presents the parameters of the co-integrating Vector Error Correction Model (VECM) for retail prices of three commodities for all the centres. Following are key observations:

1. For all the 3 commodities, the Chi^2 value of the co-integrating equation 1 indicates a good model fit. The coefficients of all three commodities (Onion, Rice and Tomato) in both Pune and Nashik centres are negative and significant. This implies presence of a *positive* long run relationship between Retail prices of these three commodities in Pune and Nashik centres, respectively, with Retail prices of these commodities in Mumbai centre. However, the coefficient of Nagpur-Rice co-integrating equation 1 is positive and significant, suggesting divergence in the long run.
2. The Chi^2 value of the co-integrating equation 2 indicates a good model fit for both Onions and Tomatoes. The coefficients of Pune-Tomato, Nashik-Onion and Nashik-Tomato are negative and significant, implying presence of a *positive* long run relationship between Retail prices of these respective centre-commodity combinations with those in the Mumbai centre. However, the coefficient of Pune-Onion is positive but insignificant.

Figure 9: Predicted Co- integrated Equation for Retail Prices across Centres



The graphs of the predicted co-integrated equation for Wholesale prices across centres are plotted and shown in Figure 9.

We also test for co-integration between prices at different pairs of centres for all the commodities. The results are given in Table 9. The key findings are shown in Table 10.

Table 9: Tests of Co-Integration between Prices at Different Centres (Pair-wise) for all commodities

		Mumbai & Nagpur			Mumbai & Pune			Mumbai & Nashik			Nagpur & Pune			Nagpur & Nashik			Pune & Nashik		
	Rank	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat
WHOLESALE PRICES																			
ONION	0	-294.44	.	33.55	-308.64	.	32.85	-301.24	.	19.07	-284.99	.	32.44	-270.01	.	18.09	-276.28	.	14.60*
	1	-278.60	0.47	1.87*	-292.92	0.47	1.41*	-292.93	0.28	2.45*	-270.11	0.45	2.69*	-262.56	0.26	3.19*	-270.20	0.22	2.44
	2	-277.66	0.04		-292.21	0.03		-291.70	0.05		-268.77	0.05		-260.97	0.06		-268.98	0.05	
POTATO	0	-167.58	.	11.45*	-182.92	.	23.51	-177.38	.	14.57*	-172.87	.	13.64*	-155.19	.	20.58	-183.37	.	22.43
	1	-163.53	0.15	3.35	-172.27	0.35	2.20*	-170.90	0.23	1.63	-168.42	0.16	4.74	-146.14	0.30	2.47*	-173.12	0.34	1.94*
	2	-161.86	0.06		-171.17	0.04		-170.09	0.03		-166.05	0.09		-144.90	0.05		-172.15	0.04	
RICE	0	-47.76	.	13.90*	-75.88	.	8.20*	-54.33	.	18.00	-77.90	.	12.44*	-55.66	.	32.70	-79.65	.	16.80
	1	-43.62	0.15	5.62	-71.81	0.15	0.05	-48.47	0.21	6.29	-72.01	0.21	0.66	-43.14	0.39	7.67	-73.15	0.23	3.78
	2	-40.81	0.11		-71.78	0.00		-45.33	0.12		-71.68	0.01		-39.31	0.14		-71.26	0.07	
TOMATO	0	-241.41	.	18.04	-249.35	.	33.68	-243.10	.	14.60*	-233.14	.	23.12	-215.03	.	16.91	-239.78	.	17.94
	1	-234.50	0.24	4.23	-234.92	0.44	4.82	-238.13	0.18	4.65	-223.45	0.32	3.75*	-208.81	0.22	4.46	-232.81	0.24	3.99
	2	-232.39	0.08		-232.51	0.09		-235.81	0.09		-221.58	0.07		-206.58	0.09		-230.81	0.08	
RETAIL PRICES																			
ONION	0	-292.42	.	13.92*	-315.14	.	18.15	-299.33	.	21.92	-289.36	.	15.27*	-278.86	.	26.38	-290.56	.	13.29*
	1	-287.16	0.19	3.41	-307.22	0.27	2.30*	-290.41	0.30	4.07	-283.41	0.21	3.38	-268.09	0.35	4.85	-286.02	0.17	4.21
	2	-285.46	0.07		-306.06	0.05		-288.38	0.08		-281.72	0.07		-265.67	0.09		-283.92	0.08	
POTATO	0	-186.78	.	12.07*	-234.80	.	9.58*	-180.45	.	8.85*	-236.20	.	21.73	-183.83	.	9.98*	-230.67	.	8.76*
	1	-181.32	0.20	1.14	-230.44	0.16	0.85	-176.19	0.16	0.32	-226.10	0.33	1.52*	-179.72	0.15	1.74	-226.85	0.14	1.12
	2	-180.75	0.02		-230.01	0.02		-176.03	0.01		-225.33	0.03		-178.85	0.03		-226.29	0.02	
RICE	0	-85.20	.	15.86	-72.82	.	7.29*	-54.60	.	24.86	-105.35	.	9.74*	-87.14	.	24.34	-74.46	.	16.24
	1	-79.36	0.21	4.19	-70.71	0.08	3.08	-46.55	0.28	8.74	-102.25	0.12	3.54	-80.11	0.25	10.28	-67.34	0.25	2.00*
	2	-77.27	0.08		-69.17	0.06		-42.17	0.16		-100.48	0.07		-74.97	0.19		-66.34	0.04	
MA	0	-263.46	.	18.63	-285.22	.	12.84*	-255.20	.	13.80*	-264.86	.	13.76*	-236.26	.	22.19	-254.98	.	14.25*

WHOLESALE PRICES																			
		Mumbai & Nagpur			Mumbai & Pune			Mumbai & Nashik			Nagpur & Pune			Nagpur & Nashik			Pune & Nashik		
	Rank	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat	LL	Eigen-value	Trace Stat
	1	-256.55	0.24	4.80	-281.13	0.15	4.66	-250.64	0.17	4.68	-260.23	0.17	4.50	-227.64	0.29	4.94	-250.72	0.16	5.75
	2	-254.15	0.09		-278.80	0.09		-248.30	0.09		-257.98	0.09		-225.17	0.09		-247.85	0.11	

The 5% critical values are 15.41 at Rank 0 and 3.76 at Rank 1

Table 10: Summary – Presence of Co-integration between Prices at various centre-pairs.

WHOLESALE PRICES						
Presence of Co-integration	Mumbai & Nagpur	Mumbai & Pune	Mumbai & Nashik	Nagpur & Pune	Nagpur & Nashik	Pune & Nashik
Onion	YES	YES	YES	YES	YES	NO
Potato	NO	YES	NO	NO	YES	YES
Rice	NO	NO		NO		
Tomato			NO	YES		
RETAIL PRICES						
Onion	NO	YES		NO		NO
Potato	NO	NO	NO	YES	NO	NO
Rice		NO		NO		YES
Tomato		NO	NO	NO		NO

Table 10 summarises the presence of co-integration between prices at various centre-pairs for wholesale and retail prices of four food commodities of the study. In the case of Onions, we note the presence of co-integration between Wholesale prices of all centre-pairs except Pune-Nashik. This implies that wholesale price of onions in Nagpur, Pune and Nashik, respectively, show presence of a long run relationship with that at Mumbai centre. Similarly, wholesale price of onions at Nagpur have a long run relationship with wholesale price of onions at Nashik, Pune and Mumbai.

On the other hand, retail price of onions exhibit presence of co-integration in only one centre-pair, i.e. Mumbai-Pune. Wholesale price of Potatoes in Mumbai and Pune also have a long run relationship while the retail price of Potatoes for the same centre-pair don't. This is also true for Nagpur-Nashik centre pair where wholesale price of potatoes show presence while retail price shows absence of co-integration between prices.

In the case of tomatoes, retail price does not show presence of co-integration at any of the centre-pair. However, wholesale price of tomatoes are co-integrated for Nagpur-Pune centre-pair only. Finally, Rice does not show presence of co-integration between prices at the wholesale price level at either of the centre-pairs, the retail price of Rice is co-integrated for Pune-Nashik.

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 models' 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 11. The results suggest presence of conditional heteroscedasticity in the wholesale and retail prices of onions, and wholesale price of potatoes in Mumbai; retail price of onions, wholesale price of potatoes, and both retail and wholesale price of rice and tomatoes in Nagpur; retail price of onions, wholesale price of potato and tomatoes in Pune; and both wholesale and retail price of onions, rice and tomatoes in Nashik. Thus, barring a few series, prices at most centre-commodity pair exhibit non-constant volatility, and require further examination.

For our study, we take the case of Rice (non-perishable commodity) and Tomato (perishable commodity) in Nagpur where both retail and wholesale prices are found to exhibit conditional heteroscedasticity.

Table 12 shows the parameters for the Autoregressive Conditional Heteroscedasticity Specification for Wholesale and Retail Prices of Rice and Tomato at the Nagpur centre. The last row of the table plots the conditional volatility specification. The ARCH coefficient measures the extent to which the volatility reacts to shocks/ innovation. The coefficient is found to be positive for all the cases (and less than 1) but significant only in case of the retail prices. The magnitude of the coefficient for Retail prices is also larger than that of Wholesale prices, indicating greater sensitivity of retail price volatility to past shocks.

The GARCH coefficient measures the persistence in conditional volatility, which is positive in the case of rice, and insignificant in the case of tomatoes. The sum of ARCH and GARCH coefficients must be equal to one to ensure a mean reverting variance process. In the case of wholesale price of rice, the sum is more than 0.85 indicating a slow mean reversion. In case of retail prices, the sum exceeds one, indicating an explosive series.

From the graphs in the last row, we may conclude that the case of rice suggests a sudden spike in volatility immediately post the announcement of nationwide lockdown on 24th March 2020, with a gradual phasing out of volatility and coming back to the mean levels. Tomatoes, on the other hand, exhibit much instability with volatility continuing to fluctuate in the subsequent lockdown phases, and drift away from the mean levels.

Table 11: LM Test for Autoregressive Conditional Heteroscedasticity

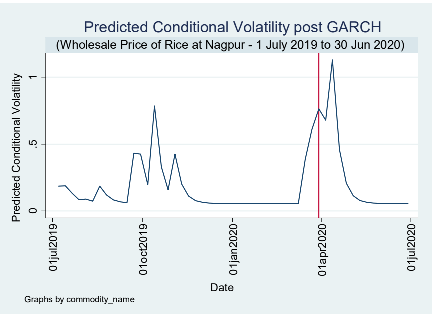
	Mumbai				Nagpur				Pune				Nashik			
	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato	Onion	Potato	Rice	Tomato
D. Wholesale Price chi2	18.147 ***	7.035 ***	2.372	1.188	2.569	6.374 **	4.896 **	6.971 ***	1.290	7.750 ***	0.688	3.071 *	3.956 **	1.166	4.307 **	3.799 *
D. Retail Price chi^2	22.700 ***	0.331	2.145	0.153	4.562 **	0.401	5.152 **	3.237 *	5.908 **	0.391	0.384	0.663	7.400 ***	0.177	3.125 *	4.139 **

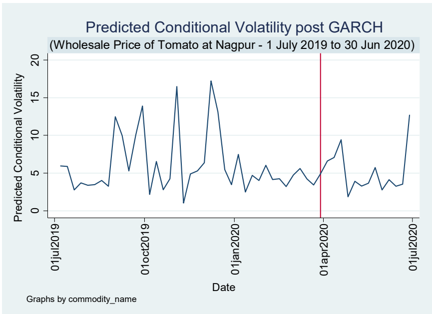
D. refers to the first differencing of the time series to convert a non-stationary series to a stationary one.

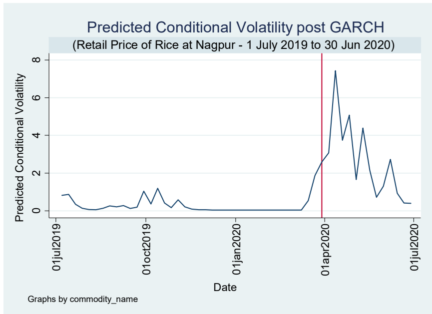
***, **, * indicate significance at 1%, 5% and 10% respectively.

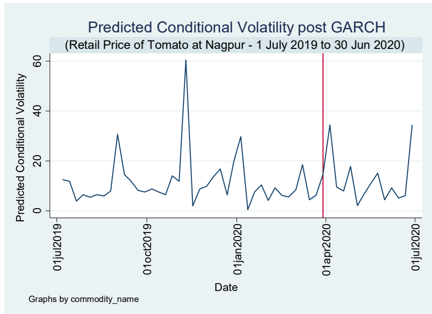
Table 12: GARCH Parameters for Nagpur Centre

	Wholesale Price		Retail Price	
Commodity	Rice	Tomato	Rice	Tomato
No. of Obs	51	51	51	51
ARCH Coefficient (L1)	0.474 (1.36)	0.560 (1.29)	0.873 (2.23) **	0.794 (1.98) **
GARCH Coefficient (L1)	0.374 (1.94) *	-0.305 (-0.91)	0.321 (2.11) **	-0.300 (-1.4)
Constant	0.035 (2.67) ***	4.499 (2.35) **	0.025 (1.31)	7.386 (2.38) **









Concluding Observations

Our analyses make two significant contributions. One is that the period covered is much longer than in most other studies. Since both wholesale and retail food commodities display considerable variation across the lockdowns and subsequent unlock 1, descriptive analyses reviewed here cannot be taken at face value. Indeed, some inferences are simply misleading (for example, resilience of the food system). The second is the use of rigorous time series models. This covers 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. Here we confine our analysis to four centres in Maharashtra – Mumbai, Nagpur, Pune and Nashik. Maharashtra has so far been the hardest hit state by the coronavirus pandemic in India, with its capital city, Mumbai, emerging as the initial epicentre. The food commodities comprise onion, potato, tomato, rice and milk. As milk prices show no variability, these are not included in the time series analysis.

As pointed out by Reardon et al. (2020), of all the food consumed, 92% is purchased. This illustrates the great importance of FSCs for India's food security. Essentially, all the food consumed in urban areas is purchased, since almost all urban households are net buyers of food. And, of the 40% of India's food that is consumed in rural areas, 80% (in value terms) is purchased (while the rest is home-produced on own farms). Hence COVID-19's most important effect will be on national food security via its effects on the FSCs, as 92% of food consumed in India is purchased from FSCs.

Since farms are relatively spread out, the human density driven COVID-19 spread will be less than in the cities. However, the indirect effect of COVID- 19 on farms is likely to be substantial, through several channels. First, Covid- 19's main effect on farmers will be through deficient effective demand from consumers via the constraints on the midstream and downstream of the FSC and because of reduction in consumers' real incomes in the crisis. Second, its effects on the midstream of input supply chains such as fertiliser and seed will hurt farmers.

Another interesting study reviewed here shows a strong relationship between cross-market price markups and (i) distance between the market pairs; (ii) density of transportation infrastructure (average value of road and rail densities, between market pairs); and (iii) urbanization.

A comparison of the distribution of markups across mandis, for each commodity, for two sub-samples—before and after the beginning of 2017—suggests considerable similarity. If market integration had improved, this would have led to a narrower distribution in the more recent period, after the reforms. Hence there is little evidence of increased integration over time.

Few descriptive studies reviewed here, however, make sweeping generalisations that are extraneous to their empirical evidence.

One, for example, does not anticipate a major long-term impact of the lockdown or lower economic growth on Indian agriculture. A normal agricultural growth in 2019-20 and exemption of farm operations during the lockdown period are likely to contribute to better farm income. For marketing of agricultural produce also, special efforts are made to ensure smooth functioning of supply chains of the perishable commodities.

Another study offers a plausible conjecture. In the near term, supply shocks more than counterbalance the collapse of demand leading to increase in food prices. It may well be that food prices will increase first before they go down. Without a verification of the reasons for changing supply-demand imbalances, a definitive inference is difficult.

We shy away from such conjectures as our analysis is constrained by limited data. Instead we confine our analysis to verifiable relationships between co-movements of wholesale and retail prices, the wedges between them, volatility in these prices and market integration between different centres within Maharashtra. Although the patterns are mixed, robust insights are obtained, as summarised below.

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. As milk prices are non- stationary, the co-integration test was applied to the remaining four food commodities in 4 food centres in Maharashtra.

A long- run relationship is observed between wholesale and retail prices of Onion at the Mumbai, Nagpur and Pune Centres, and of Rice at the Nashik centre. Or, in other words, their wholesale and retail prices show co-movements in the long-run at these centres. One reason could be variation in trade margins, for example, among retail suppliers who could charge higher margins in a situation of scarcity. Another possibility is that supply disruptions due to transportation bottlenecks during certain spells could cause spikes in wholesale prices, while consumer prices are held in check by storage by consumers.

In a refinement that allows for short-run adjustment factors and long-run relationships for wholesale and retail prices (i.e. bivariate co-integrating Vector Error Correction Model (VECM)), we obtain further insights. The adjustment factor in the Onion retail prices at both Mumbai and Pune is negative and significant. This implies a convergence in the long run, and the rate of convergence is faster for prices at the Mumbai centre compared to the Pune centre. In the case of Rice prices at Nashik, the adjustment factor for both retail and wholesale prices is positive and significant. This implies instabilities and is likely to be an indication of a structural change. For all the 4 cases on commodity-centre pairs where presence of co-integration between retail and wholesale prices is established (i.e. Onion at the Mumbai, Nagpur and Pune Centres, and of Rice at the Nashik centre), the coefficient of the Wholesale price in the co-integrating equation is negative and significant, implying presence of a *positive* long run relationship between Retail and Wholesale Prices. So both adjustment factors and long-run co-movements differ by food commodity and by centre.

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 another method (i.e. vector autoregression model) to explain co-movements. Our findings are: confirmed dependence of Retail prices of potatoes in Mumbai on the second lag of Wholesale prices, and in Nagpur and Pune on the first lag of wholesale prices. In case of Rice, dependence of Retail prices on Wholesale prices is found in second and third lags in Nagpur. And in case of Tomatoes, dependence of Retail prices on Wholesale prices is found in the first lag in case of Nagpur, and second and third lags in Pune. The dependence of Wholesale prices on Retail prices is found to be significant in case of rice in Mumbai in both the first and second lags, and in case of potatoes in Nagpur in the second lag. In both Retail and Wholesale price equations, the coefficient of the own first lag of the dependent variable is significant and positive. There is thus complex dynamics at play between Retail and Wholesale prices of food commodities that also vary spatially.

A test of integration between different market centres in Maharashtra reveals that barring the retail price of Potatoes, all the price series' (Wholesale and Retail for the various commodities) movements are synchronic across the centres. Thus there is some evidence of market integration for these 4 commodities.

Richer results are obtained through another method (VECM). Wholesale price of Onions in Pune and Nashik centres have a *positive* long run relationship with the Wholesale price of Onions in Mumbai centre. Similarly, the coefficients of Pune-Potato and Pune-Tomato combinations are negative and significant implying presence of a *positive* long run relationship between Wholesale Prices of Potatoes and Tomatoes, respectively, in Pune and Mumbai centres. The coefficients of co-integrating equation for Nagpur-Rice and Nashik-Potato combinations are positive and significant, implying presence of a *negative* long run relationship with wholesale prices in Mumbai centre of these commodities. Hence this additional evidence further corroborates market integration for selected food commodities and pairs of market centres.

Turning to the results for Retail prices across different centres in Maharashtra, using the same method, we obtain another set of rich results on market integration. Selected findings include: retail price of Onions exhibit presence of co-integration in only one centre-pair, i.e. Mumbai-Pune. Wholesale price of Potatoes in Mumbai and Pune also have a long run relationship while the Retail price of Potatoes for the same centre-pair do not. This is also true for Nagpur-Nashik centre pair where Wholesale price of potatoes show presence while Retail price shows absence of co-integration between 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.

Our analysis suggests (based on ARCH model) presence of conditional heteroscedasticity in the wholesale and retail prices of Onions, and wholesale price of Potatoes in Mumbai; retail price of Onions, wholesale price of Potatoes, and both retail and wholesale price of Rice and Tomatoes in Nagpur; retail price of Onions, wholesale price of Potato and Tomatoes in Pune; and both Wholesale and Retail price of Onions, Rice and Tomatoes in Nashik. Thus, barring a few series, price pairs of most centre-commodity exhibit non-constant volatility.

We examine the persistence in conditional volatility, which is positive in the case of Rice. Specifically, in the case of wholesale price of Rice, there is slow mean reversion. Meaningful results are not obtained for Retail prices, as the series appear to be explosive.

While our econometric analyses cover a vast ground, but they do not go far enough. Although we obtain robust results on co-movements of Wholesale and Retail food commodities' prices, the wedge between them, integration between different market centres and non-constant volatility of Wholesale prices of Rice, we are unable to unravel the food price dynamics during the lockdown. There is one major gap that we propose to address in our on-going research –specifically, how Farmgate prices relate to Wholesale prices, and whether the gap between them has widened during the lockdowns. An attempt could then be made to analyse these gaps by farm size. The data are sketchy and do not cover the lockdown period. We also need to understand better the relationship between mandi arrivals and wholesale prices for cereals and vegetables. Finally, we propose to pull these strands together to estimate their impacts on farm and non-farm incomes, food security and poverty.

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