Identification of Nodal Agricultural Markets for Price Monitoring

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Abstract

Effective monitoring of agricultural prices is crucial since large and frequent movements of prices impact producers' income; consumers' access to food and governments' ability to plan exports / imports. Given that there are thousands of agricultural markets in India, the paper tries to identify a set of nodal markets for effective price monitoring for TOP commodities (Tomato, Onion and Potato), based on a systematic econometric analysis. The study uses secondary data on weekly market arrivals and prices of these three perishable commodities from the AGMARKNET database for the period from January 2010 to December 2019. There are a total of 169 tomato markets, 211 onion markets and 180 potato markets for which data is available in the AGMARKNET database. In the first stage based on market arrivals, 32 tomato markets, 25 onion markets and 29 potato markets have been identified as major markets. From this set, in the second stage by using the VAR-GC analysis, nine tomato (MulakalaCheruvu, Patna, Tiphra, Bowenpally, Delhi, Ahmedabad, Chintamani, Solapur, Kolhapur); eight onion (Ahmedabad, Pimplagaon, Lasalgaon, Rahuri, Solapur, Chennai, Agra, Malegaon); and six potato (Jaipur, Jammu, Chennai, Ajmer, Indore, Raipur) markets were identified as the leading/nodal markets. Important peripheral and following markets were also identified. Thus it will be administratively and logistically more feasible if policymakers focus on the nodal and peripheral markets (that have been identified) to understand the market price dynamics of these commodities. This will help in timely decisions on production planning; exports and imports.

Keywords: agricultural prices, food price monitoring, agricultural markets, TOP commodities, lead-lag relationship

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1. Introduction

Large and frequent movements in prices of agricultural products have large implications for producers, consumers and the governments. Such frequent movements impact producers' income; consumers' economic access to food and governments' ability to plan exports / imports. Hence, monitoring of agricultural prices in general and food prices in particular becomes extremely important.

However, when the number of markets is large and the conditions of supply and demand vary greatly, as is the case in a large country like India, this task becomes a lot more difficult. Is it possible to identify a smaller set of markets (called nodal markets hereafter) through a systematic analysis, to aid price monitoring? What is the role of these markets in price leadership? What are the lead-lag relationships among prices in these nodal markets and other markets?

Answers to these questions will help policymakers focus intensively on a small number of markets and effectively monitor prices in these markets, which in turn can help in deciphering the upcoming price trends in all other markets. This will greatly reduce the cost of monitoring and will improve operational efficiency. In the backdrop of the recent developments, particularly with rising food inflation due to supply disruptions because of COVID-19 and Russia-Ukraine war, the issue of market prices received by farmers has assumed renewed significance, as they have major implications for farmers' purchasing power. The present study hopes to contribute to this discourse.

Market price integrates the information held by millions of economic agents and therefore, is a crucial source of information to policymakers. Furthermore, it is possible to observe and record prices at frequent intervals, almost on a continual basis, as opposed to either production or market arrivals. This makes price an extremely important tool to assess the state of the markets in the short-run. Although there are a few situations when markets may not work perfectly, prices nonetheless continue to be extremely valuable sources of information about the market conditions and the expectations of economic agents.

Given the large variety of commodities consumed in India and the large number of markets, it is important to focus on few important commodities. In the present analysis, we confine to three perishable commodities – tomato, onion and potato, hereafter TOP commodities - which experienced frequent price fluctuations in the past and continue to experience almost every alternate year.

After a brief introduction in this section, a survey of the relevant literature is presented in Section 2. The objectives of the study and a description of the data sources and methodology is presented in Section 3 and 4 respectively. This is followed by an overview of the TOP commodities in Section 5. The main results of the analysis are presented and analyzed in Section 6. Section 7 concludes with a summary and policy implications.

2. Review of literature

Volatility in agricultural commodity prices has a significant impact on the income of the producers/farmers, purchasing power of the consumer and is a key concern for policy makers as well (FAO-OECD 2011). Thus, frequent and unpredictable movement in agricultural prices have wide-reaching welfare and policy implications for an economy. Among the agricultural commodities, a major share of household income is allocated to food, mostly in developing countries.[4] Given the increasing food price volatility and its consequent adverse effect on food security among the vulnerable population, food price monitoring on a continuous basis assumes significance. One way to monitor food prices is through the use of information on prices to identify markets that play a leading role in influencing prices at the national and regional level (Araujo et al. 2012). It has been argued that monitoring of price movements at leading markets can help in forecasting future price crisis (ibid).

In the existing literature on agricultural markets, the issue of lead-lag relationship has been explored particularly with respect to future and spot prices of agricultural commodities (Garcia et al.1986; Pradhan et al. 2021 among others); market integration between oil and commodity prices (Tiwari et al. 2018). With a few exceptions, majority of these studies are concentrated in developed countries. The most common empirical methodology used for analyzing the lead-lag relationship is Granger causality. While assessing and analyzing changes in future and spot prices as well as oil and commodity prices are important, an understanding of domestic price movements and identifying the leading markets for monitoring of food prices is also necessary for reducing uncertainties.

[4] https://www.weforum.org/agenda/2016/12/this-map-shows-how-much-each-country-spends-on-food/ (accessed on 11th February, 2022)

It needs to be noted that with a few exceptions, studies identifying the lead-lag relationship of a particular agricultural commodity across different markets and that too for the purpose of food price monitoring are sparse. These exceptions include studies such as by Miller (1980); Spriggs et al. (1982); Bessler and Brandt (1982); Ziemer and Collins (1984); Araujo et al. (2012); FAO (2017). Miller (1980) and Spriggs et al. (1982) had analyzed the lead-lag relationship in livestock and crops prices respectively; and Bessler and Brandt (1982) for livestock prices and other causal variables; while Ziemer and Collins (1984) for both crops and livestock prices; but not particularly with the purpose of food price monitoring. Though the context and objective of these studies vary, nevertheless, important insights could be drawn from these studies on the method of analysis used. Whereas the study by Araujo et al. (2012) and FAO (2017) explicitly deals with identifying lead-lag relationship for food price monitoring which directly concerns the objectives of the present study.

To elaborate, Miller (1980) had explored the lead-lag relationships among the weekly changes in retail, wholesale and farm level prices of a livestock commodity, pork. The study used univariate residual cross-correlation analysis. It is a method based on the concept due to Granger i.e., "a time-ordered variable X is said to lead another time-ordered variable Y if Y may be better predicted with the use of the history of X than without" (Miller 1980: 73). They find that pork prices at farm level lead wholesale prices by up to 2-3 weeks and in turn, wholesale prices lead retail prices by up to 2-3 weeks. Bessler and Brandt (1982) also examined the lead-lag relationships of several variables in the cattle and hog markets. The study tests the exogeneity of cattle on feed, cattle slaughter and income on live cattle prices and the exogeniety of sow farrowings, hog slaughter and income on live hog prices. Using Granger causality tests, the study finds strongest evidence on leads and lags from sow farrowing to hog prices and from cattle price to cattle on feed.

Besides, livestock, lead-lag relationships have also been explored for agricultural crops. Spriggs et al. (1982) analyzed the lead-lag relationship between Canadian and U.S. wheat prices. The study employed granger causality as a way of detecting the existence of price leadership between wheat prices in the two countries. The analysis was based on daily prices of wheat in Canada and U.S. during the period 1963/64 to 1978/79. It showed that over 1974/75 and 1975/76, wheat prices in U.S. led the wheat prices in Canada. Prior to 1972/73, no significant price relationship was found. They further highlight the relevance of applying Granger causality as a means for detecting price leadership. However, they note that the evidence of anomalous negative cross-correlation in 1977-78 shows that the method is not infallible. They also point out that “if the method indicates only instantaneous causality, this does not rule out the possibility of price leadership in which the maximum lag is less than one day” (Spriggs et al. 1982: 571).

Hence, with respect to the application of Granger causality on both crop and livestock prices in U.S, study by Ziemer and Collins (1984) have argued that while using the concept of Granger causality, one need to be cautious of inferring correlation as causality and the test has to be used in conjunction with economic theory. As Araujo et al. (2012: 1884) has rightly stated that “Granger causality test does not by itself indicate causality, but identifies precedence between two variables and measures the information context of lagged variables.” Thus, considering these caveats, the test could be used to identify the leading markets i.e., the markets that Granger cause a large number of other markets, but are themselves Granger caused by only a few markets (Araujo et al. 2012). The prices prevalent in those leading markets can be helpful in forecasting of prices in other markets in future (ibid).

The study by Araujo et al. (2012) identifies the leading markets for millet in countries such as Mali, Burkina Faso and Niger, using Granger causality tests conducted in a multivariate vector autoregressive (VAR) framework. Along with it, they have also undertaken a detailed analysis of warning indicators for explaining the scope and intensity of future price crises using panel data qualitative choice models. The warning indicators are based on the deviation of the prices from their trend values. Their analysis shows the possibility of anticipating crises from the observation of past price movements. Their findings indicate that monitoring all the markets during the harvest period does not add significant extra information rather monitoring select leading markets during crucial periods of the year can help in forecasting future price crises.

The only and the most recent study pertaining to India on identification of leading markets for agricultural crops for effective price monitoring is that by FAO (2017). Using VAR and Granger causality, the study analyses the markets for crops such as wheat, paddy, arhar, soybeans and maize. Instead of using only price data as was done by earlier studies, the study uses market arrivals and price data for identifying the leading/nodal markets for the selected crops.

Drawing from the existing studies, the present study tries to analyze the lead-lag relationships in agricultural prices for the purpose of identifying nodal markets that would further aid in food price monitoring. Analysis would be undertaken for perishables such as tomato, onion and potato which have not been considered in earlier studies such as by FAO (2017). Data on market arrivals along with data on wholesale prices of these agricultural commodities would be used for the analysis. Granger causality test in a multivariate VAR framework would be applied for identifying price leadership in a particular market.

3. Objectives of the study

Price monitoring involves three important steps –identifying the nodal markets for each of the commodities, quantifying the relationships between prices in the nodal markets and other markets and, identifying price bands for generating a price alert. The present exercise is confined to the first two steps.

The specific objectives of the study are

i) Identifying the nodal markets for each of the commodities.

ii) Quantifying the relationships between prices in the nodal markets and other markets.

4. Data sources and methodology

4.1 Data sources

We have used the AGMARKNET database of the Directorate of Marketing & Inspection (DMI), Ministry of Agriculture and Farmers Welfare, Government of India. This database provides an online platform (www.agmarnet.nic.in) for collection and dissemination of detailed information on daily market arrivals and wholesale prices. The basic source for this database is the Agricultural Produce Market Committees (APMC) in various states. In states where APMCs are not functional, prices from the wholesale markets are reported. We have used the data on daily market arrivals and modal wholesale prices.

Our geographical coverage is All-India. We have collected daily data from the first week of January 2005 to the last week of December 2019. However, since there were long data gaps during the early years in many of the markets, we have finally used data for the period beginning from the 1st week of 2010 to the last week of 2019. In case of tomato, this period is even shorter, from 1st week of 2016 to the last week of 2019 because of long gaps in the data for many markets. Our terminal year of analysis is 2019. After 2019, particularly after the nationwide lockdown in March 2020 due to outbreak of Covid-19, there are long gaps in the reportage of data in several markets.

4.2 Methodology

The methodology is presented in Figure 1. The following two-stage procedure has been adopted in the selection of major markets

Stage 1: Identification of initial set of markets based on market arrivals during the last ten years, i.e. from 2010 to 2019

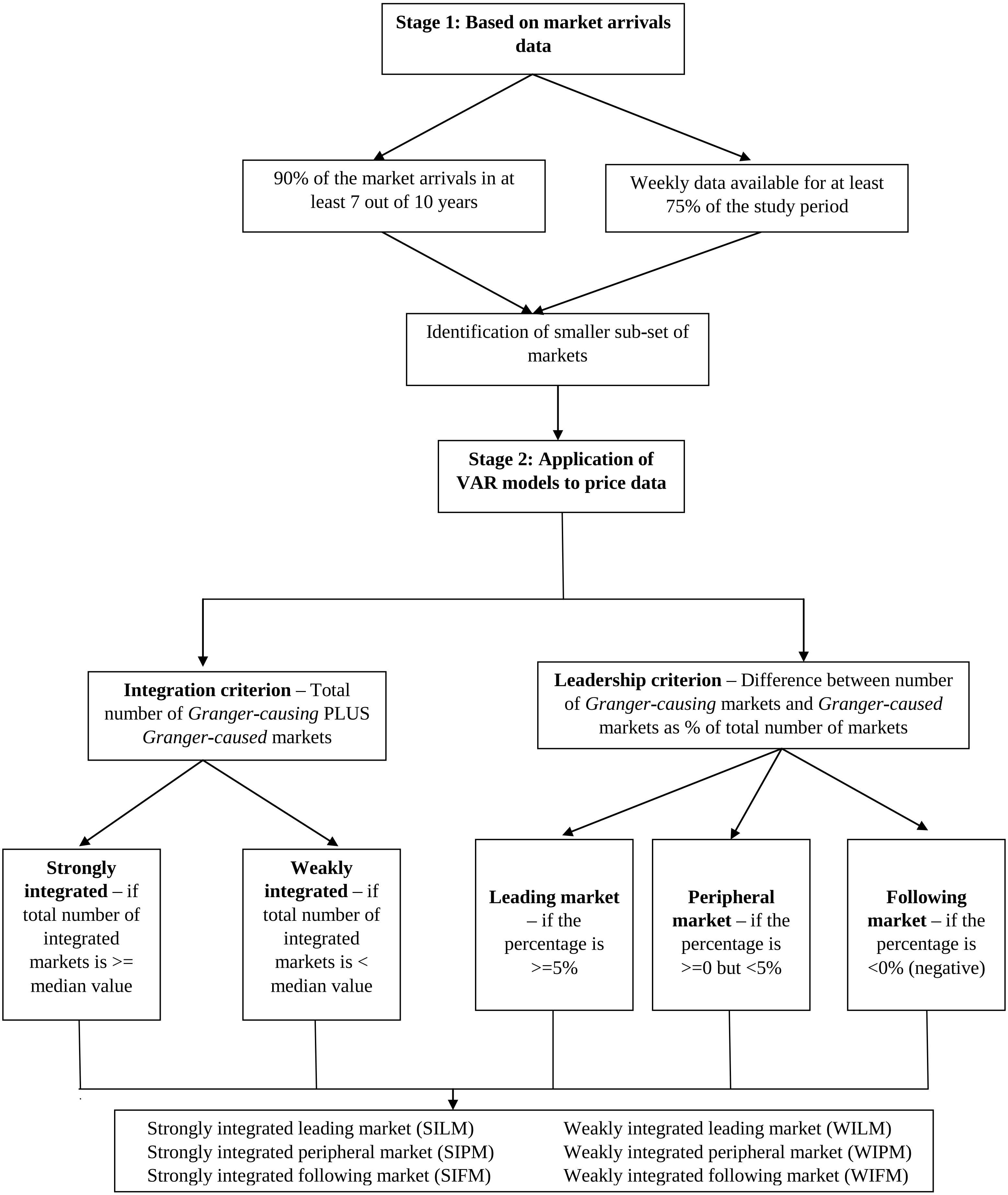
We have adopted two major criteria for initial selection of markets

1) Markets are first arranged in descending order of annual market arrivals. The markets contributing 90% of the total market arrivals in seven or more years during the period of analysis (2010 to 2019 including both the years) are shortlisted. In case of tomato, this criterion becomes 3 out of 4 years from 2016 to 2019, since the data for tomato has a large number of breaks before 2016 and has become available on a consistent basis only after 2016.

2) The second criterion used is the availability of continuous data on weekly arrivals in a market for at least 75% of the study period. There are in all 505 weeks during the period of analysis. All the onion markets, for which the weekly arrival data is available for at least 400 out of a total of 505 weeks (79%), are shortlisted. The market arrivals data of potato is better with fewer breaks. Hence, all the markets for which data is available for 450 weeks or more have been shortlisted (89%). Data for tomato is consistently available only from 2016. Therefore we have shortlisted only those markets for which the data is available for at least 75% of the total 209 weeks, which is 157 weeks.

3) Finally, combining both these criteria, all the markets that contribute 90% of the market arrivals (criterion 1) and which possess market arrival data for at least 75% of the study period (criterion 2) have been selected.

Figure 1: Methodology: A schematic diagram



Stage 2: Identification of the nodal markets based on prices through vector auto regression (VAR) and Granger-causality methods.

From the set of markets identified in Stage 1, a smaller set of important nodal markets is identified using the methodology of VAR and Granger-causality (GC), through the use of high-frequency weekly data on prices (see Araujo et al. 2012, Wilson 2001, Sekhar 2012, FAO 2017). VAR and GC methods have gained wide acceptability in literature. Since the main objective of the study is to identify the major markets for the purpose of price monitoring, the relationship among prices in the set of markets identified in stage 1 is explored further to identify the core/nodal markets. The VAR in prices is estimated in three specifications – i) using only prices (with no controls); ii) using prices along with total market arrivals as a control variable; iii) prices along with arrivals in major markets as a control variable

The broad analytical framework of model is as follows.

$\Delta p_t = \gamma\alpha' p_{t-1} + \sum_{i=1}^{\infty}\Gamma_i \Delta p_{t-i} + X_t + \varepsilon_t$ where p_t is a set of prices in n markets, Δ is the first difference of prices. α is the set of coefficients of long-term relationship between prices (or cointegrating relationship), γ is the speed of adjustment (of this long-run relationship), Γ_i is the set of coefficients of short-run price adjustments, X is the set of other variables influencing price movements and ε is the error term. The markets showing a significant long-run relationship with other markets (cointegration) and also significantly influencing prices in other markets in the short-run (error-correction) can be identified through this VECM framework. If the variables (here prices) are non-stationary but there's no cointegration among them, then a simple VAR in first differences is used. If the variables are stationary, then a VAR in levels is used.

(a) VAR model

The VAR model takes into account the fact that prices are determined simultaneously in a number of markets. VAR incorporates the dynamic nature of price adjustments. Each price is treated as endogenous and is expressed as a function of the lagged values of all of the prices in all the other markets.

The estimated VAR model is of the following form

$p_{it} = \sum_{i=1}^{k}\sum_{j=1}^{p} A_{ij} p_{i,t-j} + \sum_{i=1}^{k} x_{it} + \varepsilon_{it}$; i=1,….,k; j=1….p, t = 1, . . ., T.

where p_{it} is the price in market i in time t. A_{ij} is a matrix of coefficients to be estimated x_{it} is the vector of other covariates (market arrivals in this study) and ε_{it} is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables.

E(ε_{it}) = 0; $E(\varepsilon_{it}\varepsilon_{it^{'}}) = \Sigma$ (a positive semi definite matrix) for all $t = t^{'}$ and $E(\varepsilon_{it}\varepsilon_{it^{'}}) = 0$ for all $t \neq t^{'}$. The lag order p is selected using the Schwarz information criterion.

All the prices are first tested for non-stationarity by including time trend wherever appropriate. Plots of the price series are used to identify the possible presence of time trend in the series. Non-stationarity is tested assuming individual unit root processes (Im, Pesaran and Shin W-stat; ADF-Fisher Chi-square ; and PP–Fisher Chi-square). If the prices are stationary, a simple VAR in levels is estimated. In case the prices are found to be non-stationary, then these prices are tested for the existence of a cointegrating relationship. **In the present study, all the prices have been found to be stationary / trend-stationary**. After estimating the VAR in levels, lag length tests were used to identify the optimum lag length. Granger-causality and Block-Exogeneity tests are then used to identify the nodal markets for each commodity.

(b) The Granger causality test (GC)

The GC test helps in identifying a statistically significant relationship, if any, between current prices in market i and lagged prices in market j. For example, under the null hypothesis that p_2 (price in market 2) does not Granger cause p_1 (price in market 1), the coefficients of the lagged prices of market 2 in p_1 price equation are statistically insignificant and are close to zero. However, it needs to be noted that the GC test does not reveal the true causal relationship between prices. It only indicates whether movements in one set of prices *consistently precede* the movements in the other set. In other words, p_1 is said to be Granger caused by p_2 if lagged values of p_2 are significant and help in predicting p_1 and vice versa. Thus, this test identifies the precedence of prices in some market(s) over others. This test can therefore is useful in forecasting, to identify the markets whose prices can help in forecasting prices in other markets. *The test does not imply causation*.

The GC tests in the study are performed using a VAR model for all the markets (of a commodity) identified in stage 1. The markets that Granger cause a large number of other markets, but are themselves Granger caused by only a few markets are considered as the leading/nodal markets. In other words, lagged prices in the leading/nodal markets play a significant role in influencing current prices in other markets (and can help to predict the latter). In addition, prices in the leading/nodal markets do not depend on the lagged prices in other markets (i.e., they are weakly exogenous).

5. TOP Commodities: A Brief Overview

This section provides a general overview of the TOP commodities. It basically provides a brief discussion of the relative position of TOP in the world and in India thereby highlighting the importance of these vegetables. Thereafter it examines the recent trends in variables such as cropping season and season-wise share in total production; area, production, yield; and market (international and domestic). Data collated from various secondary sources, namely, Agricultural and Processed Food Products Export Development Authority (APEDA); Horticulture Statistics at a glance 2018; Monthly report on onion, potato and tomato, March 2020, Horticulture Statistics Division; National Agricultural Cooperative Marketing Federation of India (NAFED), are used for the purpose. It needs to be noted that the period of analysis varies for the variables considered based on the availability of recent data.

5.1. Position of TOP in the world and in India

The importance of TOP vegetables could be discerned from the relative position it occupies in the world and within India. India is the second largest producer of these three vegetables, after China. India's share in world production stood at 11 percent, 20 percent and 13 percent in case of tomato, onion and potato respectively (Table 1).

Among vegetables, in 2019-20, TOP accounted for 42 percent of the total area under vegetables and 51 percent of total vegetables production[5], thereby being the most cultivated and produced vegetables in India. Furthermore, priority accorded to these three vegetables is evident in terms

[5] Calculated from 2020-21 (Second advance estimates) Area and production of horticulture crops, Horticulture Statistics Division, DAC&FW.

of launching of Operation Greens in 2018-19 by the government of India for integrated development of TOP value chain.[6]

Table 1: India's share in world production of TOP

Countries	% share in world production		
	tomato	onion	potato
	2011*	2011*	2017#
China	28	27	26
India	11	20	13
Total World	100	100	100

Source: * obtained from http://apeda.in/agriexchange/Market%20Profile/one/ONION.aspx # calculated from https://www.potatopro.com/world/potato-statistics

5.2. Cropping season and season-wise share in total production

All the three vegetables are grown in both Kharif and Rabi season, however, rabi season contributed to a major share of total production ranging from around 68 to 98 percent in 2018-19 as well as 2019-20 (Table 2). The harvesting period indicates the availability of TOP vegetables almost throughout the year barring a few months particularly in case of potato. However, it is important to note that given the perishable nature of the commodity and the lack of adequate storage and logistics infrastructure, availability of these vegetables and their prices would be affected by it.

Table 2: Cropping seasons, transplanting and harvesting period and production (Agriculture year: July-June)

Vegetables	season	transplanting	harvesting	Production (lakh tonnes)	
				2018-19 (final)	2019-20 (expected)
Tomato	Kharif	May-July	July-November	59.16 (32)	58.87 (31)
	Rabi	October-February	December-June	127.57 (68)	131.83 (69)
	Total			186.73 (100)	191.70 (100)
Onion	Kharif	July-August	October-December	48.41 (21)	39 (16)
	Late Kharif	October-November	January-March	21.5 (9)	15.74 (6)
	Rabi	December-January	End of March to May	158.28 (69)	196.72 (78)
	Total			228.19 (100)	251.46 (100)
		sowing	harvesting		
Potato	Kharif	May-July	September-November	10.16 (2)	8.45 (2)
	Rabi	End-September to November	December-March	491.74 (98)	504.35 (98)
	Total			501.90 (100)	512.80 (100)

Source: calculated from Monthly reports on onion, potato and tomato, March 2020; https://agricoop.nic.in/en/horticulture-reports?page=1

Please note that the figures in parenthesis shows season-wise share in total production.

[6] https://www.mofpi.gov.in/Schemes/operation-greens

5.3. Trends in area, production and yield

Tomato

In case of tomato, the recent trends (2017-18 to 2021-22) in area and production showed a positive but a meager CAGR of 1 percent and 0.5 percent respectively whereas yield showed a decline of -0.5 percent (Table 3).

Table 3: Area, production and yield of tomato

Year	Area ('000Ha)	Production ('000 MT)	yield (MT/Ha)
2017-18	789	19759	25
2018-19	781	19007	24.3
2019-20	818	20550	25.1
2020-21	845	21181	25.1
2021-22 (1st advance estimate)	831	20300	24.4
CAGR (%)	1.0	0.5	-0.5

Source: calculated from Horticulture Statistics at a glance 2018 and 2020-21 (Second advance estimates) Area and production of horticulture crops, Horticulture Statistics Division; https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202232832101.pdf

Onion

The recent trends in area, production and yield of onion indicate that while area and production have registered a positive CAGR of 8.3 percent and 6.0 percent respectively, its yield witnessed a sharp decline of -2.6 percent (Table 4).

Table 4: Area, production and yield of onion

Year	Area ('000Ha)	Production ('000 MT)	yield (MT/Ha)
2017-18	1285	23262	18.1
2018-19	1220	22819	18.7
2019-20	1431	26091	18.2
2020-21	1624	26641	16.4
2021-22 (1st advance estimate)	1914	31129	16.3
CAGR (%)	8.3	6.0	-2.6

Source: calculated from Horticulture Statistics at a glance 2018 and 2020-21 (Second advance estimates) Area and production of horticulture crops, Horticulture Statistics Division; https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202232832101.pdf

Potato

For potato, area, production and yield grew marginally at the rate of 0.6 percent, 0.9 percent and 0.2 percent respectively (Table 5).

Table 5: Area, production and yield of potato

Year	Area ('000Ha)	Production ('000 MT)	yield (MT/Ha)
2017-18	2142	51310	24
2018-19	2173	50190	23.1
2019-20	2051	48562	23.7

2020-21	2203	56173	25.5
2021-22 (1st advance estimate)	2208	53603	24.3
CAGR (%)	0.6	0.9	0.2

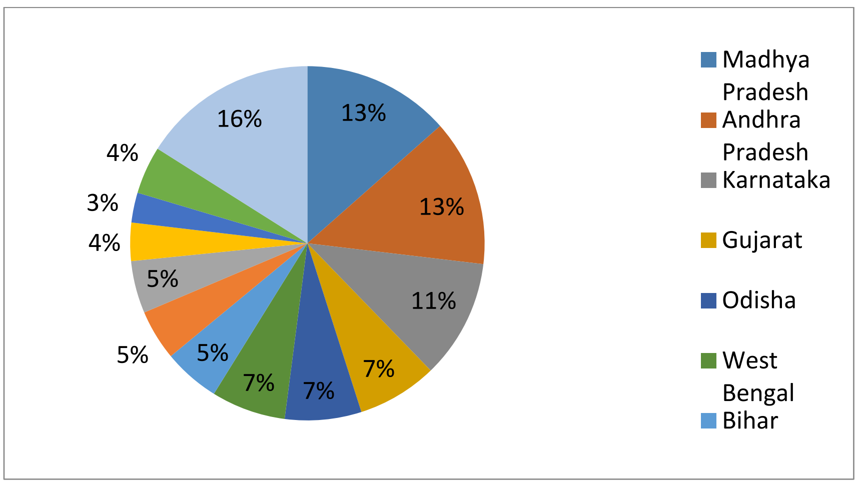
Source: calculated from Horticulture Statistics at a glance 2018 and 2020-21 (Second advance estimates) Area and production of horticulture crops, Horticulture Statistics Division; https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202232832101.pdf

Thus, in case of all the three vegetables, yield did not show a commensurate increase to area and production rather it registered a negative growth rate particularly for tomato and onion. Hence increase in production mainly seems to be emanating from area expansion and not from an improvement in yield.

5.4. Major producing states of TOP

Madhya Pradesh and Andhra Pradesh ranked as the major producers of tomato with a share of around 13 percent each in all India production (Figure 2). They are followed by states such as Karnataka (11 percent), Gujarat (7 percent), Odisha (7 percent) and Bihar (7 percent).

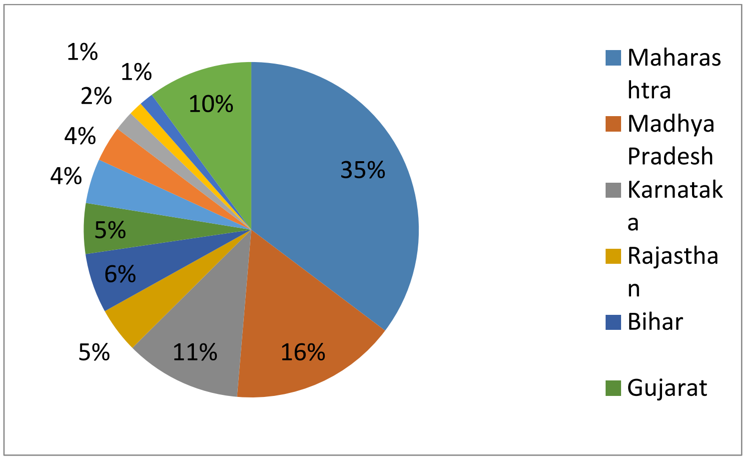
Figure 2: Major tomato producing states (2018-19)



Source: Monthly report on Onion, Potato and Tomato (March, 2020), Horticulture Statistics Division, MA&FW

In case of onion, a lion's share of production is contributed by Maharashtra (35 percent) followed by Madhya Pradesh (16 percent) and Karnataka (11 percent) (Figure 3).

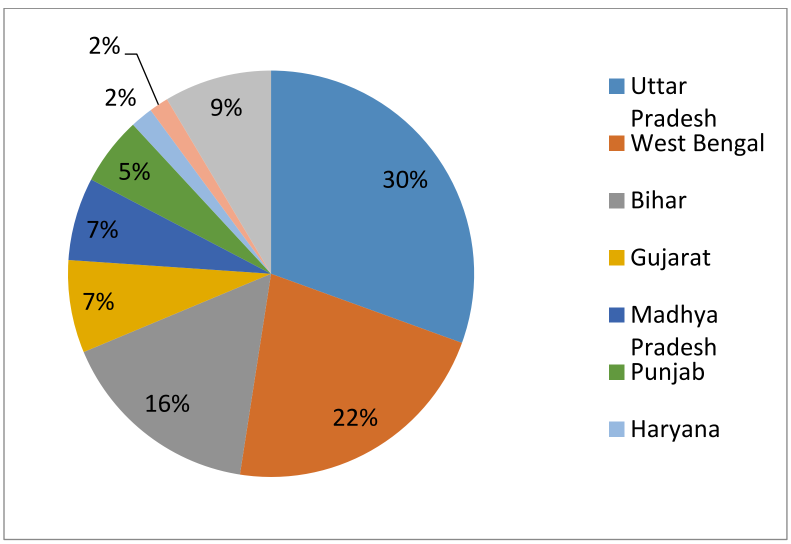
Figure 3: Major onion producing states (2018-19)



Source: Monthly report on Onion, Potato and Tomato (March, 2020), Horticulture Statistics Division, MA&FW

The major potato producing states are Uttar Pradesh, West Bengal and Bihar with a share of 30 percent, 22 percent and 16 percent respectively (Figure 4).

Figure 5: Major potato producing states (2018-19)



Source: Monthly report on Onion, Potato and Tomato (March, 2020), Horticulture Statistics Division, MA&FW

After getting an understanding of the production pattern of TOP, the next section examines the trends in both the international and domestic market for the produce.

5.5. International market

Of all the three vegetables, onions are the most traded with around 9.57 percent of production being exported in 2018-19 (Table 6). Though there was a fall in the share of onion exports to 4.4

percent in 2019-20 which could be on account of ban on exports for ensuring domestic availability, nevertheless it is relatively higher than the less than 1 percent share in case of tomato and potato. In 2020-21, the share of onion exports increased to 5.92 percent.

Table 6: Share of exports in total production (%)

	2018-19				2019-20				2020-21			
	value (Rs cr)	quantity exported (000 MT)	quantity produced (000 MT)	exports as % of prod	value (Rs cr)	quantity exported (000 MT)	quantity produced (000 MT)	exports as % of prod	value (Rs cr)	quantity exported (000 MT)	quantity produced (000 MT)	exports as % of prod
Tomato	261.79	99.80	19007	0.53	222.6	93.62	20550	0.46	242.86	88.45	21181	0.42
Onion	3467.31	2182.94	22819	9.57	2319	1149.05	26091	4.40	2821.99	1575.92	26641	5.92
Potato	440.79	367.39	50190	0.73	580.1	427.08	48562	0.88	549.45	323.69	56137	0.58

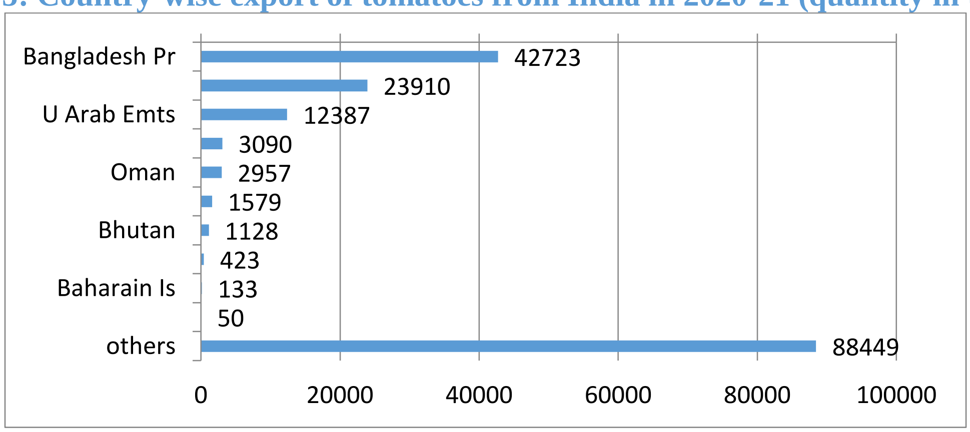
Source: computed from DGCI&S

5.5.1. Trends in exports

Tomato

In 2020-21, in terms of quantity exported, Bangladesh (42723 tonnes) followed by Nepal (23910 tonnes) and UAE (12387 tonnes) were the major export destinations of tomatoes from India (Figure 5). These three countries accounted for around 45 percent of the quantity of tomatoes exported from India.

Figure 5: Country-wise export of tomatoes from India in 2020-21 (quantity in tonnes)

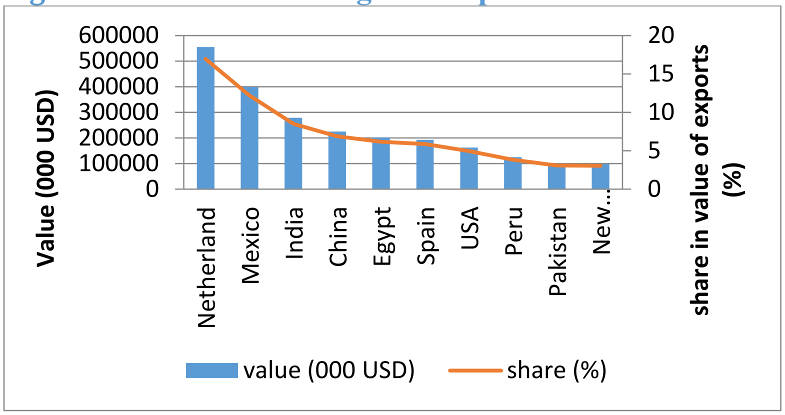


Source: DGCI&S

Onion

Among the top ten countries exporting onions, in 2020, India occupied third position in terms of value of exports (USD 277.87 million) with a share of 8.5 percent in global exports value (Figure 6). India exported around 789.37 thousand MT of onions during the period.

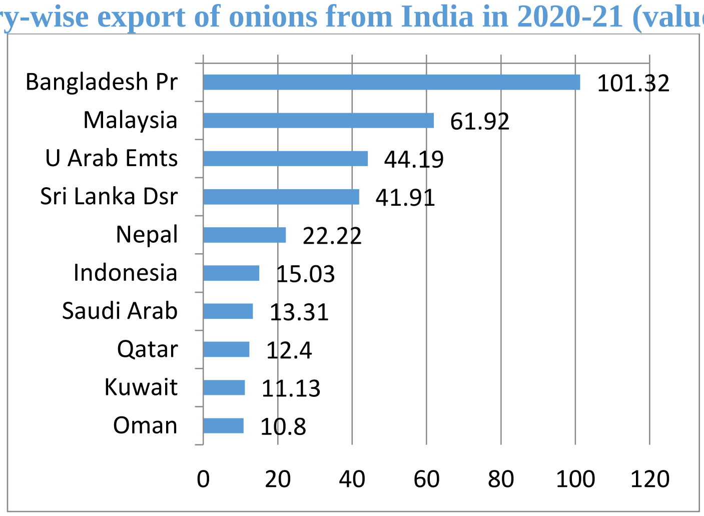
Figure 6: India's share in global exports of onions in 2020



Source: UNCOMTRADE data as provided in
https://agriexchange.apeda.gov.in/product_profile/india_standing.aspx?categorycode=0201

In 2020-21, among the top 10 countries where onions were exported from India, Bangladesh (USD 101.32 million) was the major export destination followed by Malaysia (USD 61.92 million) and UAE (USD 44.19 million) (Figure 7).

Figure 7: Country-wise export of onions from India in 2020-21 (value in USD million)

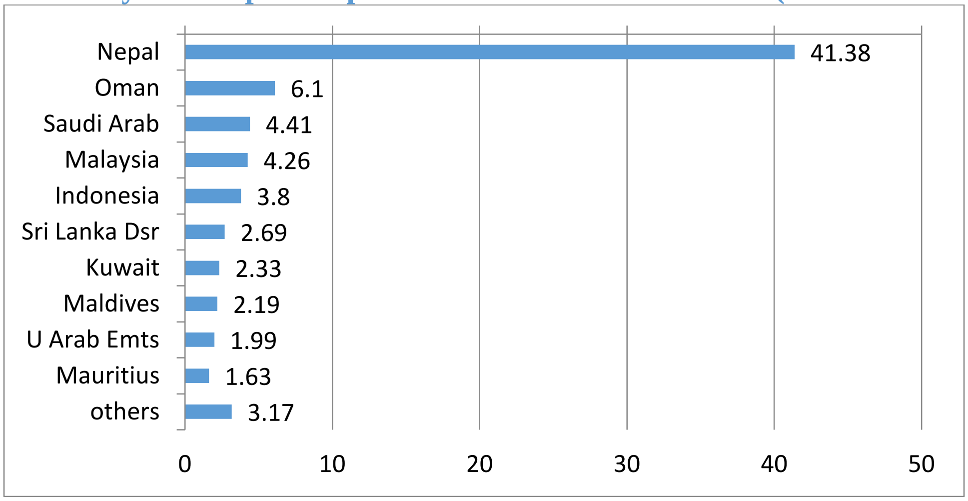


Source: DGCI&S as provided in
https://agriexchange.apeda.gov.in/indexp/Product_description_32headChart.aspx?gcode=0201

Potato

Potato from India is mainly exported to Nepal accounting for around 56 percent of the total exported value in 2020-21 (Figure 8). This was followed by other export destinations such as Oman (USD 6.1 million), Saudi Arab (USD 4.4 million) and Malaysia (USD 4.26 million).

Figure 8: Country-wise export of potatoes from India in 2020-21 (value in USD million)



Source: DGCI&S as provided in https://agriexchange.apeda.gov.in/indexp/Product_description.aspx?hscode=07019000

5.6. Domestic market

Besides being an export oriented vegetable, domestic market is also important for onion. So is the case for tomato and potato whose presence in the export market is meager as was evident in the earlier section.

Tomato

Considering the domestic market**,** the major tomato consuming states are Delhi, Maharashtra, Gujarat, Madhya Pradesh, West Bengal, Uttar Pradesh and Karnataka (Table 7). Based on market arrival of tomatoes, Delhi occupied the first position as the main tomato consuming market with 1161 tonnes in March 2022.

Table 7: Major tomato consuming states/markets in India (as on 2022-03-10)

State	**Market**	**District**	**Variety**	**Arrival [Tonnes]**
Delhi	Azadpur	Delhi	Tomato	611
	Azadpur	Delhi	Local	550
Sub-total				**1161**
Maharashtra	Pune	Pune	Local	205
	Mumbai	Mumbai	Local	193
	Mumbai	Mumbai	Other	193
Sub-total				**591**
Gujarat	Ahmedabad	Ahmedabad	Desi	232
	Ahmedabad	Ahmedabad	Other	177.9
Sub-total				**409.9**
Madhya Pradesh	Indore	Indore	Local	100
	Indore	Indore	Other	11.2
Sub-total				**111.2**
West Bengal	Kolkata	Kolkata	Hybrid	90

Uttar Pradesh	Lucknow	Lucknow	Deshi	70
Karnataka	Bangalore	Bangalore	Local	39

Source: https://miews.nafed-india.com/snapshot.php?commodity_id=3&markets_type=C&stateid=&clustername=&s_c=&d_s=&source_id=

Onion

The major onion consuming states were Maharashtra, Karnataka, Madhya Pradesh, Delhi, Tamil Nadu, Punjab, Gujarat, Uttar Pradesh and West Bengal (Table 8). Among the consuming states, Maharashtra recorded the highest market arrival of 5721 tonnes of onions in March, 2022.

Table 8: Major onion consuming states/markets in India (as on 2022-03-10)

States	**Market**	**District**	**Variety**	**Arrival [Tonnes]**
Maharashtra	Pune	Pune	Red	1800
	Pune	Pune	Local	1797
	Mumbai	Mumbai	Red	1245
	Vashi	Thane	Other	879
Sub-total				**5721**
Karnataka	Bangalore	Bangalore	Local	2445
	Bangalore	Bangalore	Puna	2445
Sub-total				**4890**
Madhya Pradesh	Indore	Indore	Local	2500
	Bhopal (MP)	Bhopal	Pune	150
Sub-total				**2650**
Delhi	Azadpur	Delhi	Red	1400
	Azadpur	Delhi	Onion	481.8
Sub-total				**1881.8**
Tamil Nadu	Chennai	Chennai	Nasik	1425
Punjab	Amritsar	Amritsar	Red	800
Gujarat	Ahmedabad	Ahmedabad	Local	584
Uttar Pradesh	Lucknow	Lucknow	Red	290
West Bengal	Kolkata (WB)	Kolkata	Red	166

Source: https://miews.nafed-india.com/snapshot.php?s_c=&source_id=&rdate=2022-03-10&markets_type=C&commodity_id=2

Potato

The major potato consuming states were Madhya Pradesh, Maharashtra, Karnataka, Delhi, Gujarat, Uttar Pradesh, Punjab, Tamil Nadu and West Bengal (Table 9). Of all the major consuming states, Madhya Pradesh witnessed the highest market arrival of 4550 tonnes of potatoes in March 2022.

Table 9: Major potato consuming states/markets in India (as on 2022-03-10)

States	Market	District	Variety	Arrival [Tonnes]
Madhya Pradesh	Indore	Indore	Store	4500
	Bhopal	Bhopal	Store	50
Sub-total				**4550**
Maharashtra	Pune	Pune	Store	774
	Vashi	Thane	Other	753
	Pune	Pune	Other	749
	Mumbai	Mumbai	Store	648
Sub-total				**2924**
Karnataka	Bangalore	Bangalore	Local	928
	Bangalore	Bangalore	Potato	928
	Bangalore (KA)	Bangalore	Store	900
Sub-total				**2756**
Delhi	Azadpur	Delhi	Store	1600
	Azadpur	Delhi	Potato	1036
Sub-total				**2636**
Gujarat	Ahmedabad	Ahmedabad	Store	598
Uttar Pradesh	Lucknow	Lucknow	Desi	370
Punjab	Amritsar	Amritsar	Local Store	250
Tamil Nadu	Chennai	Chennai	Store	230
West Bengal	Kolkata	Kolkata	Store	120

Source: https://miews.nafed-india.com/snapshot.php?commodity_id=1&markets_type=C&stateid=&clustername=&s_c=&d_s=&source_id

6. Results

As already described, in the first stage, markets with a cumulative share of 90% in total market arrivals in majority of the study period are shortlisted (Table 10). There are a total of 169 tomato markets, 211 onion markets and 180 potato markets for which data is reported in the AGMARKNET database. Following the procedure outlined above, 32 tomato markets, 25 onion markets and 29 potato markets have been selected in stage 1. The details of the selected markets in stage 1 are as follows.

Table 10: Markets selected for analysis in stage 1
(based on percentage of market arrivals and weekly arrival data)

S.NO	ONION	POTATO	TOMATO
1	AGRA(UP)	AGRA(UP)	AGRA(UP)
2	AHMEDABAD(GUJ)	AHMEDABAD(GUJ)	AHMEDABAD(GUJ)
3	BANGALORE	AJMER(RAJ)	ALIGARH(UP)
4	BELGAUM(KNT)	ALIGARH(UP)	BAREILLY(UP)
5	CHENNAI	AMRITSAR(PB)	BINNY MILL (KNT)
6	DELHI	BANGALORE	BOWENPALLY(TELANGANA)
7	DEVALA(MS)	BAREILLY(UP)	CHENNAI
8	DHULIA(MS)	BELGAUM(KNT)	CHINTAMANI (KNT)
9	HUBLI(KNT)	BHUBNESWER(OR)	DELHI
10	INDORE(MP)	CHENNAI	INDORE(MP)

11	JAIPUR	DELHI	JALANDHAR(PB)
12	KOLHAPUR(MS)	FAIZABAD(UP)	KANPUR(UP)
13	KOLKATA	FARUKHABAD(UP)	KHANNA(PB)
14	KURNOOL(AP)	HUBLI(KNT)	KOLAR(KNT)
15	LASALGAON(MS)	INDORE(MP)	KOLHAPUR(MS)
16	MAHUVA(GUJ)	JAIPUR	KOLKATA
17	MALEGAON(MS)	JAMMU	MULAKALACHERUVU (AP)
18	MANMAD(MS)	JODHPUR(RAJ)	MUMBAI
19	MUMBAI	KANPUR(UP)	PATNA
20	NAGPUR	KHANNA(PB)	PUNE(MS)
21	PIMPALGAON(MS)	KOLKATA	RAIPUR(CHGARH)
22	PUNE(MS)	LUCKNOW	RAJKOT(GUJ)
23	RAHURI(MS)	MUMBAI	SAHARANPUR(UP)
24	SOLAPUR(MS)	PATNA	SOLAPUR(MS)
25	YEOLA(MS)	PUNE(MS)	TIPHRA (CHATT)
26		RAIPUR(CHGARH)	VARANASI(UP)
27		RAJKOT(GUJ)	AMRITSAR(PB)
28		SURAT(GUJ)	BHUBNESWER(OR)
29		UDAIPUR(RAJ)	DEHRADOON(UTT)
30			GUDIMALKAPUR (TELANGANA)
31			JAIPUR
32			LUCKNOW
Total	**25 (out of 211)**	**29 (out of 180)**	**32 (out of 169)**

We have further checked whether the markets identified in Stage 1 for the three commodities tally with the important markets as outlined in various government sources. These sources include commodity profiles provided by Agricultural Marketing Information Network (AGMARKNET) and National Agricultural Cooperative Marketing Federation of India (NAFED). The results of our matching exercise are as follows (Table 11 to 13)

Table 11: Matched major markets/mandies (Onion)

States	**Matched major markets/mandies**
Maharashtra	Lasalgaon, Pimplagaon, Malegaon, Solapur, Pune, Yeola, Devala, Mumbai
Karnataka	Bangalore, Hubli
Gujarat	Ahmedabad,
Madhya Pradesh	Indore
Andhra Pradesh	Kurnool
Tamil Nadu	Chennai
Uttar Pradesh	Agra
West Bengal	Kolkata

Source: compiled from NAFED (https://miews.nafed-india.com/snapshot.php?commodity_id=2)

Table 12: Matched major markets/mandies (Potato)

States	**Matched major markets/mandies**
Uttar Pradesh	Aligarh, Agra, Lucknow, Farukkabad
West Bengal	Kolkata
Bihar	Patna

Punjab	Amritsar, Khanna
Gujarat	Rajkot, Ahmedabad,
Rajasthan	Ajmer, Udaipur
Karnataka	Bangalore, Hubli
Madhya Pradesh	Indore
Tamil Nadu	Chennai
Maharashtra	Pune, Mumbai

Source: compiled from NAFED (https://miews.nafed-india.com/snapshot.php?commodity_id=1)

Table 13: Matched major markets/mandies (Tomato)

States	Matched major markets/mandies
Andhra Pradesh	Mulakalacheruvu
Karnataka	Kolar
Maharashtra	Solapur, Kolhapur, Mumbai, Pune
West Bengal	Kolkata
Bihar	Patna
Tamil Nadu	Chennai
Gujarat	Ahmedabad, Rajkot
Telangana	Bowenpally
Madhya Pradesh	Indore
Punjab	Amritsar, Khanna, Jalandhar
Uttar Pradesh	Agra, Aligarh, Lucknow

Source: Compiled from NAFED (https://miews.nafed-india.com/snapshot.php?commodity_id=3)

Stage 2: In the second stage VAR and Granger Causality are applied to identify the markets whose price signals help predict prices in other markets. As in the first stage, two criteria have been used in the second stage as well. The importance of any market depends upon the total number of markets it is integrated with, and out of these, the number of markets in which it can influence the price. Thus, these two criteria have been used in this stage to identify the nodal markets.

To illustrate, Suppose the price of a market *Granger causes* the current price in 'x' number of markets and the price in this market *is Granger-caused* by lagged prices in 'y' other markets, then, two criteria – integration criterion and leadership criterion have been used to categorize the markets

i) **Integration criterion:** The total number of markets integrated (with this market) = **x+y**

ii) **Leadership criterion:** The number of markets granger-caused by this market relative to total number of markets = **(x-y)/total number of markets**

A market is classified into two categories based on criterion 1 – weakly integrated and strongly integrated. A market is 'weakly integrated' *if the total number of markets it is integrated with is less than the median value* (of integrated markets). Otherwise, it is classified as 'strongly integrated'. For example, if a market x is integrated with 10 other markets and the median value is 12, then the market is categorized as 'weakly integrated'.

Similarly, a market is classified into three categories based on criterion 2 - leading/nodal market, peripheral market, following market. A market is a 'leading/nodal market' if the difference between the number of markets it is Granger-causing and the number of markets it is Granger-caused by is at least 5% of the total number of markets. If this difference is zero or greater but less than 5%, then the market is classified as a 'peripheral market'. It is classified as a 'following market' if the percentage is less than zero (if the number of markets it is Granger-causing is less than the number of markets it is Granger-caused by). For example, if there is a total of 25 markets. If the market of our interest is Granger-causing prices in 10 markets and is Granger-caused by 5 markets, then the percentage difference is 20% ((10-5)/25). Since the difference is more than 5%, this market is classified as a leading/nodal market.

Combining both the criteria, we thus have six possible categories.

1. Strongly integrated leading market - SILM
2. Strongly integrated peripheral market - SIPM
3. Strongly integrated following market - SIFM
4. Weakly integrated leading market - WILM
5. Weakly integrated peripheral market - WIPM
6. Weakly integrated following market - WIFM

6.1 Tomato

As discussed above, along with a simple specification with only prices, two specifications have been tried by controlling for market arrivals – arrivals in all markets and arrivals in major markets. Major markets are those which recorded arrivals of more than 10000 tons as of January 2020 or which are in the major tomato producing states (share of at least 3% in the production during 2014-15 to 2018-19), have been included. Although a threshold of 5% share has been used in case of potato, a slightly lower threshold has been used for tomato because tomato production is more evenly distributed across the country (NHB Monthly Report on Onion, Potato, Tomato 2020). The following tables (Table 14 to Table 16) summarize the findings based on vector autoregressions (VARs) based on only prices; prices plus market arrivals of all markets as control; and prices plus market arrivals of major markets as control. The final categorization (Table 17, Table 18 and Figure 9 & 10) is taken as the best of the three categorizations.

First the interpretation of Table 14 is presented. The interpretation of other tables is similar. Let's consider the market in the first row, Mulakalacheruvu (A.P). Column 3 denotes the number of markets that 'Mulakalacheruvu' is Granger-casuing, which can be seen as 11. This means that the previous week's tomato price in Mulakalacheruvu market is influencing the current week's price in 11 other markets significantly. In other words, Mulakalacheruvu is leading 11 other markets. Similarly, column 4 denotes the number of markets by which 'Mulakalacheruvu' is Granger-caused, which can be seen as 7. This means that there are 7 markets whose previous week's tomato price is influencing significantly the current week's price in Mulakalacheruvu. In other words, Mulakalacheruvu is lagging these 7 markets. For all the remaining markets, the number of Granger-causing and Granger-caused markets are identified.

Column 5 gives the total number of markets Granger-causing and Granger-caused. This can be seen as 18, which is the sum of 11 (Granger-casing) and 7 (Granger-caused). This means that Mulakalacheruvu is integrated with 18 markets in all. This is the 'total number of integrated markets' of Mulakalacheruvu. This number is worked out similarly for all the remaining markets and the median value is given in the last row of column 5, which can be seen as 11. Thus the total number of integrated markets of Mulakalacheruvu, which is 18, is greater than the median value, which is 11. Thus as per the 'integration criterion' discussed earlier, this market is classified as 'strongly integrated'.

Moving to column 6, this column gives the difference between the number of markets Granger-causing and Granger-caused by as a percentage of total number of markets. In other words, this gives us a measure of whether a particular market is leading other markets or lagging them. For example, the number of markets Mulakalacheruvu is Granger-causing or leading is 11. The number of markets Mulakalacheruvu is Granger-caused by or lagging is 7. The difference is 4. Since the total number of tomato markets is 32, the percentage of this difference to total number of markets works out to 12.5%, which is given in col 6. This percentage is greater than 5% and following the 'leadership criterion' discussed earlier, this market is categorized as a 'leading' market.

Thus combining these two criteria, the ‘integration criterion’ and the ‘leadership criterion’, the market Mulakalacheruvu is categorized as ‘strongly integrated leading market’ or ‘SILM’ (col 9). The same procedure is followed for the remaining 31 markets. Following this process, we could identify ten leading markets (nine strongly integrated and one weakly integrated) for VAR specification with only prices. Other markets are categorized as peripheral or following markets.

A similar analysis is carried out for the other two VAR specifications, namely, VAR with all market arrivals as control and VAR with major market arrivals as control and markets are categorized into six categories.

The categorization of markets in the three VAR specifications is presented in Table 17. The final categorization of the markets is based on the ‘best of the three’ results. For example, Kolar market is categorized in Table 17 as SIPM in VAR with prices; SILM in VAR with all market arrivals and as SIPM again in VAR with major market arrivals. Since two of the three specifications give the result ‘SIPM’ the market is categorized as SIPM. Following this procedure, from the set of 32 markets identified in stage 1, about nine markets - Mulakala Cheruvu, Patna, Tiphra, Bowenpally, Delhi, Ahmedabad, Chintamani, Solapur, Kolhapur – have emerged as leading/nodal markets at the national level (strongly integrated) and at the regional level (weakly integrated) (Table 18, figure 9 & 10). About six peripheral markets – Kolar, Jaipur, Mumbai, Indore, Khanna and Chennai – have also been identified. The rest are following markets. Pune is one market where a clear categorization was not possible because the market seemed to fall into different categories in different specifications.

Table 14: VAR results based on only prices with 1 lag (Tomato)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (32) (6) = [(3)-(4)] / 32	Test for integration (7)	Test for leadership (8)	Final Market category (9)
TM_L_P_AP_MUL	Mulakalacheruvu	11	7	18	12.50	SI	LM	SILM
TM_L_P_BH_PAT	Patna	11	4	15	21.88	SI	LM	SILM
TM_L_P_CH_RAI	Raipur	3	5	8	-6.25	WI	FM	WIFM
TM_L_P_CH_TIP	Tiphra	14	5	19	28.13	SI	LM	SILM
TM_L_P_DL_DEL	Delhi	11	8	19	9.38	SI	LM	SILM
TM_L_P_GJ_AHM	Ahmedabad	13	6	19	21.88	SI	LM	SILM
TM_L_P_GJ_RAJ	Rajkot	4	7	11	-9.38	SI	FM	SIFM
TM_L_P_KR_BIN	Binny Mill	7	9	16	-6.25	SI	FM	SIFM
TM_L_P_KR_CHI	Chintamani	8	5	13	9.38	SI	LM	SILM
TM_L_P_KR_KOL	Kolar	6	6	12	0.00	SI	PM	SIPM
TM_L_P_MH_KOL	Kolhapur	6	2	8	12.50	WI	LM	WILM
TM_L_P_MH_MUM	Mumbai	4	4	8	0.00	WI	PM	WIPM
TM_L_P_MH_PUN	Pune	3	3	6	0.00	WI	PM	WIPM
TM_L_P_MH_SOL	Solapur	7	4	11	9.38	SI	LM	SILM
TM_L_P_MP_IND	Indore	3	3	6	0.00	WI	PM	WIPM
TM_L_P_OR_BHU	Bhubneswer	2	3	5	-3.13	WI	FM	WIFM
TM_L_P_PB_AMR	Amritsar	1	4	5	-9.38	WI	FM	WIFM
TM_L_P_PB_JAL	Jalandhar	5	6	11	-3.13	SI	FM	SIFM
TM_L_P_PB_KHA	Khanna	4	5	9	-3.13	WI	FM	WIFM
TM_L_P_RJ_JAI	Jaipur	7	7	14	0.00	SI	PM	SIPM
TM_L_P_TL_BOW	Bowenpally	9	4	13	15.63	SI	LM	SILM
TM_L_P_TL_GUD	Gudimalkapur	0	4	4	-12.50	WI	FM	WIFM
TM_L_P_TN_CHE	Chennai	6	4	10	6.25	WI	LM	WILM
TM_L_P_UK_DEH	Dehradoon	2	7	9	-15.63	WI	FM	WIFM
TM_L_P_UP_AGR	Agra	3	6	9	-9.38	WI	FM	WIFM
TM_L_P_UP_ALI	Aligarh	6	14	20	-25.00	SI	FM	SIFM
TM_L_P_UP_BAR	Bareilly	10	9	19	3.13	SI	PM	SIPM
TM_L_P_UP_KAN	Kanpur	1	5	6	-12.50	WI	FM	WIFM
TM_L_P_UP_LUC	Lucknow	1	7	8	-18.75	WI	FM	WIFM
TM_L_P_UP_SAH	Saharanpur	4	3	7	3.13	WI	PM	WIPM
TM_L_P_UP_VAR	Varanasi	4	8	12	-12.50	SI	FM	SIFM
TM_L_P_WB_KOL	Kolkata	6	8	14	-6.25	SI	FM	SIFM

Note : SI – strongly integrated; WI- weakly integrated
LM-leading market; PM-peripheral market; FM-following market

Table 15: VAR results based on all market arrivals as control variable with 1 lag (Tomato)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (32) (6) = [(3)-(4)] / 32	Test for integration (7)	Test for leadership (8)	Final Market category (9)
TM_L_P_AP_MUL	Mulakalacheruvu	11	7	18	12.50	1	1	SILM
TM_L_P_BH_PAT	Patna	11	4	15	21.88	1	1	SILM
TM_L_P_CH_RAI	Raipur	3	5	8	-6.25	2	3	WIFM
TM_L_P_CH_TIP	Tiphra	14	6	20	25.00	1	1	SILM
TM_L_P_DL_DEL	Delhi	11	8	19	9.38	1	1	SILM
TM_L_P_GJ_AHM	Ahmedabad	15	6	21	28.13	1	1	SILM
TM_L_P_GJ_RAJ	Rajkot	4	7	11	-9.38	1	3	SIFM
TM_L_P_KR_BIN	Binny Mill	6	7	13	-3.13	1	3	SIFM
TM_L_P_KR_CHI	Chintamani	7	5	12	6.25	1	1	SILM
TM_L_P_KR_KOL	Kolar	8	6	14	6.25	1	1	SILM
TM_L_P_MH_KOL	Kolhapur	6	2	8	12.50	2	1	WILM
TM_L_P_MH_MUM	Mumbai	4	5	9	-3.13	1	3	SIFM
TM_L_P_MH_PUN	Pune	2	3	5	-3.13	2	3	WIFM
TM_L_P_MH_SOL	Solapur	7	2	9	15.63	1	1	SILM
TM_L_P_MP_IND	Indore	3	3	6	0.00	2	2	WIPM
TM_L_P_OR_BHU	Bhubneswer	2	3	5	-3.13	2	3	WIFM
TM_L_P_PB_AMR	Amritsar	1	4	5	-9.38	2	3	WIFM
TM_L_P_PB_JAL	Jalandhar	4	5	9	-3.13	1	3	SIFM
TM_L_P_PB_KHA	Khanna	4	4	8	0.00	2	2	WIPM
TM_L_P_RJ_JAI	Jaipur	7	7	14	0.00	1	2	SIPM
TM_L_P_TL_BOW	Bowenpally	7	5	12	6.25	1	1	SILM
TM_L_P_TL_GUD	Gudimalkapur	1	4	5	-9.38	2	3	WIFM
TM_L_P_TN_CHE	Chennai	4	3	7	3.13	2	2	WIPM
TM_L_P_UK_DEH	Dehradoon	2	7	9	-15.63	1	3	SIFM
TM_L_P_UP_AGR	Agra	3	6	9	-9.38	1	3	SIFM
TM_L_P_UP_ALI	Aligarh	6	14	20	-25.00	1	3	SIFM
TM_L_P_UP_BAR	Bareilly	7	8	15	-3.13	1	3	SIFM
TM_L_P_UP_KAN	Kanpur	1	5	6	-12.50	2	3	WIFM
TM_L_P_UP_LUC	Lucknow	2	7	9	-15.63	1	3	SIFM
TM_L_P_UP_SAH	Saharanpur	1	2	3	-3.13	2	3	WIFM
TM_L_P_UP_VAR	Varanasi	5	9	14	-12.50	1	3	SIFM
TM_L_P_WB_KOL	Kolkata	7	7	14	0.00	1	2	SIPM
Median value				9	-3.125			

Table 16: VAR results based on major market arrivals as control variable with 1 lag (Tomato)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (32) (6) = [(3)-(4)] / 32	Test for integration (7)	Test for leadership (8)	Final Market category (9)
TM_L_P_AP_MUL	Mulakalacheruvu	11	7	18	12.50	1	1	SILM
TM_L_P_BH_PAT	Patna	11	4	15	21.88	1	1	SILM
TM_L_P_CH_RAI	Raipur	3	5	8	-6.25	2	3	WIFM
TM_L_P_CH_TIP	Tiphra	15	5	20	31.25	1	1	SILM
TM_L_P_DL_DEL	Delhi	11	8	19	9.38	1	1	SILM
TM_L_P_GJ_AHM	Ahmedabad	13	7	20	18.75	1	1	SILM
TM_L_P_GJ_RAJ	Rajkot	3	7	10	-12.50	1	3	SIFM
TM_L_P_KR_BIN	Binny Mill	6	7	13	-3.13	1	3	SIFM
TM_L_P_KR_CHI	Chintamani	11	5	16	18.75	1	1	SILM
TM_L_P_KR_KOL	Kolar	6	5	11	3.13	1	2	SIPM
TM_L_P_MH_KOL	Kolhapur	6	2	8	12.50	2	1	WILM
TM_L_P_MH_MUM	Mumbai	4	4	8	0.00	2	2	WIPM
TM_L_P_MH_PUN	Pune	5	3	8	6.25	2	1	WILM
TM_L_P_MH_SOL	Solapur	7	3	10	12.50	1	1	SILM
TM_L_P_MP_IND	Indore	3	5	8	-6.25	2	3	WIFM
TM_L_P_OR_BHU	Bhubneswer	2	3	5	-3.13	2	3	WIFM
TM_L_P_PB_AMR	Amritsar	1	4	5	-9.38	2	3	WIFM
TM_L_P_PB_JAL	Jalandhar	4	5	9	-3.13	2	3	WIFM
TM_L_P_PB_KHA	Khanna	4	4	8	0.00	2	2	WIPM
TM_L_P_RJ_JAI	Jaipur	7	7	14	0.00	1	2	SIPM
TM_L_P_TL_BOW	Bowenpally	8	3	11	15.63	1	1	SILM
TM_L_P_TL_GUD	Gudimalkapur	3	4	7	-3.13	2	3	WIFM
TM_L_P_TN_CHE	Chennai	4	4	8	0.00	2	2	WIPM
TM_L_P_UK_DEH	Dehradoon	1	7	8	-18.75	2	3	WIFM
TM_L_P_UP_AGR	Agra	3	8	11	-15.63	1	3	SIFM
TM_L_P_UP_ALI	Aligarh	6	14	20	-25.00	1	3	SIFM
TM_L_P_UP_BAR	Bareilly	7	9	16	-6.25	1	3	SIFM
TM_L_P_UP_KAN	Kanpur	1	5	6	-12.50	2	3	WIFM
TM_L_P_UP_LUC	Lucknow	2	7	9	-15.63	2	3	WIFM
TM_L_P_UP_SAH	Saharanpur	1	3	4	-6.25	2	3	WIFM
TM_L_P_UP_VAR	Varanasi	5	8	13	-9.38	1	3	SIFM
TM_L_P_WB_KOL	Kolkata	6	8	14	-6.25	1	3	SIFM
Median value				10	-3.125			

Table 17: Final categorization of markets –Tomato

Market	Market name	Only prices	All market arrivals (lag 1)	Major market arrivals (lag 1)	**FINAL CATEGORY**
TM_L_P_AP_MUL	Mulakalacheruvu	SILM	SILM	SILM	**SILM**
TM_L_P_BH_PAT	Patna	SILM	SILM	SILM	**SILM**
TM_L_P_CH_RAI	Raipur	WIFM	WIFM	WIFM	**WIFM**
TM_L_P_CH_TIP	Tiphra	SILM	SILM	SILM	**SILM**
TM_L_P_DL_DEL	Delhi	SILM	SILM	SILM	**SILM**
TM_L_P_GJ_AHM	Ahmedabad	SILM	SILM	SILM	**SILM**
TM_L_P_GJ_RAJ	Rajkot	SIFM	SIFM	SIFM	**SIFM**
TM_L_P_KR_BIN	Binny Mill	SIFM	SIFM	SIFM	**SIFM**
TM_L_P_KR_CHI	Chintamani	SILM	SILM	SILM	**SILM**
TM_L_P_KR_KOL	Kolar	SIPM	SILM	SIPM	**SIPM**
TM_L_P_MH_KOL	Kolhapur	WILM	WILM	WILM	**WILM**
TM_L_P_MH_MUM	Mumbai	WIPM	SIFM	WIPM	**WIPM**
TM_L_P_MH_PUN	Pune	WIPM	WIFM	WILM	**Not Clear**
TM_L_P_MH_SOL	Solapur	SILM	SILM	SILM	**SILM**
TM_L_P_MP_IND	Indore	WIPM	WIPM	WIFM	**WIPM**
TM_L_P_OR_BHU	Bhubneswer	WIFM	WIFM	WIFM	**WIFM**
TM_L_P_PB_AMR	Amritsar	WIFM	WIFM	WIFM	**WIFM**
TM_L_P_PB_JAL	Jalandhar	SIFM	SIFM	WIFM	**SIFM**
TM_L_P_PB_KHA	Khanna	WIFM	WIPM	WIPM	**WIPM**
TM_L_P_RJ_JAI	Jaipur	SIPM	SIPM	SIPM	**SIPM**
TM_L_P_TL_BOW	Bowenpally	SILM	SILM	SILM	**SILM**
TM_L_P_TL_GUD	Gudimalkapur	WIFM	WIFM	WIFM	**WIFM**
TM_L_P_TN_CHE	Chennai	WILM	WIPM	WIPM	**WIPM**
TM_L_P_UK_DEH	Dehradoon	WIFM	SIFM	WIFM	**WIFM**
TM_L_P_UP_AGR	Agra	WIFM	SIFM	SIFM	**SIFM**
TM_L_P_UP_ALI	Aligarh	SIFM	SIFM	SIFM	**SIFM**
TM_L_P_UP_BAR	Bareilly	SIPM	SIFM	SIFM	**SIFM**
TM_L_P_UP_KAN	Kanpur	WIFM	WIFM	WIFM	**WIFM**
TM_L_P_UP_LUC	Lucknow	WIFM	SIFM	WIFM	**WIFM**
TM_L_P_UP_SAH	Saharanpur	WIPM	WIFM	WIFM	**WIFM**
TM_L_P_UP_VAR	Varanasi	SIFM	SIFM	SIFM	**SIFM**
TM_L_P_WB_KOL	Kolkata	SIFM	SIPM	SIFM	**SIFM**

Table 18: Tomato markets (total 32)

	Leading/nodal	Peripheral	Following
Strongly integrated (Nationally important)	Mulakala Cheruvu (AP), Patna (Bih), Tiphra (Chg), Bowenpally (Tel), Delhi, Ahmedabad (Guj), Chintamani (Kar), Solapur (Mah)	Kolar (Kar), Jaipur (Raj),	Varanasi (UP), Rajkot (Guj), Binny Mills (Kar), Jalandhar (Pun), Agra (UP), Aligarh (UP), Bareilly (UP), Kolkata (WB),
Weakly integrated (Locally important)	Kolhapur (Mah)	Mumbai (Mah), Indore (MP), Khanna (Pun), Chennai (TN),	Raipur (Chg), Bhubaneswar (Ori), Sahranpur (UP), Kanpur (UP), Amritsar (Pung), Gudimalkapur (Tel), Dehradun (UK), Lucknow (UP),
Not clear	Pune (Mah),		

Figure 9: Strongly Integrated Markets (Tomato)

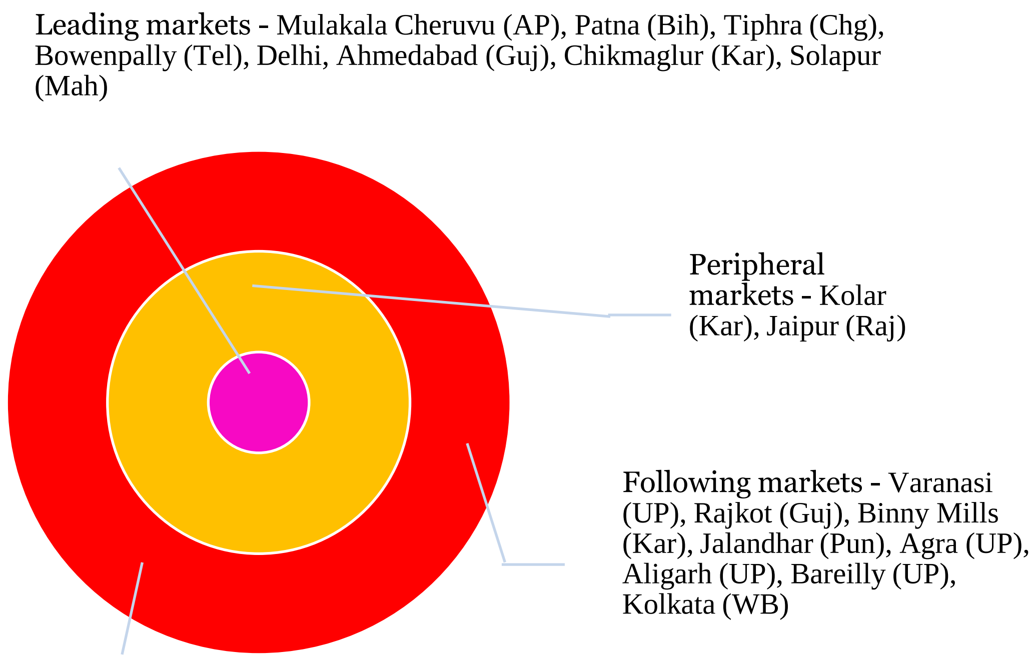
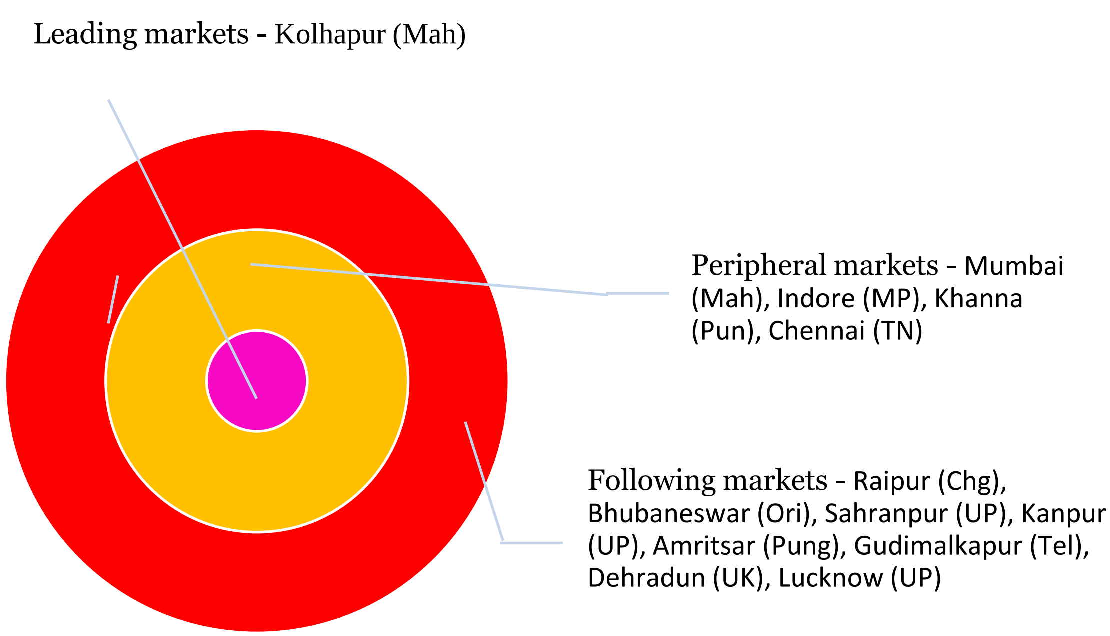


Figure 10: Weakly integrated markets (Tomato)



6.2 Onion

As in tomato, three specifications of the VAR model have been used – VAR with only prices; VAR with prices after controlling for arrivals at all markets; and VAR with prices after controlling for arrivals at major markets of Lasalgaon, Pimplagaon, Malegaon and Yeola (as control). The market arrivals are used to control for their effect on the relationship among the prices (in different markets). In the last specification, these four markets have been selected because Lasalgaon and Pimplagaon are the two major onion markets in the country and the other two markets lie within a radius of less than 60 kms. Final list of the nodal markets is identified as the best of the three specifications. The following tables (Table 19 to Table 21) summarize the findings from VARs based on *only* prices; prices plus market arrivals of all markets as control; and prices plus market arrivals of major markets as control.

The interpretation of tables 19 to 21 is exactly as explained in section 6.1. The final categorization (Table 22, Table 23 and Figures 11 & 12) is taken as the best of the three categorizations. From the set of 25 markets identified in Stage 1, eight markets - Ahmedabad, Pimplagaon, Lasalgaon, Rahuri, Solapur, Chennai, Agra and Malegaon – have been identified as leading/nodal markets at the national and local levels. Additionally, seven markets - Bangalore, Mumbai, Yeola, Jaipur, Mahua, Dhulia and Indore – have emerged as the peripheral markets. The rest are following markets.

Table 19: VAR results based on only prices (Onion)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (25) (6) = [(3)-(4)] / 25	Test for integration (7)	Test for leadership (8)	Final Market category (9)
L_AP_KUR	Kurnool	4	10	14	-24	1	3	SIFM
L_DL_DEL	Delhi	9	11	20	-8	1	3	SIFM
L_GJ_AHM	Ahmedabad	19	11	30	32	1	1	SILM
L_GJ_MAH	Mahuva	5	5	10	0	2	2	WIPM
L_KR_BAN	Bangalore	9	12	21	-12	1	3	SIFM
L_KR_BEL	Belgaum	4	4	8	0	2	2	WIPM
L_KR_HUB	Hubli	7	4	11	12	2	1	WILM
L_MH_DEV	Devala	6	10	16	-16	1	3	SIFM
L_MH_DHU	Dhulia	6	5	11	4	2	2	WIPM
L_MH_KOL	Kolkata	3	10	13	-28	1	3	SIFM
L_MH_LAS	Lasalgaon	8	5	13	12	1	1	SILM
L_MH_MAL	Malegaon	8	6	14	8	1	1	SILM
L_MH_MAN	Manmad	1	8	9	-28	2	3	WIFM
L_MH_MUM	Mumbai	13	10	23	12	1	1	SILM
L_MH_NAG	Nagpur	5	8	13	-12	1	3	SIFM
L_MH_PIM	Pimplagaon	8	6	14	8	1	1	SILM
L_MH_PUN	Pune	4	8	12	-16	2	3	WIFM
L_MH_RAH	Rahuri	11	5	16	24	1	1	SILM
L_MH_SOL	Solapur	21	6	27	60	1	1	SILM
L_MH_YEO	Yeola	5	7	12	-8	2	3	WIFM
L_MP_IND	Indore	6	6	12	0	2	2	WIPM
L_RJ_JAI	Jaipur	7	6	13	4	1	2	SIPM
L_TN_CHE	Chennai	15	13	28	8	1	1	SILM
L_UP_AGR	Agra	14	9	23	20	1	1	SILM
L_WB_KOL	Kolkata	3	10	13	-28	1	3	SIFM
Median value				13	0.00			

Table 20: VAR results based on all market arrivals as control variable with 1 lag (Onion)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (25) (6) = [(3)-(4)] / 25	Test for integration (7)	Test for leadership (8)	Final Market category (9)
L_AP_KUR	Kurnool	4	9	13	-20	2	3	WIFM
L_DL_DEL	Delhi	9	10	19	-4	1	3	SIFM
L_GJ_AHM	Ahmedabad	19	10	29	36	1	1	SILM
L_GJ_MAH	Mahuva	8	7	15	4	1	2	SIPM
L_KR_BAN	Bangalore	9	9	18	0	1	2	SIPM
L_KR_BEL	Belgaum	1	4	5	-12	2	3	WIFM
L_KR_HUB	Hubli	1	4	5	-12	2	3	WIFM
L_MH_DEV	Devala	8	6	14	8	1	1	SILM
L_MH_DHU	Dhulia	5	5	10	0	2	2	WIPM
L_MH_KOL	Kolkata	1	9	10	-32	2	3	WIFM
L_MH_LAS	Lasalgaon	9	4	13	20	2	1	WILM
L_MH_MAL	Malegaon	8	5	13	12	2	1	WILM
L_MH_MAN	Manmad	2	6	8	-16	2	3	WIFM
L_MH_MUM	Mumbai	10	10	20	0	1	2	SIPM
L_MH_NAG	Nagpur	9	7	16	8	1	1	SILM
L_MH_PIM	Pimplagaon	8	6	14	8	1	1	SILM
L_MH_PUN	Pune	4	9	13	-20	2	3	WIFM
L_MH_RAH	Rahuri	9	6	15	12	1	1	SILM
L_MH_SOL	Solapur	20	8	28	48	1	1	SILM
L_MH_YEO	Yeola	10	6	16	16	1	1	SILM
L_MP_IND	Indore	7	6	13	4	2	2	WIPM
L_RJ_JAI	Jaipur	7	7	14	0	1	2	SIPM
L_TN_CHE	Chennai	12	13	25	-4	1	3	SIFM
L_UP_AGR	Agra	11	9	20	8	1	1	SILM
L_WB_KOL	Kolkata	4	10	14	-24	1	3	SIFM
Median value				14	0.00			

Table 21: VAR results based on aggregate arrivals of major markets (Lasalgaon+Pimplagaon+Yeola) as control variable with 1 lag (Onion)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (25) (6) = [(3)-(4)] / 25	Test for integration (7)	Test for leadership (8)	Final Market category (9)
L_AP_KUR	Kurnool	2	11	13	-36	2	3	WIFM
L_DL_DEL	Delhi	7	10	17	-12	1	3	SIFM
L_GJ_AHM	Ahmedabad	18	10	28	32	1	1	SILM
L_GJ_MAH	Mahuva	6	5	11	4	2	2	WIPM
L_KR_BAN	Bangalore	9	9	18	0	1	2	SIPM
L_KR_BEL	Belgaum	1	4	5	-12	2	3	WIFM
L_KR_HUB	Hubli	2	5	7	-12	2	3	WIFM
L_MH_DEV	Devala	5	8	13	-12	2	3	WIFM
L_MH_DHU	Dhulia	6	5	11	4	2	2	WIPM
L_MH_KOL	Kolkata	3	8	11	-20	2	3	WIFM
L_MH_LAS	Lasalgaon	8	6	14	8	1	1	SILM
L_MH_MAL	Malegaon	7	4	11	12	2	1	WILM
L_MH_MAN	Manmad	1	7	8	-24	2	3	WIFM
L_MH_MUM	Mumbai	10	10	20	0	1	2	SIPM
L_MH_NAG	Nagpur	6	9	15	-12	1	3	SIFM
L_MH_PIM	Pimplagaon	8	6	14	8	1	1	SILM
L_MH_PUN	Pune	4	9	13	-20	2	3	WIFM
L_MH_RAH	Rahuri	10	7	17	12	1	1	SILM
L_MH_SOL	Solapur	23	6	29	68	1	1	SILM
L_MH_YEO	Yeola	8	7	15	4	1	2	SIPM
L_MP_IND	Indore	6	5	11	4	2	2	WIPM
L_RJ_JAI	Jaipur	8	6	14	8	1	1	SILM
L_TN_CHE	Chennai	15	12	27	12	1	1	SILM
L_UP_AGR	Agra	14	9	23	20	1	1	SILM
L_WB_KOL	Kolkata	5	10	15	-20	1	3	SIFM
Median value				14	0.00			

Table 22: Final categorization of markets – Onion

Market	Market name	Only Prices	All market arrivals	Lasalgaon+Pimplagaon+Malegaon+Yeola arrivals	**Final category**
L_AP_KUR	Kurnool	SIFM	WIFM	WIFM	**WIFM**
L_DL_DEL	Delhi	SIFM	SIFM	SIFM	**SIFM**
L_GJ_AHM	Ahmedabad	SILM	SILM	SILM	**SILM**
L_GJ_MAH	Mahuva	WIPM	SIPM	WIPM	**WIPM**
L_KR_BAN	Bangalore	SIFM	SIPM	SIPM	**SIPM**
L_KR_BEL	Belgaum	WIPM	WIFM	WIFM	**WIFM**
L_KR_HUB	Hubli	WILM	WIFM	WIFM	**WIFM**
L_MH_DEV	Devala	SIFM	SILM	WIFM	**SIFM**
L_MH_DHU	Dhulia	WIPM	WIPM	WIPM	**WIPM**
L_MH_KOL	Kolkata	SIFM	WIFM	WIFM	**WIFM**
L_MH_LAS	Lasalgaon	SILM	WILM	SILM	**SILM**
L_MH_MAL	Malegaon	SILM	WILM	WILM	**WILM**
L_MH_MAN	Manmad	WIFM	WIFM	WIFM	**WIFM**
L_MH_MUM	Mumbai	SILM	SIPM	SIPM	**SIPM**
L_MH_NAG	Nagpur	SIFM	SILM	SIFM	**SIFM**
L_MH_PIM	Pimplagaon	SILM	SILM	SILM	**SILM**
L_MH_PUN	Pune	WIFM	WIFM	WIFM	**WIFM**
L_MH_RAH	Rahuri	SILM	SILM	SILM	**SILM**
L_MH_SOL	Solapur	SILM	SILM	SILM	**SILM**
L_MH_YEO	Yeola	WIFM	SILM	SIPM	**SIPM**
L_MP_IND	Indore	WIPM	WIPM	WIPM	**WIPM**
L_RJ_JAI	Jaipur	SIPM	SIPM	SILM	**SIPM**
L_TN_CHE	Chennai	SILM	SIFM	SILM	**SILM**
L_UP_AGR	Agra	SILM	SILM	SILM	**SILM**
L_WB_KOL	Kolkata	SIFM	SIFM	SIFM	**SIFM**

Table 23: Onion Markets (total 25)

	Leading/nodal	Peripheral	Following
Strongly integrated (Nationally important)	Ahmedabad (Guj), Pimplagaon (Mah), Lasalgaon (Mah), Rahuri (Mah), Solapur (Mah), Chennai (TN), Agra (UP)	Bangalore (Kar), Mumbai (Mah), Yeola (Mah), Jaipur (Raj)	Delhi, Devala (Mah), Nagpur (Mah), Kolkata (WB)
Weakly integrated (Locally important)	Malegaon (Mah)	Mahua (Guj), Dhulia (Mah), Indore (MP),	Kurnool (AP), Belgaum (Kar), Hubli (Kar), Kolhapur (Mah), Manmad (Mah), Pune (Mah),
Not clear (Important on a few criteria)			

Figure 11: Strongly Integrated Markets (Onion)

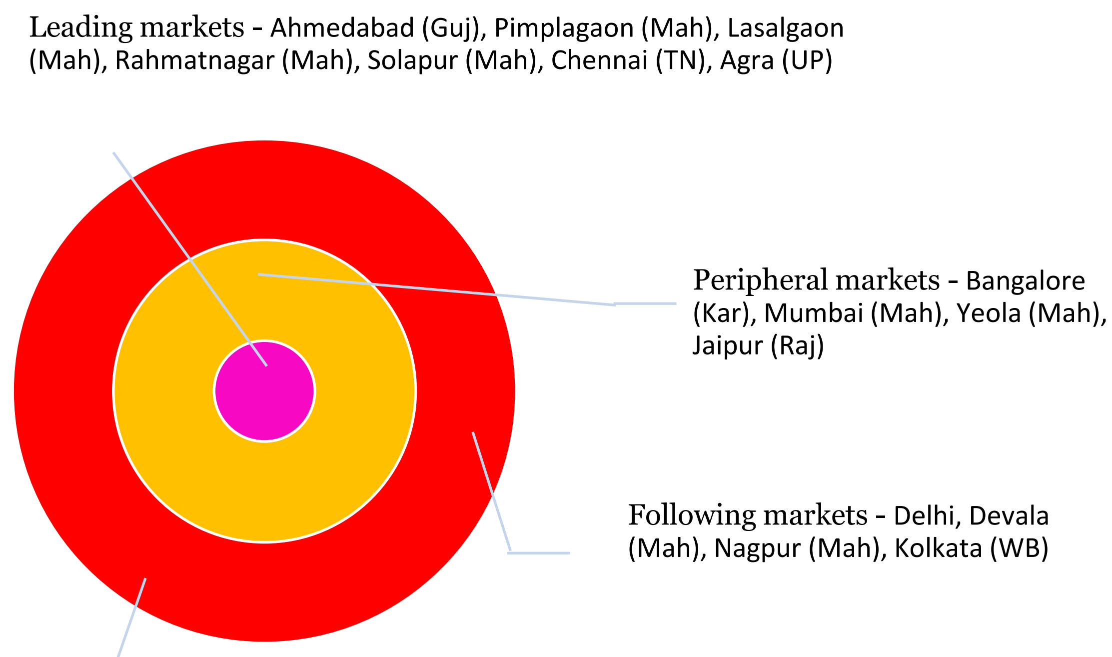
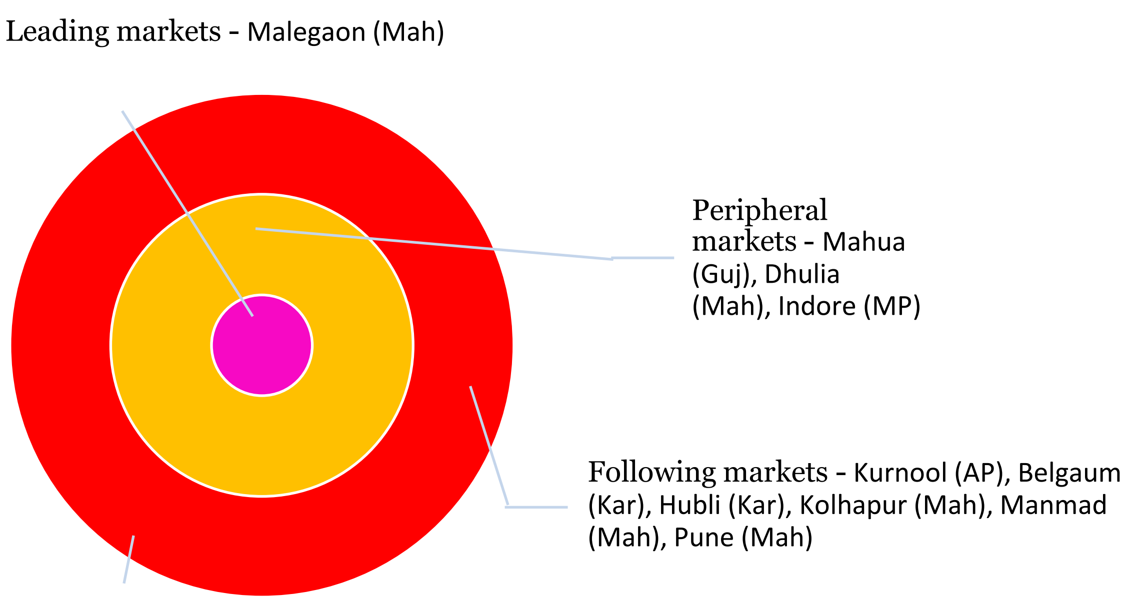


Figure 12: Weakly integrated markets (Onion)



6.3 Potato

Along with VAR in prices, two specifications have been tried by controlling for market arrivals – arrivals in all markets and arrivals in major markets. Major markets are those which recorded arrivals of more than 10000 tons in January 2020 or which are in the major potato producing states (share of at least 5% in the production during 2014-15 to 2018-19), have been included *(NHB Monthly Report on Onion, Potato, Tomato 2020).* Table 24 to Table 26 summarize the findings from VARs based on *only* prices; prices plus market arrivals of all markets as control; and prices plus market arrivals of major markets as control. The interpretation of tables 24 to 26 is exactly as explained in section 6.1.The final categorization (Table 27, Table 28 and Figure 13 & 14) is taken as the best of the three categorizations. From the set of 29 markets identified in Stage 1, six markets - Jaipur, Jammu, Chennai, Ajmer, Indore, Raipur - markets have emerged as the leading/nodal markets at the national and local levels, based on the VAR-GC analysis using prices. In addition, six markets – Delhi, Rajkot, Kolkata, Khanna, Bangalore and Farukkabad - have been identified as peripheral markets.

Table 24: VAR results based on only prices (Potato)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (29) (6) = [(3)-(4)] / 29	Test for integration (7)	Test for leadership (8)	Final Market category (9)
PT_L_P_BH_PAT	Patna	8	9	17	-3	1	3	SIFM
PT_L_P_CH_RAI	Raipur	10	7	17	10	1	1	SILM
PT_L_P_DL_DEL	Delhi	12	10	22	7	1	1	SILM
PT_L_P_GJ_AHM	Ahmedabad	6	11	17	-17	1	3	SIFM
PT_L_P_GJ_RAJ	Rajkot	8	8	16	0	1	2	SIPM
PT_L_P_GJ_SUR	Surat	5	6	11	-3	2	3	WIFM
PT_L_P_JK_JAM	Jammu	15	8	23	24	1	1	SILM
PT_L_P_KR_BAN	Bangalore	3	3	6	0	2	2	WIPM
PT_L_P_KR_BEL	Belgaum	4	5	9	-3	2	3	WIFM
PT_L_P_KR_HUB	Hubli	6	8	14	-7	2	3	WIFM
PT_L_P_MH_MUM	Mumbai	7	9	16	-7	1	3	SIFM
PT_L_P_MH_PUN	Pune	4	5	9	-3	2	3	WIFM
PT_L_P_MP_IND	Indore	13	5	18	28	1	1	SILM
PT_L_P_OR_BHU	Bhubneswer	5	8	13	-10	2	3	WIFM
PT_L_P_PB_AMR	Amritsar	5	5	10	0	2	2	WIPM
PT_L_P_PB_KHA	Khanna	6	5	11	3	2	2	WIPM
PT_L_P_RJ_AJM	Ajmer	14	5	19	31	1	1	SILM
PT_L_P_RJ_JAI	Jaipur	17	10	27	24	1	1	SILM
PT_L_P_RJ_JOD	Jodhpur	4	11	15	-24	2	3	WIFM
PT_L_P_RJ_UDA	Udaipur	6	9	15	-10	2	3	WIFM
PT_L_P_TN_CHE	Chennai	16	6	22	34	1	1	SILM
PT_L_P_UP_AGR	Agra	8	9	17	-3	1	3	SIFM
PT_L_P_UP_ALI	Aligarh	4	14	18	-34	1	3	SIFM
PT_L_P_UP_BAR	Bareilly	9	12	21	-10	1	3	SIFM
PT_L_P_UP_FAI	Faizabad	4	8	12	-14	2	3	WIFM
PT_L_P_UP_FAR	Farukhabad	7	8	15	-3	2	3	WIFM
PT_L_P_UP_KAN	Kanpur	10	12	22	-7	1	3	SIFM
PT_L_P_UP_LUC	Lucknow	8	8	16	0	1	2	SIPM
PT_L_P_WB_KOL	Kolkata	8	8	16	0	1	2	SIPM
Median value				16	-3.448			

Table 25: VAR results based on all market arrivals as control variable with 1 lag (Potato)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (29) (6) = [(3)-(4)] / 29	Test for integration (7)	Test for leadership (8)	Final Market category (9)
PT_L_P_BH_PAT	Patna	6	9	15	-10	2	3	WIFM
PT_L_P_CH_RAI	Raipur	11	6	17	17	1	1	SILM
PT_L_P_DL_DEL	Delhi	11	10	21	3	1	2	SIPM
PT_L_P_GJ_AHM	Ahmedabad	5	10	15	-17	2	3	WIFM
PT_L_P_GJ_RAJ	Rajkot	8	8	16	0	1	2	SIPM
PT_L_P_GJ_SUR	Surat	5	7	12	-7	2	3	WIFM
PT_L_P_JK_JAM	Jammu	18	6	24	41	1	1	SILM
PT_L_P_KR_BAN	Bangalore	4	4	8	0	2	2	WIPM
PT_L_P_KR_BEL	Belgaum	4	5	9	-3	2	3	WIFM
PT_L_P_KR_HUB	Hubli	8	8	16	0	1	2	SIPM
PT_L_P_MH_MUM	Mumbai	7	11	18	-14	1	3	SIFM
PT_L_P_MH_PUN	Pune	3	4	7	-3	2	3	WIFM
PT_L_P_MP_IND	Indore	14	6	20	28	1	1	SILM
PT_L_P_OR_BHU	Bhubneswer	5	8	13	-10	2	3	WIFM
PT_L_P_PB_AMR	Amritsar	5	6	11	-3	2	3	WIFM
PT_L_P_PB_KHA	Khanna	6	6	12	0	2	2	WIPM
PT_L_P_RJ_AJM	Ajmer	12	5	17	24	1	1	SILM
PT_L_P_RJ_JAI	Jaipur	19	11	30	28	1	1	SILM
PT_L_P_RJ_JOD	Jodhpur	5	9	14	-14	2	3	WIFM
PT_L_P_RJ_UDA	Udaipur	6	9	15	-10	2	3	WIFM
PT_L_P_TN_CHE	Chennai	13	6	19	24	1	1	SILM
PT_L_P_UP_AGR	Agra	7	9	16	-7	1	3	SIFM
PT_L_P_UP_ALI	Aligarh	4	14	18	-34	1	3	SIFM
PT_L_P_UP_BAR	Bareilly	10	12	22	-7	1	3	SIFM
PT_L_P_UP_FAI	Faizabad	4	8	12	-14	2	3	WIFM
PT_L_P_UP_FAR	Farukhabad	8	7	15	3	2	2	WIPM
PT_L_P_UP_KAN	Kanpur	10	13	23	-10	1	3	SIFM
PT_L_P_UP_LUC	Lucknow	9	10	19	-3	1	3	SIFM
PT_L_P_WB_KOL	Kolkata	8	8	16	0	1	2	SIPM
Median value				16	-3.448			

Table 26: VAR results based on major market arrivals as control variable with 1 lag (Potato)

Market (1)	Market name (2)	Granger causing (3)	Granger caused by (4)	Total Integrated Markets (5) = (3) + (4)	% Difference to total number of markets (29) (6) = [(3)-(4)] / 29	Test for integration (7)	Test for leadership (8)	Final Market category (9)
PT_L_P_BH_PAT	Patna	9	7	16	7	1	1	SILM
PT_L_P_CH_RAI	Raipur	10	7	17	10	1	1	SILM
PT_L_P_DL_DEL	Delhi	10	10	20	0	1	2	SIPM
PT_L_P_GJ_AHM	Ahmedabad	4	10	14	-21	1	3	SIFM
PT_L_P_GJ_RAJ	Rajkot	9	7	16	7	1	1	SILM
PT_L_P_GJ_SUR	Surat	3	5	8	-7	2	3	WIFM
PT_L_P_JK_JAM	Jammu	16	5	21	38	1	1	SILM
PT_L_P_KR_BAN	Bangalore	4	5	9	-3	2	3	WIFM
PT_L_P_KR_BEL	Belgaum	1	4	5	-10	2	3	WIFM
PT_L_P_KR_HUB	Hubli	5	5	10	0	2	2	WIPM
PT_L_P_MH_MUM	Mumbai	5	8	13	-10	2	3	WIFM
PT_L_P_MH_PUN	Pune	5	3	8	7	2	1	WILM
PT_L_P_MP_IND	Indore	17	6	23	38	1	1	SILM
PT_L_P_OR_BHU	Bhubneswer	5	7	12	-7	2	3	WIFM
PT_L_P_PB_AMR	Amritsar	5	6	11	-3	2	3	WIFM
PT_L_P_PB_KHA	Khanna	5	6	11	-3	2	3	WIFM
PT_L_P_RJ_AJM	Ajmer	12	4	16	28	1	1	SILM
PT_L_P_RJ_JAI	Jaipur	15	7	22	28	1	1	SILM
PT_L_P_RJ_JOD	Jodhpur	4	8	12	-14	2	3	WIFM
PT_L_P_RJ_UDA	Udaipur	9	9	18	0	1	2	SIPM
PT_L_P_TN_CHE	Chennai	5	6	11	-3	2	3	WIFM
PT_L_P_UP_AGR	Agra	5	11	16	-21	1	3	SIFM
PT_L_P_UP_ALI	Aligarh	3	14	17	-38	1	3	SIFM
PT_L_P_UP_BAR	Bareilly	9	8	17	3	1	2	SIPM
PT_L_P_UP_FAI	Faizabad	4	8	12	-14	2	3	WIFM
PT_L_P_UP_FAR	Farukhabad	7	6	13	3	2	2	WIPM
PT_L_P_UP_KAN	Kanpur	9	10	19	-3	1	3	SIFM
PT_L_P_UP_LUC	Lucknow	6	7	13	-3	2	3	WIFM
PT_L_P_WB_KOL	Kolkata	6	8	14	-7	1	3	SIFM
Median value				14	-3.448			

Table 27: Final categorization of markets – Potato

Market	Market name	Only prices	All market arrivals	Major market arrivals	FINAL CATEGORY
PT_L_P_BH_PAT	Patna	SIFM	WIFM	SILM	**Not Clear**
PT_L_P_CH_RAI	Raipur	SILM	SILM	SILM	**SILM**
PT_L_P_DL_DEL	Delhi	SILM	SIPM	SIPM	**SIPM**
PT_L_P_GJ_AHM	Ahmedabad	SIFM	WIFM	SIFM	**SIFM**
PT_L_P_GJ_RAJ	Rajkot	SIPM	SIPM	SILM	**SIPM**
PT_L_P_GJ_SUR	Surat	WIFM	WIFM	WIFM	**WIFM**
PT_L_P_JK_JAM	Jammu	SILM	SILM	SILM	**SILM**
PT_L_P_KR_BAN	Bangalore	WIPM	WIPM	WIFM	**WIPM**
PT_L_P_KR_BEL	Belgaum	WIFM	WIFM	WIFM	**WIFM**
PT_L_P_KR_HUB	Hubli	WIFM	SIPM	WIPM	**Not Clear**
PT_L_P_MH_MUM	Mumbai	SIFM	SIFM	WIFM	**SIFM**
PT_L_P_MH_PUN	Pune	WIFM	WIFM	WILM	**WIFM**
PT_L_P_MP_IND	Indore	SILM	SILM	SILM	**SILM**
PT_L_P_OR_BHU	Bhubneswer	WIFM	WIFM	WIFM	**WIFM**
PT_L_P_PB_AMR	Amritsar	WIPM	WIFM	WIFM	**WIFM**
PT_L_P_PB_KHA	Khanna	WIPM	WIPM	WIFM	**WIPM**
PT_L_P_RJ_AJM	Ajmer	SILM	SILM	SILM	**SILM**
PT_L_P_RJ_JAI	Jaipur	SILM	SILM	SILM	**SILM**
PT_L_P_RJ_JOD	Jodhpur	WIFM	WIFM	WIFM	**WIFM**
PT_L_P_RJ_UDA	Udaipur	WIFM	WIFM	SIPM	**WIFM**
PT_L_P_TN_CHE	Chennai	SILM	SILM	WIFM	**SILM**
PT_L_P_UP_AGR	Agra	SIFM	SIFM	SIFM	**SIFM**
PT_L_P_UP_ALI	Aligarh	SIFM	SIFM	SIFM	**SIFM**
PT_L_P_UP_BAR	Bareilly	SIFM	SIFM	SIPM	**SIFM**
PT_L_P_UP_FAI	Faizabad	WIFM	WIFM	WIFM	**WIFM**
PT_L_P_UP_FAR	Farukhabad	WIFM	WIPM	WIPM	**WIPM**
PT_L_P_UP_KAN	Kanpur	SIFM	SIFM	SIFM	**SIFM**
PT_L_P_UP_LUC	Lucknow	SIPM	SIFM	WIFM	**Not Clear**
PT_L_P_WB_KOL	Kolkata	SIPM	SIPM	SIFM	**SIPM**

Table 28: Potato Markets (total 29)

	Leading/nodal	Peripheral	Following
Strongly integrated (Nationally important)	Jaipur (Raj), Jammu (J&K), Chennai, Ajmer (Raj), Indore (MP), Raipur (Chg)	Delhi, Rajkot (Guj), Kolkata (WB)	Ahmedabad (Guj), Mumbai (Mah), Kanpur (UP), Bareilly (UP), Aligarh (UP), Agra (UP)
Weakly integrated (Locally important)		Khanna (Pun), Bangalore (Kar), Farukkabad (UP)	Udaipur (Raj), Jodhpur (Raj), Bhubaneswar (Ori), Faizabad (UP), Surat (Guj), Amritsar (Pun), Belgaon (Kar), Pune (Mah)
Not clear (Important on a few criteria)	Patna (Bih), Lucknow (UP), Hubli (Kar)		

Figure 13: Strongly Integrated Markets (Potato)

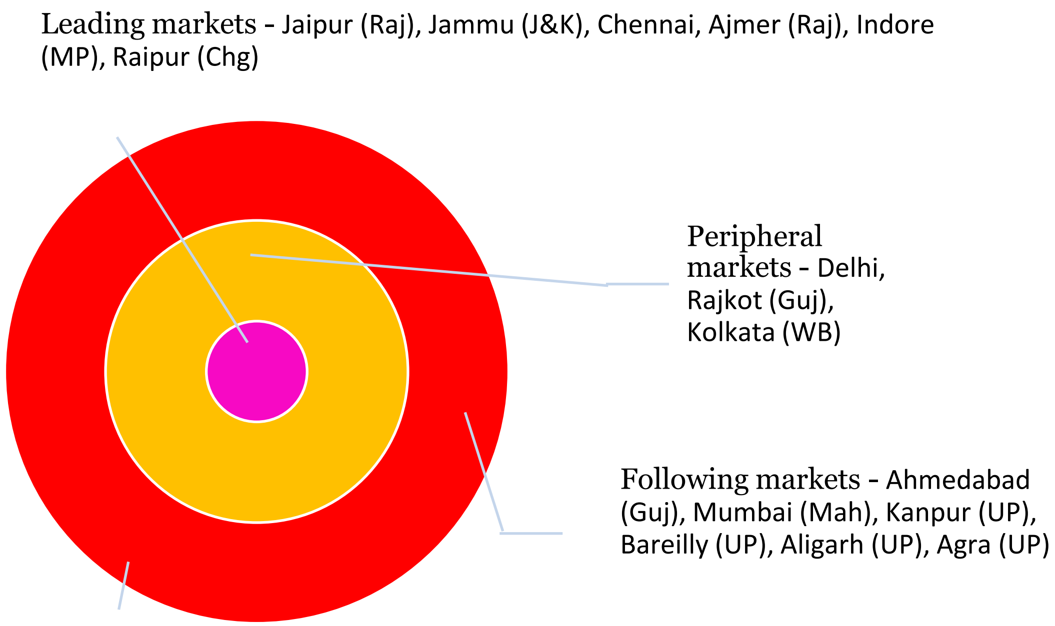
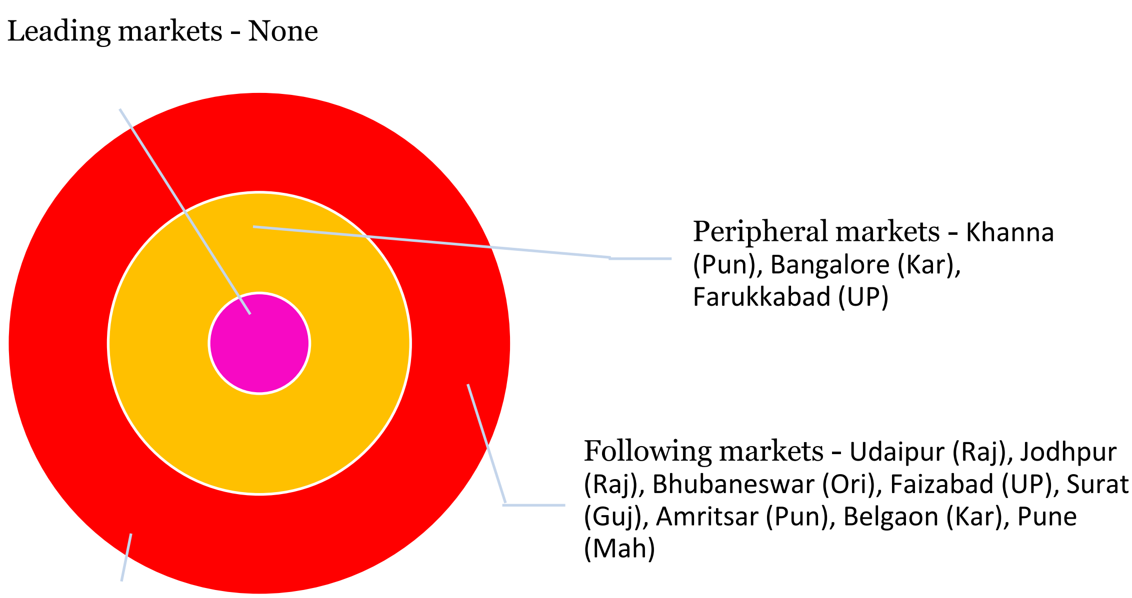


Figure 14: Weakly integrated markets (Potato)



7. Summary, conclusions and policy implications

Large and frequent movements in agricultural prices impact producers' income; consumers' economic access to food and governments' ability to plan exports / imports. Hence, monitoring of agricultural prices in general and food prices in particular is extremely important. The present study attempts to identify a set of nodal markets in order to facilitate easier price monitoring, based on a systematic econometric analysis.

The study applied the vector auto regression (VAR) / vector error correction (VECM) models and Granger–causality tests to identify the nodal markets. The study used secondary data on market arrivals and prices from the AGMARKNET database. The commodities covered in the study are tomato, onion and potato (the TOP commodities). The period of analysis is from January 2010 to December 2019.

A two-stage procedure based on market arrivals and prices has been used identifying the nodal markets. From a total of 169 tomato markets, 211 onion markets and 180 potato markets for which data is reported in the AGMARKNET database, 32 tomato markets, 25 onion markets and 29 potato markets have been selected in stage 1 based on market arrivals. From this set of markets, about nine tomato (Mulakala Cheruvu, Patna, Tiphra, Bowenpally, Delhi, Ahmedabad, Chintamani, Solapur, Kolhapur); eight onion (Ahmedabad, Pimplagaon, Lasalgaon, Rahuri, Solapur, Chennai, Agra, Malegaon); and six potato (Jaipur, Jammu, Chennai, Ajmer, Indore, Raipur) markets have emerged as the leading/nodal markets based on the VAR-GC analysis using prices. Peripheral and following markets have also been identified.

The main policy implication of the study is that it will be administratively and logistically more feasible if policymakers focus on the nodal and peripheral markets (that have been identified) to understand the market price dynamics of these commodities. This will help in timely decisions on production planning; exports and imports.

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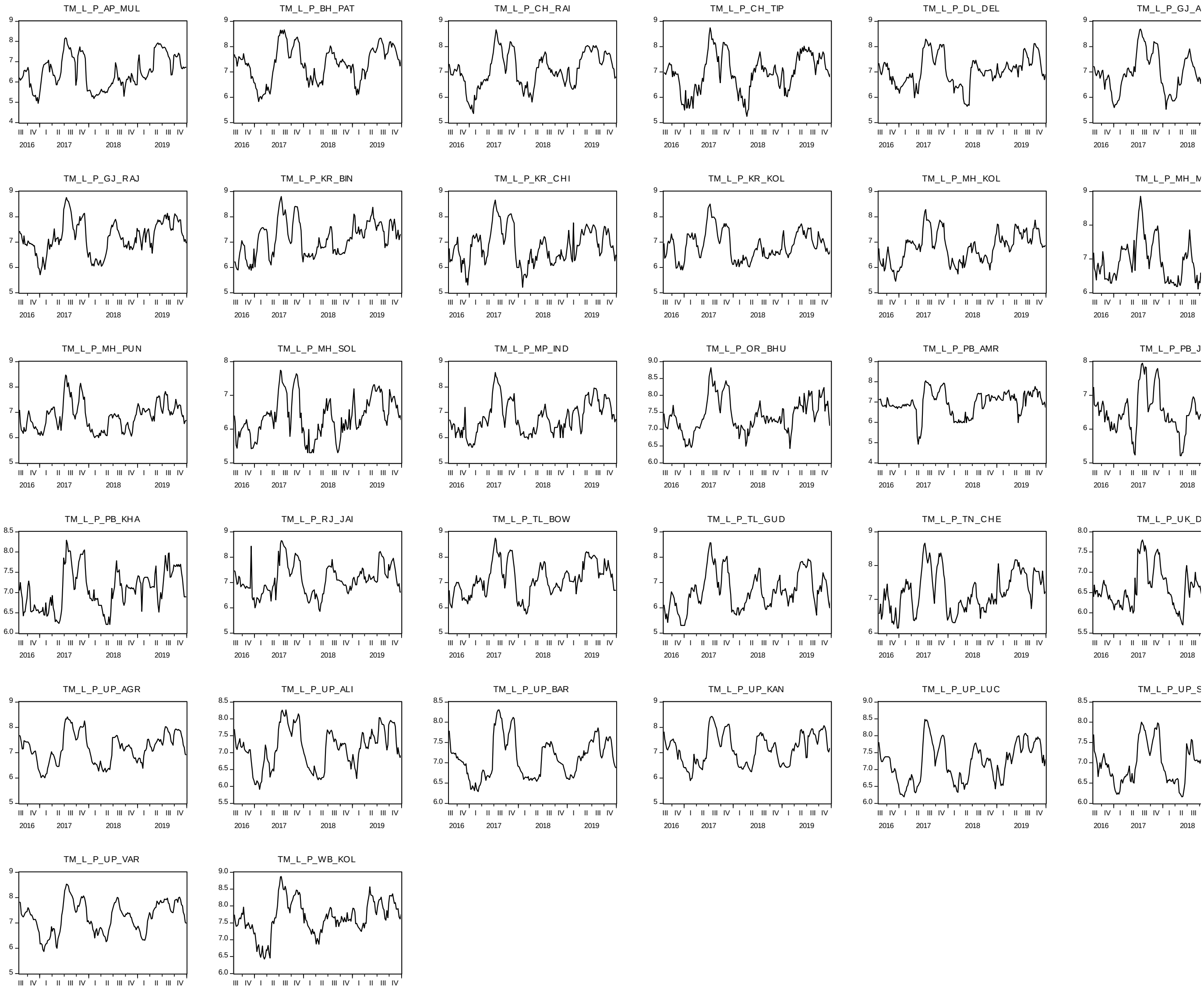
Appendix A: Tomato

A.1. Plots of price series show absence of a deterministic time trend in the data



A.2 Group unit root test: Summary

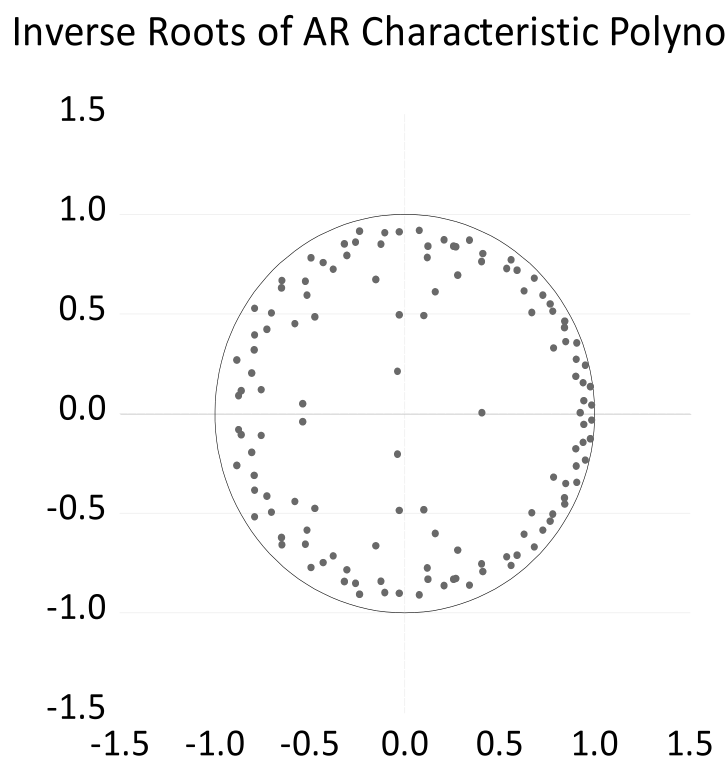
Unit root test assumes individual intercept and no deterministic time trend. **Results show that the price series are stationary**

Series: TM_L_P_AP_MUL, TM_L_P_BH_PAT, TM_L_P_CH_RAI, TM_L_P_CH_TIP, TM_L_P_DL_DEL, TM_L_P_GJ_AHM, TM_L_P_GJ_RAJ, TM_L_P_KR_BIN, TM_L_P_KR_CHI, TM_L_P_KR_KOL, TM_L_P_MH_KOL, TM_L_P_MH_MUM, TM_L_P_MH_PUN, TM_L_P_MH_SOL, TM_L_P_MP_IND, TM_L_P_OR_BHU, TM_L_P_PB_AMR, TM_L_P_PB_JAL, TM_L_P_PB_KHA, TM_L_P_RJ_JAI, TM_L_P_TL_BOW, TM_L_P_TL_GUD, TM_L_P_TN_CHE, TM_L_P_UK_DEH, TM_L_P_UP_AGR, TM_L_P_UP_ALI, TM_L_P_UP_BAR, TM_L_P_UP_KAN, TM_L_P_UP_LUC, TM_L_P_UP_SAH, TM_L_P_UP_VAR, TM_L_P_WB_KOL
Date: 03/02/22 Time: 17:35
Sample: 8/05/2016 12/27/2019
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 3
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-0.84660	0.1986	32	5641
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.53812	0.0000	32	5641
ADF - Fisher Chi-square	212.793	0.0000	32	5641
PP - Fisher Chi-square	215.671	0.0000	32	5664

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

A.3. The inverse AR roots of the Characteristic polynomial fall within the unit circle, indicating the stability of VAR



A.4 VAR Lag Order Selection Criteria

Endogenous variables: TM_L_P_AP_MUL TM_L_P_BH_PAT TM_L_P_CH_RAI TM_L_P_CH_TIP TM_L_P_DL_DEL TM_L_P_GJ_AHM TM_L_P_GJ_RAJ TM_L_P_KR_BIN TM_L_P_KR_CHI TM_L_P_KR_KOL TM_L_P_MH_KOL TM_L_P_MH_MUM TM_L_P_MH_PUN TM_L_P_MH_SOL TM_L_P_MP_IND TM_L_P_OR_BHU TM_L_P_PB_AMR TM_L_P_PB_JAL TM_L_P_PB_KHA TM_L_P_RJ_JAI TM_L_P_TL_BOW TM_L_P_TL_GUD TM_L_P_TN_CHE TM_L_P_UK_DEH TM_L_P_UP_AGR TM_L_P_UP_ALI TM_L_P_UP_BAR TM_L_P_UP_KAN TM_L_P_UP_LUC TM_L_P_UP_SAH TM_L_P_UP_VAR TM_L_P_WB_KOL

Exogenous variables: C

Date: 03/11/22   Time: 11:59

Sample: 8/05/2016 12/27/2019

Included observations: 174

Lag	LogL	LR	FPE	AIC	SC	HQ
0	989.7926	NA	6.02e-45	-11.00911	-10.42813	-10.77343
1	3628.462	4276.464	6.08e-53	-29.56853	-10.39633*	-21.79110*
2	4619.924	1242.176	2.57e-52	-29.19452	8.568895	-13.87536
3	5962.721	1188.453	1.92e-52	-32.85886	23.49578	-9.997953
4	8306.923	1212.518*	3.95e-55*	-48.03360*	26.91227	-17.63095

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

A.5. Group unit root test: Summary: Only Prices

The Group unit root test for residuals of VAR with prices shows that the residuals are stationary.

Series: RESID01, RESID02, RESID03, RESID04, RESID05, RESID06, RESID07, RESID08, RESID09, RESID10, RESID11, RESID12, RESID13, RESID14, RESID15, RESID16, RESID17, RESID18, RESID19, RESID20, RESID21, RESID22, RESID23, RESID24, RESID25, RESID26, RESID27, RESID28, RESID29, RESID30, RESID31, RESID32

Date: 03/02/22 Time: 17:40

Sample: 8/05/2016 12/27/2019

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0 to 1

Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-75.7737	0.0000	32	5627
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-70.1036	0.0000	32	5627
ADF - Fisher Chi-square	2794.79	0.0000	32	5627
PP - Fisher Chi-square	2854.00	0.0000	32	5632

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

A.6. Group unit root test: Summary: All market arrivals

The Group unit root test for residuals of VAR with prices and all market arrivals shows that the residuals are stationary

Series: RESID33, RESID34, RESID35, RESID36, RESID37, RESID38,
RESID39, RESID40, RESID41, RESID42, RESID43, RESID44,
RESID45, RESID46, RESID47, RESID48, RESID49, RESID50,
RESID51, RESID52, RESID53, RESID54, RESID55, RESID56,
RESID57, RESID58, RESID59, RESID60, RESID61, RESID62,
RESID63, RESID64

Date: 03/02/22 Time: 17:44

Sample: 8/05/2016 12/27/2019

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0 to 1

Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-76.8110	0.0000	32	5627
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-71.0259	0.0000	32	5627
ADF - Fisher Chi-square	2826.58	0.0000	32	5627
PP - Fisher Chi-square	2882.95	0.0000	32	5632

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

A.7. Group unit root test: Summary: Major market arrivals

The Group unit root test for residuals of VAR with prices and major market arrivals shows that the residuals are stationary

Series: RESID65, RESID66, RESID67, RESID68, RESID69, RESID70,
RESID71, RESID72, RESID73, RESID74, RESID75, RESID76,
RESID77, RESID78, RESID79, RESID80, RESID81, RESID82,
RESID83, RESID84, RESID85, RESID86, RESID87, RESID88,
RESID89, RESID90, RESID91, RESID92, RESID93, RESID94,
RESID95, RESID96

Date: 03/02/22 Time: 17:46

Sample: 8/05/2016 12/27/2019

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0 to 1

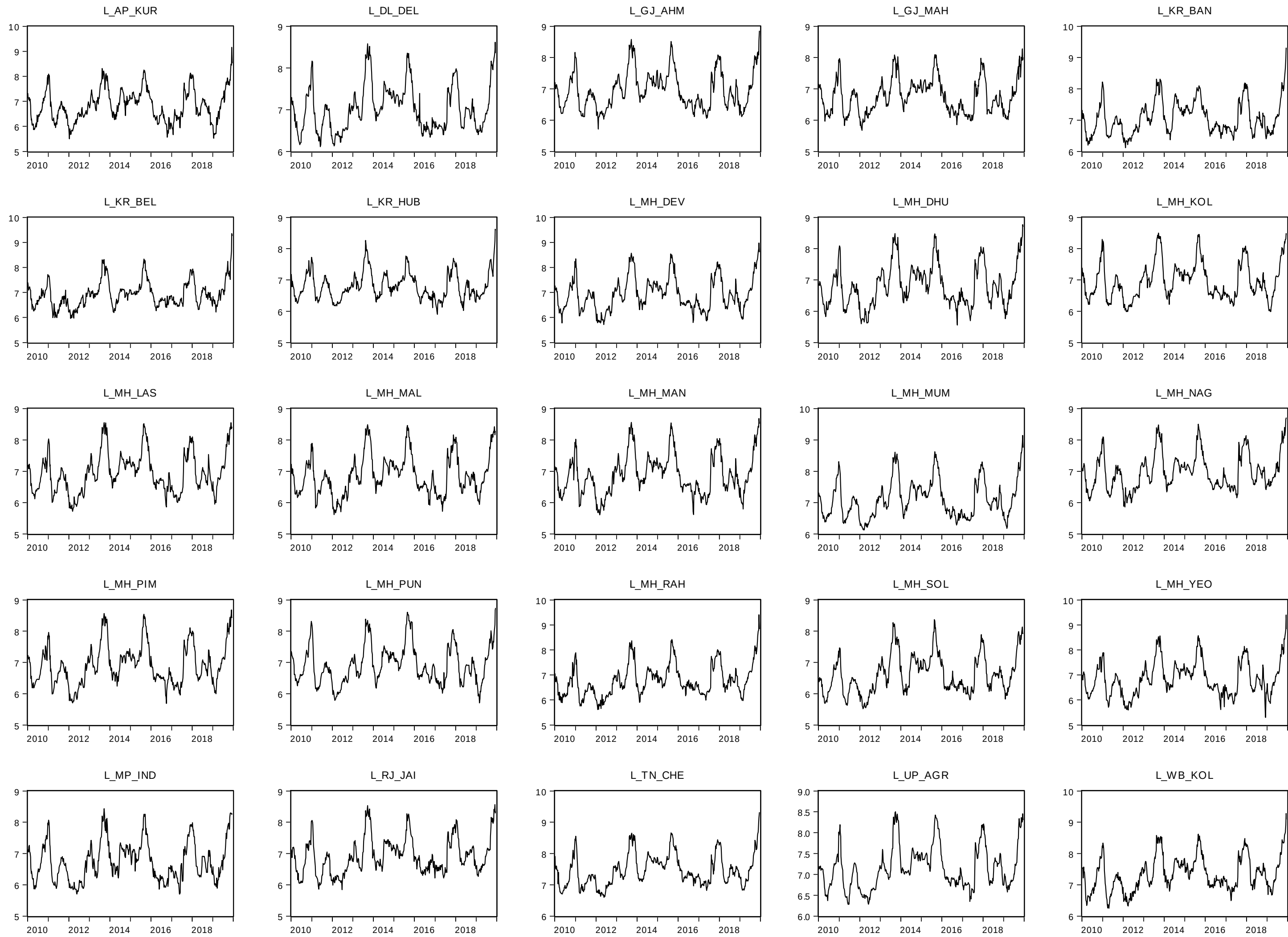
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-77.2892	0.0000	32	5628
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-71.1203	0.0000	32	5628
ADF - Fisher Chi-square	2832.93	0.0000	32	5628
PP - Fisher Chi-square	2876.56	0.0000	32	5632

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Appendix B: Onion

B.1. Plots of price series show absence of a deterministic time trend in the data



B.2. Group unit root test: Summary

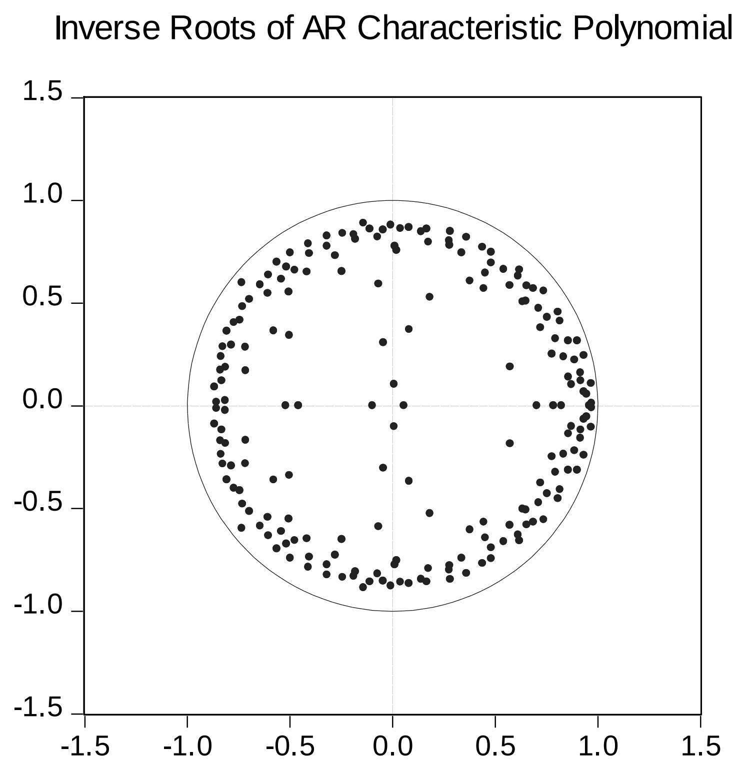
Unit root test assumes individual intercept and no deterministic time trend. **Results show that the price series are stationary**

Series: L_AP_KUR, L_DL_DEL, L_GJ_AHM, L_GJ_MAH, L_KR_BAN, L_KR_BEL, L_KR_HUB, L_MH_DEV, L_MH_DHU, L_MH_KOL, L_MH_LAS, L_MH_MAL, L_MH_MAN, L_MH_MUM, L_MH_NAG, L_MH_PIM, L_MH_PUN, L_MH_RAH, L_MH_SOL, L_MH_YEO, L_MP_IND, L_RJ_JAI, L_TN_CHE, L_UP_AGR, L_WB_KOL
Date: 12/13/20 Time: 00:41
Sample: 1/01/2010 12/27/2019
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 3
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	6.30064	1.0000	25	12949
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-5.97397	0.0000	25	12949
ADF - Fisher Chi-square	120.188	0.0000	25	12949
PP - Fisher Chi-square	169.449	0.0000	25	12975

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

B.3. The inverse AR roots of the Characteristic polynomial fall within the unit circle, indicating stability of VAR



B.4. VAR Lag Order Selection Criteria

Endogenous variables: L_AP_KUR L_DL_DEL L_GJ_AHM L_GJ_MAH L_KR_BAN L_KR_BEL L_KR_HUB L_MH_DEV L_MH_DHU L_MH_KOL L_MH_LAS L_MH_MAL L_MH_MAN L_MH_MUM L_MH_NAG L_MH_PIM L_MH_PUN L_MH_RAH L_MH_SOL L_MH_YEO L_MP_IND L_RJ_JAI L_TN_CHE L_UP_AGR L_WB_KOL
Exogenous variables: C
Date: 12/12/20   Time: 22:45
Sample: 1/01/2010 12/27/2019
Included observations: 512

Lag	LogL	LR	FPE	AIC	SC	HQ
0	7670.151	NA	1.65e-44	-29.86387	-29.65692	-29.78275
1	13124.17	10354.12	1.06e-52	-48.72724	-43.34655*	-46.61801*
2	13755.15	1136.244	1.05e-52*	-48.75057*	-38.19615	-44.61324
3	14219.46	790.7776	2.05e-52	-48.12288	-32.39472	-41.95744
4	14660.82	708.6031	4.54e-52	-47.40556	-26.50367	-39.21202
5	15148.72	735.6519	8.81e-52	-46.86999	-20.79436	-36.64834
6	15670.36	735.5970	1.60e-51	-46.46625	-15.21688	-34.21650
7	16197.54	691.9230*	3.10e-51	-46.08414	-9.661037	-31.80628
8	16734.49	652.3121	6.41e-51	-45.74020	-4.143361	-29.43424

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

B.5. Group unit root test: Summary: Only Prices

The Group unit root test for residuals of VAR with prices shows that the residuals are stationary.

Series: RESID01, RESID02, RESID03, RESID04, RESID05, RESID06,
RESID07, RESID08, RESID09, RESID10, RESID11, RESID12,
RESID13, RESID14, RESID15, RESID16, RESID17, RESID18,
RESID19, RESID20, RESID21, RESID22, RESID23, RESID24

Date: 03/02/22   Time: 17:09

Sample: 1/01/2010 12/27/2019

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-143.827	0.0000	24	12384
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-122.210	0.0000	24	12384
ADF - Fisher Chi-square	4068.82	0.0000	24	12384
PP - Fisher Chi-square	4068.30	0.0000	24	12384

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

B.6. Group unit root test: Summary: All market arrivals

The Group unit root test for residuals of VAR with prices and all market arrivals shows that the residuals are stationary.

Series: RESID25, RESID26, RESID27, RESID28, RESID29, RESID30, RESID31, RESID32, RESID33, RESID34, RESID35, RESID36, RESID37, RESID38, RESID39, RESID40, RESID41, RESID42, RESID43, RESID44, RESID45, RESID46, RESID47, RESID48, RESID49

Date: 03/02/22 Time: 17:11

Sample: 1/01/2010 12/27/2019

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-137.225	0.0000	25	12925
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-117.071	0.0000	25	12925
ADF - Fisher Chi-square	4265.15	0.0000	25	12925
PP - Fisher Chi-square	4264.14	0.0000	25	12925

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

B.7. Group unit root test: Summary: Major market arrivals

The Group unit root test for residuals of VAR with prices and major market arrivals shows that the residuals are stationary.

Series: RESID50, RESID51, RESID52, RESID53, RESID54, RESID55,
RESID56, RESID57, RESID58, RESID59, RESID60, RESID61,
RESID62, RESID63, RESID64, RESID65, RESID66, RESID67,
RESID68, RESID69, RESID70, RESID71, RESID72, RESID73

Date: 03/02/22 Time: 17:15

Sample: 1/01/2010 12/27/2019

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0

Newey-West automatic bandwidth selection and Bartlett kernel

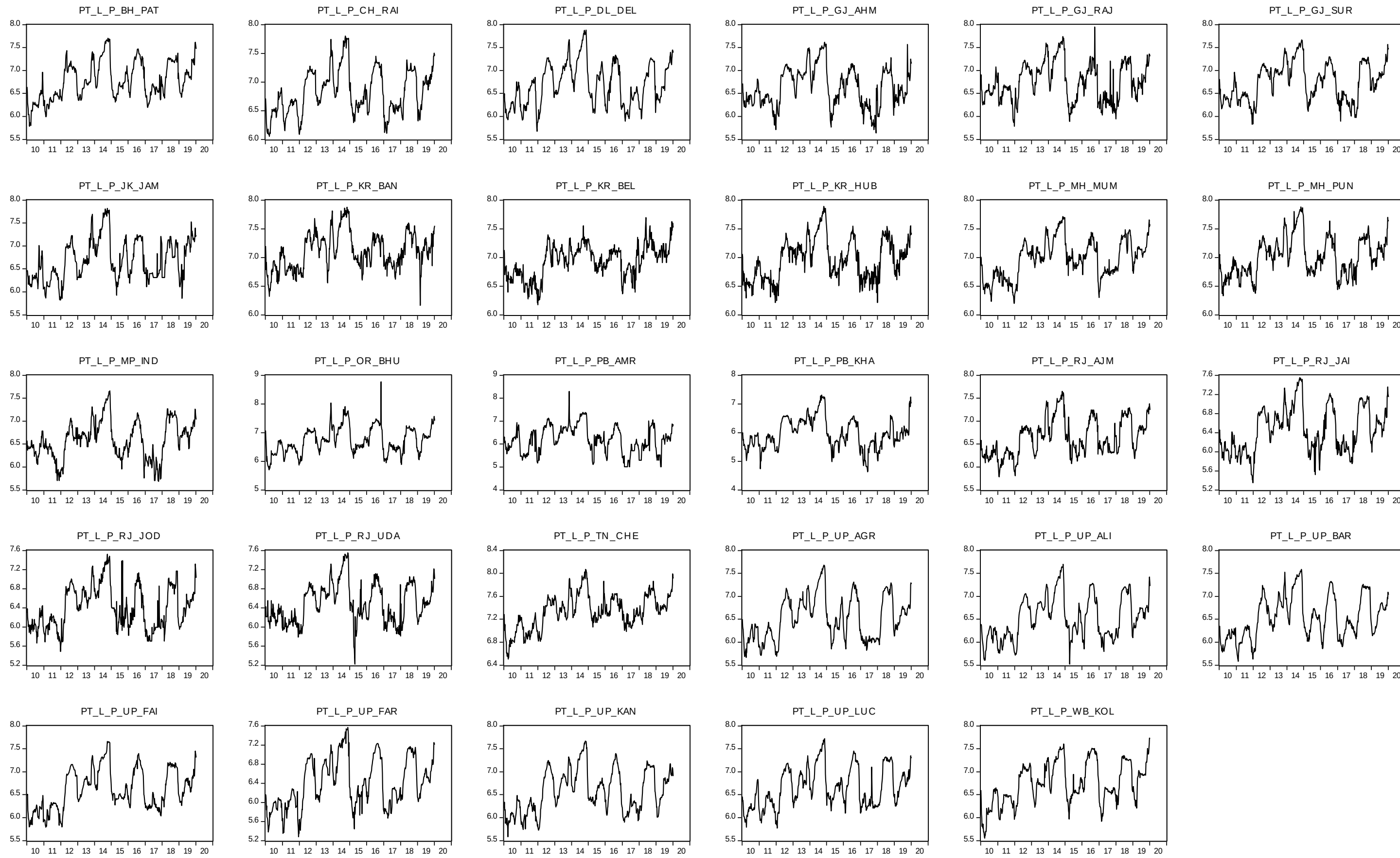
Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-134.566	0.0000	24	12408
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-114.564	0.0000	24	12408
ADF - Fisher Chi-square	4093.86	0.0000	24	12408
PP - Fisher Chi-square	4092.95	0.0000	24	12408

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

Appendix C: Potato

C.1. Plots of price series show absence of a deterministic time trend in the data



C.2. Group unit root test: Summary

Unit root test assumes individual intercept and no deterministic time trend. **Results show that the price series are stationary**

Series: PT_L_P_BH_PAT, PT_L_P_CH_RAI, PT_L_P_DL_DEL, PT_L_P_GJ_AHM, PT_L_P_GJ_RAJ, PT_L_P_GJ_SUR, PT_L_P_JK_JAM, PT_L_P_KR_BAN, PT_L_P_KR_BEL, PT_L_P_KR_HUB, PT_L_P_MH_MUM, PT_L_P_MH_PUN, PT_L_P_MP_IND, PT_L_P_OR_BHU, PT_L_P_PB_AMR, PT_L_P_PB_KHA, PT_L_P_RJ_AJM, PT_L_P_RJ_JAI, PT_L_P_RJ_JOD, PT_L_P_RJ_UDA, PT_L_P_TN_CHE, PT_L_P_UP_AGR, PT_L_P_UP_ALI, PT_L_P_UP_BAR, PT_L_P_UP_FAI, PT_L_P_UP_FAR, PT_L_P_UP_KAN, PT_L_P_UP_LUC, PT_L_P_WB_KOL

Date: 03/02/22 Time: 19:26

Sample: 1/01/2010 12/25/2020

Exogenous variables: Individual effects

Automatic selection of maximum lags

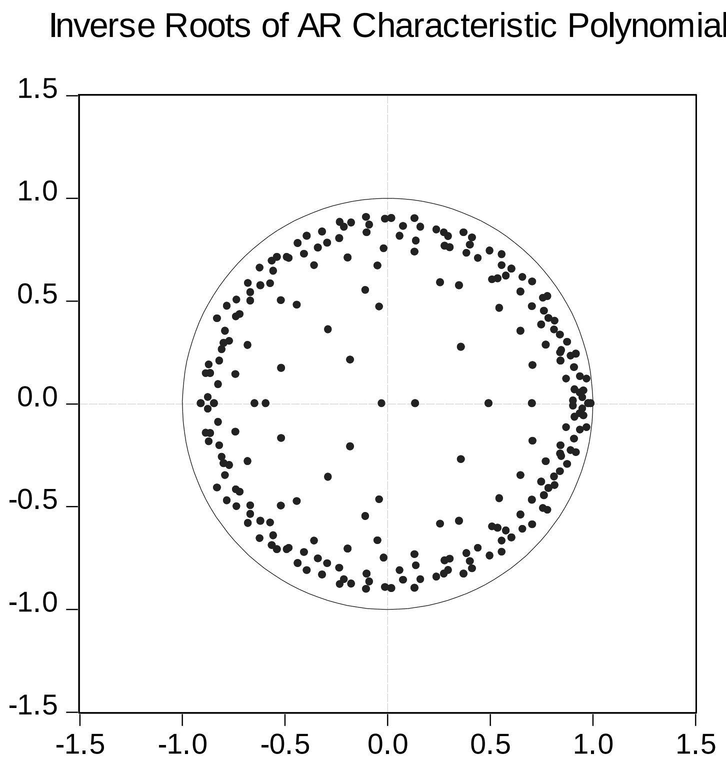
Automatic lag length selection based on SIC: 0 to 3

Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	1.22060	0.8889	29	15106
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.22193	0.0000	29	15106
ADF - Fisher Chi-square	199.375	0.0000	29	15106
PP - Fisher Chi-square	242.858	0.0000	29	15138

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

C.3. The inverse AR roots of the Characteristic polynomial fall within the unit circle, indicating the stability of VAR



C.4. VAR Lag Order Selection Criteria

Endogenous variables: PT_L_P_BH_PAT PT_L_P_CH_RAI PT_L_P_DL_DEL PT_L_P_GJ_AHM PT_L_P_GJ_RAJ PT_L_P_GJ_SUR PT_L_P_JK_JAM PT_L_P_KR_BAN PT_L_P_KR_BEL PT_L_P_KR_HUB PT_L_P_MH_MUM PT_L_P_MH_PUN PT_L_P_MP_IND PT_L_P_OR_BHU PT_L_P_PB_AMR PT_L_P_PB_KHA PT_L_P_RJ_AJM PT_L_P_RJ_JAI PT_L_P_RJ_JOD PT_L_P_RJ_UDA PT_L_P_TN_CHE PT_L_P_UP_AGR PT_L_P_UP_ALI PT_L_P_UP_BAR PT_L_P_UP_FAI PT_L_P_UP_FAR PT_L_P_UP_KAN PT_L_P_UP_LUC PT_L_P_WB_KOL
Exogenous variables: C
Date: 12/13/20 Time: 14:58
Sample: 1/01/2010 12/25/2020
Included observations: 515

Lag	LogL	LR	FPE	AIC	SC	HQ
0	8320.030	NA	1.88e-50	-32.19818	-31.95918	-32.10451
1	15603.33	13718.06	2.58e-61	-57.21681	-50.04705*	-54.40697*
2	16473.48	1540.935	2.36e-61*	-57.33004*	-43.22951	-51.80402
3	17119.26	1070.854	5.40e-61	-56.57187	-35.54058	-48.32968
4	17769.03	1004.317	1.30e-60	-55.82926	-27.86720	-44.87089
5	18444.89	968.5144	3.10e-60	-55.18794	-20.29512	-41.51339
6	19192.24	986.7813	6.35e-60	-54.82422	-13.00063	-38.43349
7	20026.07	1007.077*	1.09e-59	-54.79639	-6.042038	-35.68949
8	20827.03	877.1645	2.62e-59	-54.64088	1.044234	-32.81780

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

C.5. Group unit root test: Summary: Only Prices

The Group unit root test for residuals of VAR with prices shows that the residuals are stationary.

Series: RESID30, RESID31, RESID32, RESID33, RESID34, RESID35, RESID36, RESID37, RESID38, RESID39, RESID40, RESID41, RESID42, RESID43, RESID44, RESID45, RESID46, RESID47, RESID48, RESID49, RESID50, RESID51, RESID52, RESID53, RESID54, RESID55, RESID56, RESID57, RESID58

Date: 03/02/22 Time: 19:17

Sample: 1/01/2010 12/25/2020

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0 to 2

Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-128.505	0.0000	29	15100
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-109.885	0.0000	29	15100
ADF - Fisher Chi-square	4462.27	0.0000	29	15100
PP - Fisher Chi-square	4875.11	0.0000	29	15109

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

C.6. Group unit root test: Summary: All market arrivals

The Group unit root test for residuals of VAR with prices and all market arrivals shows that the residuals are stationary.

Series: RESID88, RESID89, RESID90, RESID91, RESID92, RESID93, RESID94, RESID95, RESID96, RESID97, RESID98, RESID99, RESID100, RESID101, RESID102, RESID103, RESID104, RESID105, RESID106, RESID107, RESID108, RESID109, RESID110, RESID111, RESID112, RESID113, RESID114, RESID115, RESID116

Date: 03/02/22 Time: 19:21

Sample: 1/01/2010 12/25/2020

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0

Newey-West automatic bandwidth selection and Bartlett kernel

Balanced observations for each test

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-161.541	0.0000	29	14906
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-134.665	0.0000	29	14906
ADF - Fisher Chi-square	4903.03	0.0000	29	14906
PP - Fisher Chi-square	4897.25	0.0000	29	14906

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

C.7. Group unit root test: Summary: Major market arrivals

The Group unit root test for residuals of VAR with prices and major market arrivals shows that the residuals are stationary.

Series: RESID59, RESID60, RESID61, RESID62, RESID63, RESID64, RESID65, RESID66, RESID67, RESID68, RESID69, RESID70, RESID71, RESID72, RESID73, RESID74, RESID75, RESID76, RESID77, RESID78, RESID79, RESID80, RESID81, RESID82, RESID83, RESID84, RESID85, RESID86, RESID87

Date: 03/02/22 Time: 19:19

Sample: 1/01/2010 12/25/2020

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic lag length selection based on SIC: 0 to 2

Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-139.428	0.0000	29	15101
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-116.740	0.0000	29	15101
ADF - Fisher Chi-square	4566.33	0.0000	29	15101
PP - Fisher Chi-square	4876.50	0.0000	29	15109

** Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.

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