Extended Abstract
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Paper/Poster Title	**Weather Anomalies and Price Transmission in Agricultural Supply Chain: Evidence from the Indian Onion Market**

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	***200 words max***
The effects of erratic and torrential rainfall patterns across India affect the production of onions, and in turn, prices. A VAR-X model is proposed that allows us to analyse the dynamic interaction between retail and wholesale onion prices along with onion arrivals to the market which are treated as endogenous variables and rainfall anomalies which enter as an exogenous variable. We conduct an analysis in four major Indian cities to examine the impact rainfall anomalies have on arrivals, wholesale and retail prices of onions and compare with the counterfactual where there is normal rainfall. We find that rainfall anomalies have a significant positive effect on onion prices within the range of 8 to 17 percent, whereas negative on arrivals ranging between 2 to 6 percent. Dynamic responses over a one-year time horizon are generated through simulations and we draw policy implications that can help both consumers and producers	

Keywords	Onion arrivals, retail prices, wholesale prices, rainfall, VAR-X
JEL Code	C32; Q11; Q13 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

This paper aims to develop a model that explores the interconnectedness of onion arrivals with retail and wholesale prices, considering the exogenous variable of rainfall anomalies, which have become increasingly frequent due to climate change. Given that onions are a staple ingredient in almost every Indian meal, any sharp increase in onion prices resonates with the government and its constituents, culminating into mass protests. There have been numerous instances of sharp increases in onion prices, resulting in a total of eleven protests by both producers and consumers. This inherent characteristic of agricultural prices poses risks for both farmers, who may adjust their production and input investments in response lower-income consumers, who allocate a significant portion of their income to food expenditures. This paper aims to test the following research questions: (i) If the government intervenes to stabilise onion prices in by adjusting minimum export prices, then are shocks to onion prices likely to be transitory in nature? (ii) How do arrivals cause wholesale and in turn retail prices? (iii) How do rainfall anomalies affect onion prices (both retail and wholesale) and arrivals of onions? We set up a VAR-X model to quantify these effects, linkages and responses. The results of these studies will be informative to policy makers given the huge political importance onions have on the population, especially the poorer strata, whether they be sellers or consumers.

Methodology | ***100 – 250 words***

We assume no contemporaneous correlation of onion supply A_t with prices (wholesale and/or retail) as the demand for onion is viewed as being highly inelastic. Wholesale and retail prices are affected by lagged arrivals and prices of wholesale and retail prices, which are predetermined variables. Accordingly, we can construct the structural model for the Indian onion market as follows:

$$P_t^R = \beta P_t^W + \rho A_t + \varphi_{RR} P_{t-1}^R + \varphi_{RW} P_{t-1}^W + \varphi_{RA} A_{t-1} + \eta_t^R \quad (1)$$
$$P_t^W = \zeta A_t + \varphi_{WR} P_{t-1}^R + \varphi_{WW} P_{t-1}^W + \varphi_{WA} A_{t-1} + \eta_t^W \quad (2)$$
$$A_t = \mu_{AR} P_{t-1}^R + \varphi_{AW} P_{t-1}^W + \varphi_{AA} A_{t-1} + \eta_t^A \quad (3)$$

where P_t^R,P_t^W and A_t denote retail prices, wholesale prices and availability of onions respectively. The structural error terms η_t^R, η_t^W and η_t^A are white noise.

We obtain a reduced form VAR to estimate the model and the relationship between the structural and reduced form errors is:

$$\begin{bmatrix} 1 & -\beta & -\rho \\ 0 & 1 & -\zeta \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{Rt} \\ \varepsilon_{Wt} \\ \varepsilon_{At} \end{bmatrix} = \begin{bmatrix} \eta_t^R \\ \eta_t^W \\ \eta_t^A \end{bmatrix} \quad (4)$$

Accordingly, we set out our VAR-X model with the vector R_T of rainfall deviations treated as exogenous, of the following form:

$$\begin{bmatrix} P_t^R \\ P_t^W \\ A_t \end{bmatrix} = \begin{bmatrix} A_{01} \\ A_{02} \\ A_{03} \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} P_{t-1}^R \\ P_{t-1}^W \\ A_{t-1} \end{bmatrix} + \begin{bmatrix} c_R R_{t-i} \\ c_W R_{t-i} \\ c_A R_{t-i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{Rt} \\ \varepsilon_{Wt} \\ \varepsilon_{At} \end{bmatrix} \quad (5)$$

where the parameters c_k $(k = R, W, A)$ measure the influence of lagged rainfall deviations on the variables. We assume $R_j = 0$ for $j >$ March 2022 and generate the forecasts over a 26-month period up to April 2024. We then take the average rainfall deviation over the last 26 months of the sample period and set this period average to be the values of R_j for $j >$ March 2022 over the forecast period and generate the forecasts. This procedure would allow us to measure and compare the impact of rainfall deviation on the prices and availability of onions. We further conduct an impulse response analysis on P_t^R, P_t^W, A_t in response to a 1 standard deviation structural shock.

Results | ***100 – 250 words***

First, we find the effects of shocks on both retail and wholesale onion prices are transitory. This implies that the government intervention to stabilise onion prices by adjusting minimum export prices causes any shocks to onion prices to be temporary. If the minimum export price is low, it is more profitable for farmers to export onions rather than sell them domestically, whereas if the minimum export price is high farmers find it difficult to export and instead sell the onions to the domestic market Therefore, through such intervention onion prices spikes should not be persistent, which is

supported by the results of the unit root tests and impulse response functions. Secondly, the causality of onion prices with arrivals varies by individual cities. We find that arrivals can have an ameliorating effect on onion prices, though the extent may differ among various cities. The finding that wholesale price leads the retail prices in two cities implies the wholesale market seems to quickly incorporate market signals from retail points. Finally, rainfall anomalies have significant positive effects on onion prices and negative effects on arrivals. The upward pressure on retail and wholesale prices is forecast to be between a range of 8% to 17% for all the cities. Rainfall anomalies cause a downward pressure on arrivals of onions in a range between 2% to 6%, except for Kolkata where arrivals of onions are not affected.

Discussion and Conclusion	***100 – 250 words***

We find the effects of shocks on both retail and wholesale onion prices are transitory. This implies that the government intervention to stabilise onion prices by adjusting minimum export prices causes any shocks to onion prices to be temporary. The causality of onion prices with arrivals varies by individual cities. Onion production tends to be largely concentrated in the north, western and southern parts of India. One might infer that the onion prices in Kolkata are likely to be affected by the comparatively higher transportation costs as opposed to other cities such as Mumbai, Delhi and Chennai. Distance from the producing centre and a lot more variability (irregularity) in onion arrivals could have promoted an increase in transmitting price and quantity signals for Kolkata. Also, our results suggest, given the distance of Kolkata from other major onion producing regions as well as inadequate storage facilities, wholesalers must be prompt in reading signals such as prices and arrivals to make decisions. For all the cities, wholesale prices do not tend to respond to retail price shocks; however, retail prices do respond significantly to wholesale price shocks for all the cities except Chennai. Rainfall anomalies have significant positive effects on onion prices and negative effects on arrivals. Therefore, advance information on weather to the farmers can prove to be useful to help farmers prepare their planting decisions and for wholesalers and retailers along the supply chain to make their decisions regarding storage, supply and price expectations.