Assessing the Relationship between Public Stockholding and Market Price Dynamics:

The Case of Wheat Market in India

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Introduction

Price volatility, which generally reflects the market response to unanticipated shocks under inelastic short-run supply and demand, also is affected by the behaviour of inventory holders, private and public, in reaction to anticipated price movements. For instance, stockholders, including public stockholding, can reduce the prospects of future price spikes and thereby smooth consumption (Chavas and Li, 2020; Knittel and Pindyck, 2016; Gouel, 2013; Cafiero et al., 2011; Benirschka and Binkley, 1995; Gustafson, 1958; Deaton and Laroque, 1992, 1996; Williams and Wright, 1991; Gardner, 1979). The empirical evidence suggests that price spikes tend to coincide with low stock-to-use ratio (Von Braun and Torero, 2009; Wright, 2011; Bobenrieth, Wright, and Zeng, 2013), leading to a government's intervention in commodity markets (Gouel, 2013; Headey, 2011; Newberry and Stiglitz, 1981). Government intervention in setting or influencing agricultural prices is pervasive around the world. Perhaps more noteworthy is India's agriculture and its increasing reliance on price support programs and public stock policies for food grains.[1]

In India, food price sensitivity arises from the fact that food represents a significant share (around 45 percent) of the expenditure of average households.[2] Thus, price changes have a larger effect on the purchasing power and standard of living of Indian households than on those of households in other countries, (NSSO, 2013). On the production side, even today, more than half of the country's agricultural land depends on monsoons for irrigation. Any deviation in the amount of monsoon rain from its long-period average raises serious concerns

[1] Many countries worldwide have reduced or eliminated the practice of public stockholding as a part of their structural adjustment measures and market liberalization in the 1980s and 1990s (Anderson, Rausser and Swinnen, 2013).

[2] India is perhaps is the only country where an increase in onion prices can lead to a government's failure (Desai, 1999).

for the government (Gulati and Saini, 2015). Thus, it is unsurprising that intervening in stabilising food grains has been an age-old practice in India with a significant economic impact.

India currently operates the world's largest public stockpiling and distribution programme for agricultural commodities, covering approximately two-thirds of the population[3] (Banga and Sekhar, 2015; Hopewell, 2021). The objectives of the public stockpiling programme include regulating the domestic supply of food grains through adjustments in procurement, distribution, and stock levels, thus ensuring price stability, providing food security for billions of Indian consumers, and supporting farmers' income and livelihood (ICTSD 2016). India's reliance on such public stockholding programmes has only increased over the years. Since the early 2000s, India's public stock of food grains has increased significantly, cementing the government's greater involvement in the marketplace (Figure 1). For instance, between 2007-08 and 2012-13, public stock levels in food grains tripled and are still well above the buffer norms set by the government. The trajectory of the stock-to-use ratio and the wholesale market price of wheat further reveals that price spikes coincide with a low stock-to-use ratio (Appendix Figure 1). Appendix Figure 1 indicates that during 1991-2020, wheat prices spiked in the mid-1990s and went through several booms and busts after 2006. However, the impact of stockpiling food grains on price stabilization in India is still an unanswered question. The difficulty arises because government operations in India do not follow formal price band stabilisation rules.[4] To the best of our knowledge, in the context of India, the effect of public stockholding on commodity price dynamics remains a

[3] Expanded significantly with the introduction of Food Security Act of 2013.
[4] Public stocks are typically part of price support policy and are accumulated when the market price falls below the government-announced support price. Similarly, the government releases grain in the market and depletes its stock if the market price goes beyond the ceiling price (Gardner, 1987). Thus, public stocks are meant to maintain the market price within a specified band. However, in India, since the quantity sold through public distribution system is determined independent of the quantity needed to achieve the specific target of open market price, market price stabilisation is eventually a less important objective. The focus of the strategy is more on income redistribution in favour of the poor by lowering the food price for the eligible group (Dorosh, 2008).

poorly understood subject. Specifically, how stockholding policies affect domestic price distribution and volatility remains unclear.

Thus, the objective of the study is to examine how previous stock levels can affect the distribution and volatility of the market price. The study uses data from the 1990-2020 Indian wheat market. To analyse the effect of a stockholding programme on commodity price dynamics and volatility, we use a reduced-form representation[5] of price dynamics. The analysis uses the quantile autoregression (QAR) model proposed by Koenker and Xiao (2006). Quantile autoregression provides a refined and flexible representation of the price distribution and dynamics over the period. Unlike the traditional time series analysis based on the mean-variance approach, the quantile autoregression approach allows us to measure volatility based on whole price distributions (i.e., mean, variance, skewness, and tails of the distribution). Quantile autoregression analyses the odds of being in the tails of the price distribution, including the lower tails (busts) and upper tails (spikes) of distribution.

The price dynamics use lagged stock by including past prices to affect the current price distribution in the context of quantile autoregression. Since the regression is conditional on lagged stocks, it allows us to investigate the effect of previous public stock levels on price dynamics. In other words, a release of the previous public stock increases the current availability of the commodity and, in turn, puts downward pressure on prices and produces a leftward shift in the price distribution. We attempt to capture the effect of change in policy by examining the impact of different stock levels on price distribution and dynamics. To the best of our knowledge, this is the first application of the quantile autoregression approach in agricultural commodity price dynamics in the context of India.

Empirical Framework

[5] The reduced-form representation of price determination is derived from equating aggregate supply with aggregate demand and then expressing the equilibrium price as a function of some macroeconomic and sectoral fundamentals. Studies done by scholars like Deaton and Laroque (1992), Holtham (1988), Stein (1986), and Turnovsky (1983) provide the theoretical foundation of the model.

In the literature, there are two approaches to modeling agricultural prices. The first approach, the structural approach, estimates supply, demand, and market equilibrium. The second approach, known as the non-structural approach, is a reduced-form representation for variables from time-series data. The reduced-form representation has an advantage over the structural approach because a direct measurement of the demand-and-supply equation is not required. A reduced-form equation gives a valid representation of the net effects of past prices and stock policy S_t on current price P_t at time t as given by Equation (1)

$$P_t = f_t (P_{t-1},\dots, P_{t-n}; S_t; e_t) \tag{1}$$

where $Pt \in \mathbb{R}_+$ is the commodity market price at time t. We assume that price (P_t) evolves according to the n^{th}-order difference equation. The variable S_t reflects the nature of government stock policy. e_t is an independent and identically distributed random variable with a given distribution function and represents the effects of unobservable factors. Equation (1) is reduced-form representation for price determination (Zellner and Palm 1974) and consistent with the structural model in which the price is determined by equating supply (i.e., production minus change in stock) with demand. The specification in Equation (1) allows for dynamics in prices (P_t), exogenous changes (i.e., change in public stock) captured by S_t,, along with a stochastic shock represented by the random variable (e_t).

The variable S_t,, which reflects the nature of government stock policy, is measured by the level of lagged stock with the public agency. The inclusion of lagged stock allows one to investigate the effect of the previous stock level on current pricing. The release of the previous stock increases the current availability and is likely to put downward pressure on current prices. Therefore, lagged stocks S_{t-1} are included as predetermined explanatory variables. Alternatively, Equation (1) can be written in the below-mentioned form of a first-order difference equation:

$$w_t \equiv \begin{bmatrix} p_t \\ p_{t-1} \\ . \\ . \\ . \\ p_{t-n+1} \end{bmatrix} = \begin{bmatrix} f(p_{t-1,}\ p_{t-n,} S_t\ , e_t) \\ p_{t-1} \\ . \\ . \\ . \\ p_{t-n+1} \end{bmatrix} \equiv H_t(w_{t-1}, S_t, e_t) \quad (2)$$

Assuming differentiability of $H_t(w_{t-1}, S_t, e_t)$, the derivative of $H_t(w_{t-1}, S_t, e_t)$ with respect to w_{t-1} describes the nature of price dynamics. The dynamics are considered stable if the root is less than 1 and unstable if the root is greater than 1. Assuming that $\lambda_1(w_{t-1}, S_t, e_t, t)$ is the root of the dynamic system, the system is considered locally stable when its root is less than 1 and locally unstable when its root is greater than 1. In this context, the value of the modulus of the root provides information with respect to the speed of dynamic adjustments and its logarithm regarding the rate of divergence of prices (P_t) along a forward path in the neighbourhood.

Based on the reduced-form equation in (1) or (2), the conditional distribution function can be defined as $F(c|P_{t-1},\ldots,P_{t-n}; S_t, t) = Prob[P_t \leq c\ |P_{t-1},\ldots,P_{t-n}; S_t, t] = Prob[f_t\ (P_{t-1},\ldots,P_{t-n}; S_t, e_t) \leq c|P_{t-1},\ldots,P_{t-n}; S_t, t]$. Its inverse function corresponds to the associated conditional quantile function, which can be denoted as $Q(q|P_{t-1},\ldots.P_{t-n}; S_t, t) \equiv \inf_c \{c: F(c|\ P_{t-1},\ldots.P_{t-n}; S_t, t) \geq q\}$ where q is the q^{th} quantile, q € (0,1). When q=0.5, it refers to conditional median $Q(0.50|P_{t-1},\ldots.P_{t-n}; S_t)$. Under the general specification of price dynamics as given in Equation (1), a complete characterisation of price dynamics can be presented by both the distribution function $F(c|P_{t-1},\ldots,P_{t-n}; S_t, t)$ and the quantile function $Q(q|P_{t-1},\ldots.P_{t-n}; S_t, t)$. While analysing the effect of stock policy on the price dynamics P_t, we extensively used the quantile function $Q(q|P_{t-1},\ldots.P_{t-n}; S_t, t)$. We have considered the following specification for the quantile function:

$$Q(q|Y_{t-1}, S_t) = \alpha(q) + \beta(q)Y_{t-1} + \gamma(q)h(Y_{t-1}\ , S_t) \quad (3)$$

where $Y_{t-1} = P_{t-1},\ldots.P_{t-n}$. Equation (3) is linear in the parameters (α, β, γ). Equation 3 can be estimated using quantile regression as proposed by Koenker (2005); Koenker and Xiao (2006) for a given specification of (h) and conditional on $(Y_{t-1}\ , S_t)$. It provides a flexible representation of price dynamics. For instance, $Q(0.5|Y_{t-1}, S_t)$ shows the median price conditional on (Y_{t-1}, S_t) and under symmetric price distribution, this would be the conditional mean. Furthermore, in situations in which the parameter β is constant across quantiles, then Equation (3) reduces to a vector autoregressive model (VAR).

Equation (3) is a generalized form of the standard time series model on at least three accounts. First, allowing parameter α to vary across quantiles provides arbitrary marginal distribution functions for P_t. Second, the moments of the price distribution, including mean, variance, skewness, and kurtosis, can be represented by parameter β provided it varies across quantiles. This is very useful while analysing the evolution of price volatility. Third, structural changes and possible nonlinear dynamics can be captured by the parameter γ. Therefore, in sum, Equation (3) provides a flexible representation of the dynamics of the price distribution.

Description of Data

The quantile autoregression model is applied to quarterly data of wheat market prices from April 1991 to September 2020. The data on monthly prices were taken from the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India (GoI) and refer to the month-end wholesale market price of the Farm/Mexican/Red wheat in Punjab. The analysis is based on real prices, i.e., market prices divided by the Consumer Price Index (CPI = 100 in 1982). Since the study analyses the impact of the previous stock level on the dynamics of the current price, the quarterly data on public stock for wheat was collected from the database on food grains stock in the central pool maintained by the Food Corporation of India. We defined the public stock S_t as the stock-to-use ratio in the Indian market at time t. The total use is defined as total supply (i.e., opening stock + production + import) minus end stock. Summary statistics of the variables used in the analysis are reported in Table 1.

Results and Discussion

The analysis result in Table 2 shows the effect of lagged public stock S_{t-1} on current price P_t. It is argued that there is no causality running from the current price (P_t) to past stock (S_{t-1}), because recent events cannot cause the past. The evaluation of the effects of public stockholding on the distribution of agricultural prices is based on the quantile autoregression model as specified in Equation (3). We started the analysis to assess the underlying price dynamics by estimating autoregressive (AR(m)) processes. Table 2 reports the estimates of AR(m) models for lagged prices up to m periods, m=1,2,3,4. The model includes lagged stock, quarterly dummies (Q_1, Q_2, and Q_3) representing seasonality factors, and a dummy for time trend (T) capturing structural break starting in 2010, reflecting a greater reliance on public stockholding policies. In addition, the model specification includes (1) an interaction term of lagged stock and lagged price ─ capturing the stock effect on price dynamics ─ and (2) the square of lagged stock reflecting the nonlinear stock effects.

The analysis result of alternative AR(m) models is reported in Table 2. The result shows that the AR models have good explanatory power: the R square varies between 0.83 and 0.87. It provides strong evidence of price dynamics as the coefficient of the number of lagged prices is significant. Also, a significant coefficient associated with lagged stockholding shows that stockholding affects the price. Finally, the analysis reports that time trends and seasonal dummies significantly affect price distribution. The Bayesian Information Criterion (BIC) applied to alternative AR(m) models shows that the BIC value is minimum for m=1. This indicates that the AR (1) model provides a good representation of wheat price dynamics in India. Therefore, the subsequent analysis of price dynamics is based on the AR(1) model, i.e., the model includes one price lag.

Next, the QAR model was estimated with one price lag, as specified in Equation (3). The quantile regression provides estimates of the conditional distribution functions for wheat prices. In turn, this gives us a basis to investigate the distribution of wheat prices and the factors affecting its evolution over time. The quantile regression estimates are presented in Table 3 for selected quantiles q = (0.1, 0.3, 0.5, 0.7, 0.9) along with the ordinary least squares (OLS) estimate for comparison purposes. As expected, the lagged-one price shows a statistically significant coefficient for all selected quantiles, thereby revealing the importance of dynamics. Table 3 also reports the effect of public stockholding on wheat price distribution. Results show that lagged stockholding S_{t-1} affect wheat prices. However, such an effect varies across the entire price distribution (quantiles). For instance, stockholding effects on wheat prices were statistically significant in quantiles 0.1 and 0.7 but not 0.9. Thus, indicating that the public stockholding policy design and implementation helped prevent very low prices but was unsuccessful in preventing price spikes. Nonetheless, the OLS estimate shows a significant impact of stock on the mean price.

To assess the statistical relevance of the analysis, we conducted a series of tests on the estimated quantile autoregression (1) model, as reported in Table 4. First, we tested whether parameter estimates vary across quantiles, with a null hypothesis of no parameter variation across quantiles. Using a Wald test, the result shows strong evidence that parameter estimates vary across quantiles (0.1 to 0.9), with a *p*-value of 0.00. We obtained a similar impact when tested only for selected quantiles, i.e., 0.3, 0.5, 0.7 and 0.9. This indicates that price dynamics vary across the quantiles, i.e., different parts of the price distribution.

Second, the estimated model was also tested for seasonality and the effects of lagged stockholding. Results in Table 4 show strong statistical evidence of seasonality, reflecting the seasonality of agricultural production. However, the lower tail of the price distribution (e.g., q=0.1 and q=0.3) shows strong evidence of such effects. The test result also provides statistical evidence of lagged stockholding S_{t-1} affecting current prices. In particular, the previous year's public stockholding (lagged stockholding variable) was statistically significant in quantiles q=0.1 and q=0.7. The next section of the paper discusses the economic implications of these effects.

Implications of policy effects on price distribution

The quantile estimation provides useful information on the effect of the stockholding program on market price distribution and its dynamics. To evaluate, we re-estimated the QAR (1) model for all quantiles, providing the basis to assess the conditional distribution function of prices. Considered at three data points (i.e., 2000, 2010, and 2020) for January to March quarter, the estimated distribution functions are reported in Figure 3. Figure 3 shows that the distribution function shifted between 2000, 2010, and 2020: they have much higher medians in 2010 than in 2000 and 2020, showing the highest wheat price increase in 2010. Figure 4 depicts the estimated conditional distribution for the chosen quantiles (0.1, 0.3, 0.5, 0.7, 0.9) over the sample period, i.e., 1991-2020. The simulated median wheat price shown in Figure 4 is very close to the actual price, indicating that the QAR model provides a very good fit for the data.

Using QAR estimates of the price distribution, we assessed the associated moments of price. The estimated standard deviation and skewness of price over the period 1991-2020 are reported in Figure 5. The small standard deviation of the price reported in Figure 5 indicates that the QAR model fits the data well. Figure 5 also shows that the probability distribution of price is not symmetric: it is positively skewed, reflecting that the probability of being in the upper tail of the distribution ("high price") is higher than the probability of being in the lower tail ("low price"). We tested the null hypothesis that the distribution is symmetric (i.e., with zero skewness) and rejected this hypothesis at the 10 percent significance level. Finding that the conditional distribution of price is skewed stresses the need to go beyond mean and variance in the analysis of price dynamics. These results underscore the flexibility of the QAR approach in accessing policy effects on price risk.

Further, we used the estimated quantile functions to simulate an alternative public stockholding scenario to evaluate the counterfactual effects on the price distribution, holding other variables constant. To simulate the price distribution, we considered two scenarios, namely, average stockholding (stockholding distributions between 0.35 and 0.70 quantiles) and high stockholding (greater than 0.70 quantiles) from the sample data. The analysis takes the lagged prices as given, thus referring to short-term analysis. We evaluated both scenarios corresponding to a point, i.e., January-March 2000.[6] Figure 6 illustrates the impact on the price distributions under alternative stockholding levels. The figure shows that the whole price distribution, including the median and both tails, shifts to the left with increased public stockholding. Thus, having larger initial public stockholding has a negative impact on the entire price distribution. A plausible explanation is that larger initial public stockholding increases the quantity currently available for markets, thus putting downward pressure on wheat prices. Figure 6 shows that such effects were more in the lower tail of the price distribution than the upper tail. The finding confirms the earlier result that public stockholding policy is more effective when prices are very low. Alternatively, the price distribution tends to shift to the right with a decrease in stockholding S_{t-1}.

The nature and speed of dynamic adjustments can be assessed by evaluating the marginal effect of P_{t-1} , i.e., $\partial P_t/\partial P_{t-1}$ and captured by the coefficient of lagged price P_{t-1}. . It varies both across quantiles and regimes, i.e., level of stockholding. As $|\partial P_t/\partial P_{t-1}|$is the root of the dynamic system, and local stability (instability) of the system occurs when the root is less than 1 (greater than one). Based on the quantile estimates of Equation (3), we evaluated the dominant root under alternative stockholding scenarios. The estimated roots are presented in Figure 7 for different quantiles. It shows some interesting patterns. First, the root is below 1

[6] We also considered the alternative evaluation points to check the robustness of our analysis. However, our qualitative findings did not change and were similar.

for all quantiles under both stock scenarios, meaning wheat market price exhibits dynamic stability. Second, the root tends to be smaller under the high stock regime, indicating that dynamic adjustments in market prices are more stable when stocks are in the upper quantile of the stockholding distribution. Third, when stocks are in the lower quantile of their distribution, the root tends to be close to one for median and higher quantiles. Thus, in a low stockholding regime, the dynamics appear to be locally more stable but only in the lower tail of the distribution. Hence, reflecting that dynamic adjustment tends to be qualitatively different across stock regimes with evidence of a reduction of dynamic local stability, especially under the low stockholding regime and when $q>=0.5$. A plausible explanation is that once stocks are low, they cannot impact the market via government sales intervention.

Conclusions

The study shows that the previous stock level in wheat significantly affects the current price of wheat. However, the effects vary in different parts of the wheat price distribution. Our results showed that public stockholding had prevented very low wheat prices but had not prevented price spikes. This could be attributed to India’s policy of selling wheat and other major crops through the public distribution system determined independently of the quantity needed to achieve a specific wheat price target in the open market. The focus of the stockholding strategy is more on income redistribution. Second, the analysis shows how stockholding can help reduce agricultural price volatility. Third, the research indicates that increasing stockholding tends to shift the whole price distribution to the left. A plausible explanation is that having larger initial stockholding increases the quantity currently available, putting downward pressure on prices. However, such effects were more in the lower tail of the price distribution than the upper tail.

Thus, findings from this study showed that stockholding is more effective when prices are very low. Alternatively, the price distribution tends to shift to the right with a decrease in the previous year's stockholding of wheat. The analysis provides evidence of local dynamic stability in price distribution for all quantiles under both stockholding scenarios. However, dynamic price adjustments are locally more stable when stockholdings are in the upper quantile of their distribution. Thus, reflecting that dynamic price adjustments tend to be qualitatively different across stockholding regimes.

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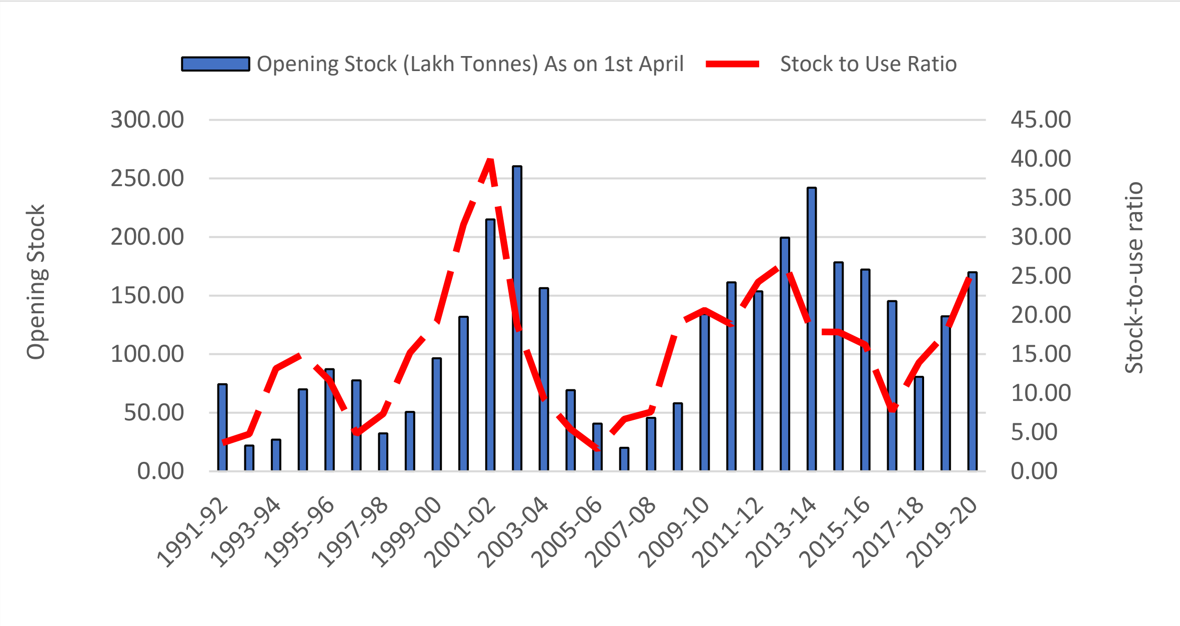
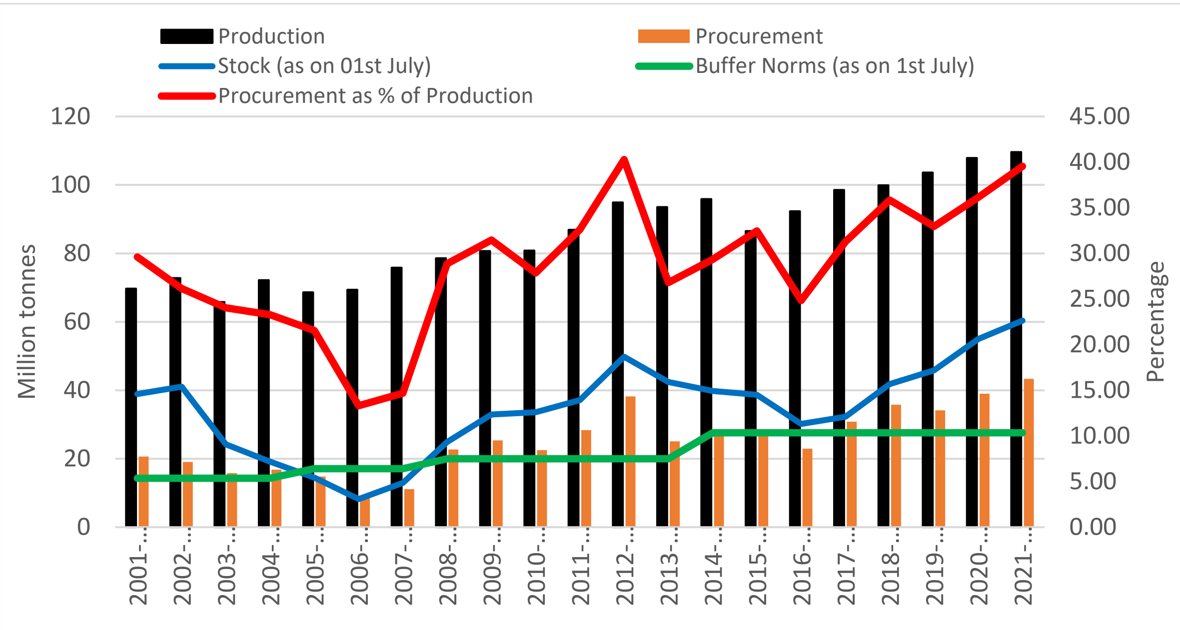
Figure 1: Wheat Stock level, India 1991-2020.



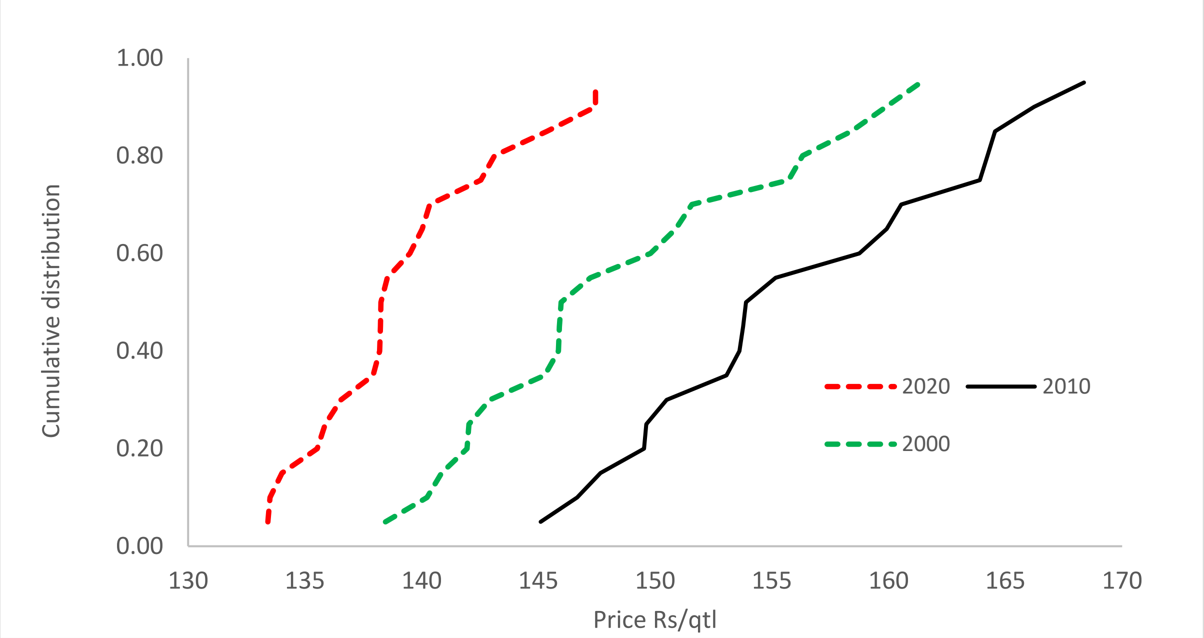
Source: Reserve Bank of India.

Figure 2: Wheat production, procurement, public stock level and norm in India, 2001-2021



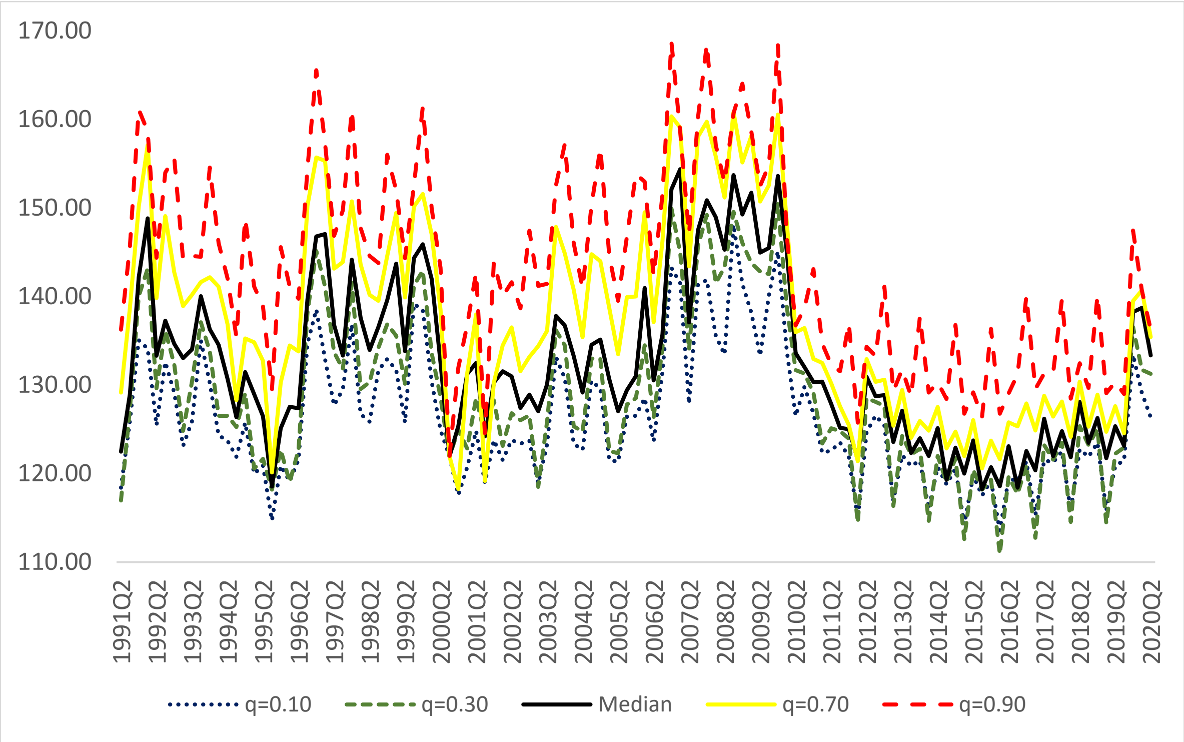
Source: Reserve Bank of India.

Figure 3: Estimated distributions of the wheat price in 2000, 2010 and 2020



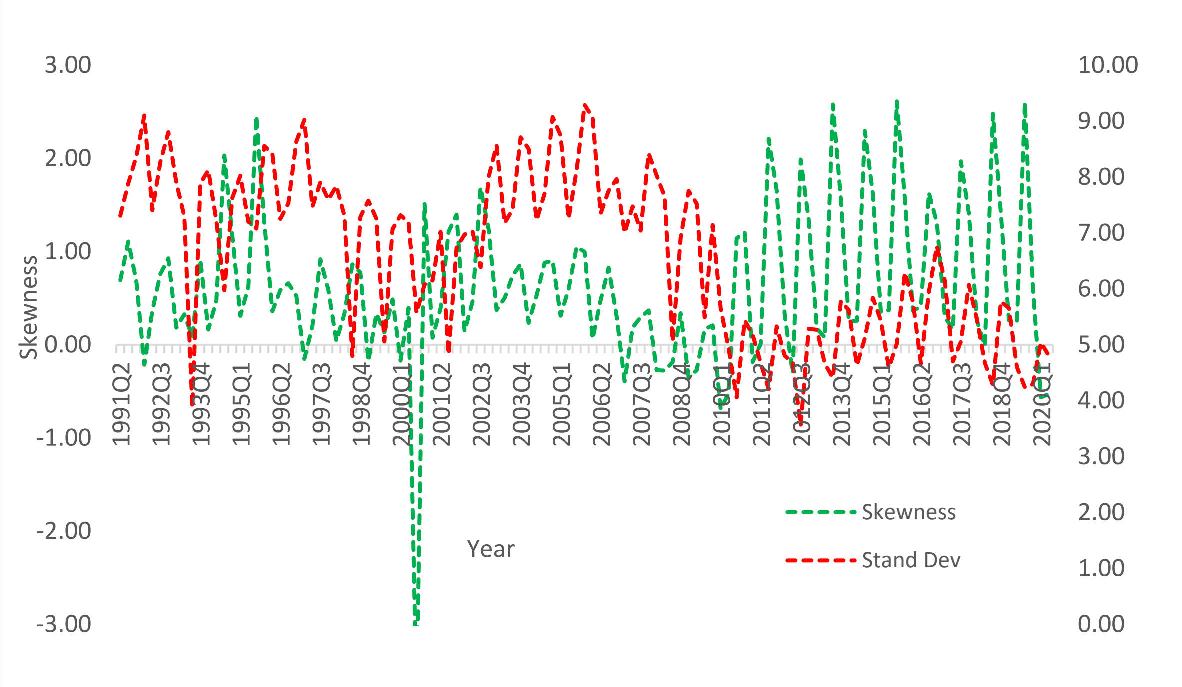
Source: Authors' calculation.

Figure 4: Quantile estimates of the distribution of wheat price in India, 1991-2020.



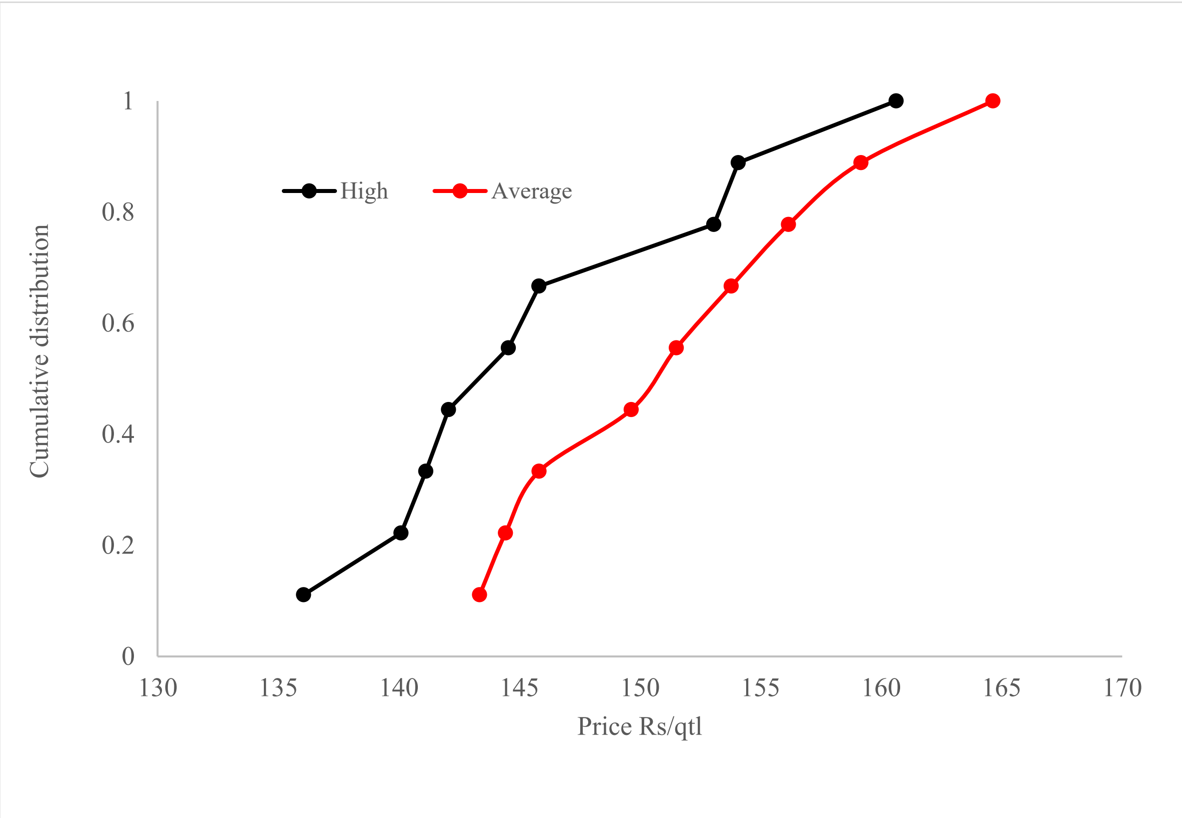
Source: Authors' calculation.

Figure 5: Estimates of moments of the wheat price distributions, 1991-2020.



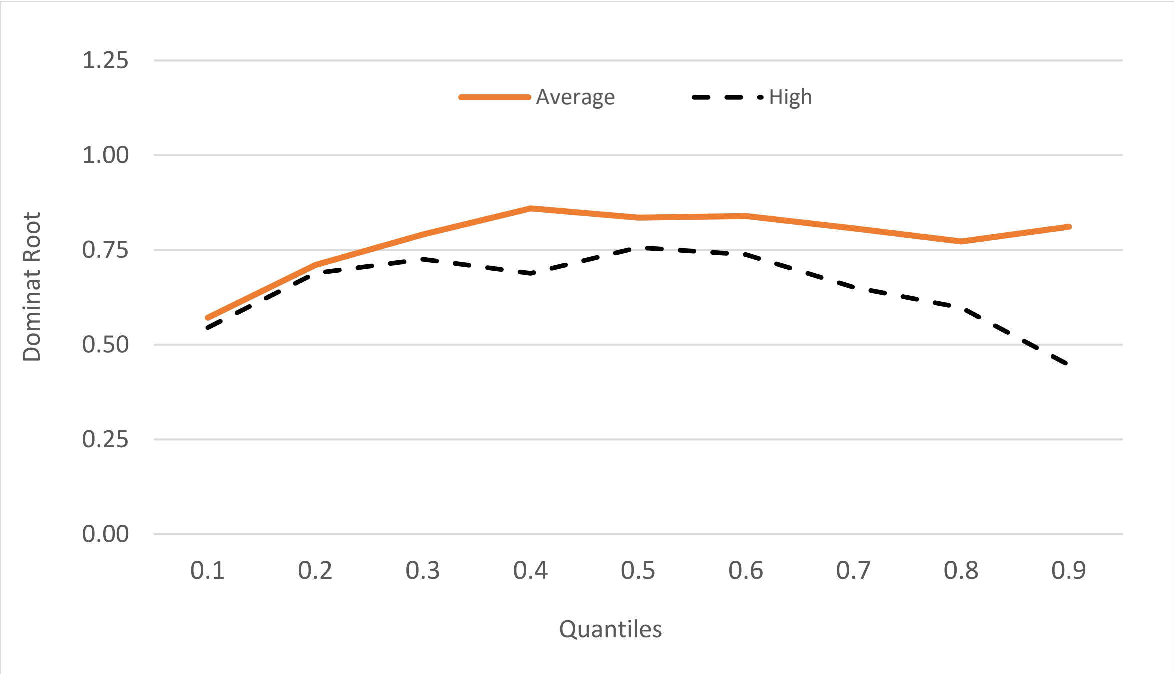
Source: Authors' calculation.

Figure 6: Simulated short-term distribution, wheat price under alternative stock scenarios



Source: Authors' calculation.

Figure 7: Dynamics of wheat price: the dominant root under different stockholding level



Note: the dominant roots are plotted across quantiles under different stockholding levels. A dominant root at or above 1 indicates instability

Table 1: Summary statistics for wheat price and public stock, 1991-2020

	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Observations
Wheat price *(Rs/qntl)*[a]	133.68	167.64	111.87	12.16	0.81	2.91	118
Wheat public stock *(stock-to-use ratio)*	3.20	29.53	0.13	3.71	3.87	24.88	118

Source: Authors' calculation.

[a] Prices deflated using consumer price index, 1982=100.

Table 2: Parameter estimates of selected AR processes

Variables	AR(1)	AR(2)	AR(3)	AR(4)
Intercept	84.099***	72.334***	71.882***	59.733***
	(13.198)	(14.130)	(14.830)	(15.936)
P_{t-1}	0.416***	0.239*	0.228	0.212
	(0.096)	(0.132)	(0.139)	(0.137)
P_{t-2}		0.258**	0.276*	0.255*
		(0.119)	(0.147)	(0.141)
P_{t-3}			-0.005	-0.037
			(0.146)	(0.176)
P_{t-4}				0.150
				(0.128)
S_{t-1}	-11.502**	-8.080**	-8.412**	-6.810*
	(3.644)	(3.899)	(3.947)	(4.153)
S^2_{t-1}	-0.003	0.002	0.005	0.003
	(0.022)	(0.022)	(0.033)	(0.032)
$S_{t-1}* P_{t-1}$	0.088***	0.168***	0.166***	0.152***
	(0.027)	(0.046)	(0.050)	(0.049)
$S_{t-1}* P_{t-2}$		-0.105**	-0.093*	-0.090*
		(0.046)	(0.050)	(0.049)
$S_{t-1}* P_{t-3}$			-0.007	-0.001
			(0.039)	(0.053)
$S_{t-1}* P_{t-4}$				-0.007
				(0.034)
Q_1	-8.895***	-8.386***	-8.347***	-6.542***
	(2.105)	(2.086)	(2.111)	(2.120)
Q_2	-5.074*	-5.899**	-5.955**	-4.590*
	(2.584)	(2.716)	(2.758)	(2.681)
Q_3	-3.505*	-3.175	-3.469	-2.060
	(2.089)	(2.068)	(2.201)	(2.358)
T	-5.162***	-4.287***	-4.119**	-3.627**
	(1.593)	(1.617)	(1.641)	(1.578)
BIC	7.154	7.188	7.263	7.243
D-W statistics	2.085	1.971	1.952	1.832

NOTE: The standard errors are reported in parentheses. Asterisks indicate the significance level: * at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level.

Table 3: Quantile regression estimates of the wheat price for selected quantiles, 1991-2020

Variables	LS	q=0.1	q=0.3	q=0.5	q=0.7	q=0.9
Intercept	84.099***	87.743***	55.379***	69.069***	82.782***	111.157***
	(13.19)	(19.11)	(20.96)	(25.27)	(17.89)	(30.18)
P_{t-1}	0.416***	0.302**	0.564***	0.477**	0.461***	0.349
	(0.09)	(0.14)	(0.16)	(0.19)	(0.13)	(0.22)
S_{t-1}	-11.502***	-11.082**	-5.065	-8.417	-13.339**	-10.767
	(3.64)	(4.39)	(4.50)	(6.49)	(5.65)	(11.62)
S^2_{t-1}	-0.003	-0.009	-0.027	-0.029	0.016	0.0130
	(0.02)	(0.06)	(0.06)	(0.06)	(0.11)	(0.17)
S_{t-1}* P_{t-1}	0.087***	0.088***	0.045	0.071	0.095**	0.073
	(0.03)	(0.03)	(0.04)	(0.05)	(0.04)	(0.08)
Q_1	-8.895***	-6.840***	-8.619***	-2.691	-4.856	-12.199**
	(2.11)	(1.95)	(2.56)	(3.09)	(3.98)	(5.68)
Q_2	-5.074*	-2.881	-1.559	0.134	-4.732	-13.500**
	(2.58)	(3.15)	(2.18)	(2.76)	(5.96)	(6.27)
Q_3	-3.505*	-1.453	-2.935*	-3.731	-0.723	-7.123
	(2.09)	(1.26)	(1.64)	(2.33)	(3.77)	(4.96)
T	-5.162***	-1.899	-2.855*	-4.096**	-7.553***	-10.283**
	(1.59)	(1.61)	(1.49)	(2.05)	(2.79)	(4.08)

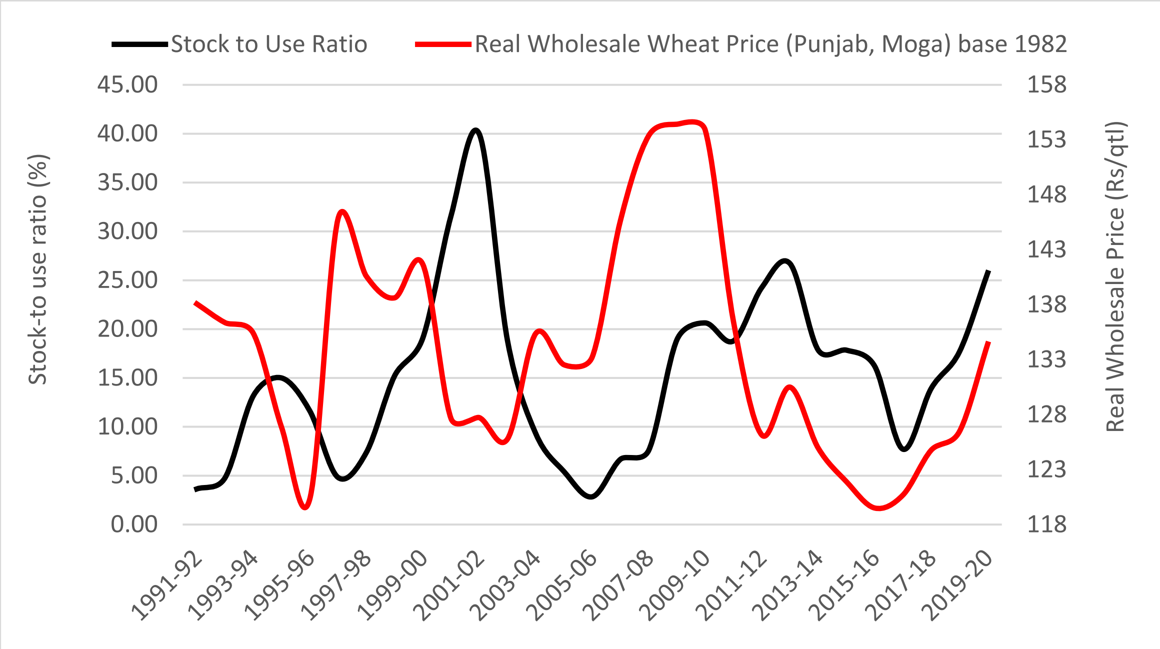
Note: Bootstrapped standard errors are used to test the hypothesis. The standard errors are reported in parentheses. Asterisks indicate the significance level: * at the 10 percent level, ** at the 5 percent level, and *** at the 1 percent level

Table 4: Hypothesis testing for quantile effects, seasonality, and stock effects

Testing items	Estimate method		p-value
Same coefficients across quantiles	QR		0.000***
Seasonality	QR	q=0.1	0.006***
		q=0.3	0.005***
		q=0.5	0.380
		q=0.7	0.616
		q=0.9	0.113*
Effects of lagged stock S_{t-1}	QR	q=0.1	0.043***
		q=0.3	0.513
		q=0.5	0.348
		q=0.7	0.063**
		q=0.9	0.581
Interaction effects between lagged stocks and lagged price	QR	q=0.1	0.009***
		q=0.3	0.215
		q=0.5	0.142*
		q=0.7	0.036***
		q=0.9	0.369

NOTE: Asterisks indicate the significance level: * at the 15 percent level, ** at the 10 percent level, and *** at the 5 percent level.

Appendix Figure 1: Trend in wheat stock-to-use ratio and real wholesale price, 1991-2020



Source: Reserve Bank of India.