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DETERMINANTS OF FUTURES PRICE VOLATILITY: A STUDY OF AGRICULTURAL MARKET

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Abstract:
Research background: Volatility in agricultural prices is a concern for producers and other stakeholders along the food chain for a developing country like India where a significant percentage of population is directly dependent on agriculture for their livelihoods. Price volatility can have a long run impact on the income of producers as it makes it difficult to plan production for future. It affects economically weaker consumers who spend a major portion of their income on food items. Therefore, it is essential to study the determinants of volatility of agricultural commodities.
Purpose of the article: The objective of the study is to identify the determinants of volatility in the futures market traded at NCDEX.
Methods: Eight agricultural commodities which are traded at NCDEX is selected for the study based on trading volume and open interest. The volatility in the futures prices of the selected commodities were tested for presence heteroscedasticity. The futures price volatility was first estimated using conditional heteroscedasticity models and then regressed with identified variables like time to maturity, volume, open interest, and past volatility.
*Findings & Value added***:** From the results it was observed that for five commodities the relationship between time to maturity and volatility is negative and significant. This means as the contract nears maturity, volatility increases which support the presence of Samuelson hypothesis. Further it was found that there is positive and significant relationship between volume and volatility for all the commodities supporting the mixed distribution hypothesis. The relation between open interest and volatility was negative and significant for all the commodities except for soya oil and turmeric. Past volatility has positive and significant relationship with present day volatility that means if the past volatility is high then it is expected that present volatility will also be high. The findings support in risk management of agricultural commodities

Keywords: Futures market, Volatility, GARCH, Spillover, DCC, MDH

JEL Classification: O13; G32; E44

1. Introduction

Price volatility is one of the most critical and important measures in both theory and practice of finance as it indicates the uncertainty of a financial instrument's distribution of returns over a time period. This measure was described as "central element that influences financial behaviour" by Nobel Laureate Robert C. Merton as it imbibes the fundamental concept of risk. Daly (1999) discussed the ill effects of volatility in a financial market. First, the absence of a concrete explanation of the reasons for price fluctuations might result in erosion of confidence in investments, leading to the erosion of capital. Second, the volatility of the company is a significant factor in determining the probability of bankruptcy, and higher the volatility higher is the risk to default. Third, volatility has a significant influence on bid-ask spread, higher the volatility, the wider is the spread, affecting the liquidity in the markets. Fourth, it affects the risk by increasing uncertainty in the financial markets. Volatility can therefore affect efficient capital allocation by forcing organisations to allocate resources to manage increased volatility. Hence, it is important for investors for risk management, portfolio selection, valuation, and designing trading strategies. For regulators, it is useful to draft policies and reduce uncertainties in the market. Therefore, it is necessary to identify the factors affecting volatility.

Volatility in agricultural prices is a concern for producers and other stakeholders along the food chain for a developing country like India, where a significant percentage of the population is directly dependent on agriculture for their livelihoods. Price volatility can have a long run impact on the income of producers as it makes it difficult to plan production for future. It affects economically weaker consumers who spend a major portion of their income on food items. For a commodity surplus country, this influences national income and for an agricultural commodity deficit country, it influences the budget allocation. This adversely affects developing countries, which do not have adequate mechanisms to reduce or manage risk originating from volatility, which results in an overall welfare loss (Aizeman and Pinto, 2005). There should be a distinction between normal and extreme volatility since price movements may be excessive relative to changes on account of shocks to demand and supply. The Efficient market hypothesis (EMH) states that in an efficient market, all the public information currently available is instantaneously incorporated into the current prices. This means that any new information arriving tomorrow is independent of the price today (Fama, 1969). However, the excess volatility is attributed to stakeholders' psychological behaviour, which can change prices as an outcome of a market wide cognitive process that can only be explained by its thoughts and beliefs about future events (Shiller, 1981).

Although futures markets were established with the objective of price discovery and risk management, they act as a system to transmit information about the future course of action to decide what to produce and how to produce it or how to employ resources. When the price levels on an average are stable or changing at a steady rate, the information is clear and easy to extract for future action, but when the prices are volatile, it becomes hard to extract information or inefficient information is observed, which has an adverse effect on returns of production. A highly volatile price system can undermine economic decision-making, resource allocation, and ultimately the efficiency of the price system. Consequently, measures of volatility must explicitly account for uncertainty (Friedman, 1976). The volatility prevailing in the prices can be natural or artificial in order to gain from price uncertainty. Therefore, an understanding of the nature of volatility is required in order to mitigate its effects in agricultural commodities for a developing country like India.

1.1 Contagion Effect of Spot and Futures Prices:

Contagion is usually correlation between market excess which is implied by economic fundamentals (Bekaert et.al, 2005). This effect results from certain fundamental links that exist amongst the financial markets. When one market suffers shock then it is transferred to other markets like subprime mortgage crisis which originated in United States and consequently spread around the world destabilising the other financial markets. Contagion effect was initially used to study the transfer of shocks and volatility spill-over from one nation to another but later on this effect was studied for closely related variables like industrial output and prices (Lee, 2005), price of energy commodities (Vacha and Barunik; 2012), index returns and stock returns (Kearney and Poti, 2003), portfolio management (Peters, 2008).

Spot prices and futures prices are bounded with lead-lag relation between the two with futures prices performing the function of price discovery. So, when futures market receives a shock then it will be passed on to spot market making subsequent adjustments in the prices of the two. Studying contagion effect between spot prices and futures prices will assist in understanding transfer of shock from one to another. From this one can comprehend the relationship and response of volatility of prices of one commodity to another.

This study provides information for developing nation where the financial market is evolving. The study is novice as the research on volatility of agricultural commodities is minimal with the latest data as the financial market is evolving. The work is original work carried by himself.

2. Literature Review

Studying variables affecting volatility has been a subject matter of extensive research which is influenced by the factors, (i)development of econometric tools to estimate volatility (ii) variables that affect volatility (iii) asset class for which the study is done like exchange rates, futures prices, agricultural prices, index etc. Samuelson (1965) in his seminal paper proposed that "volatility of futures price increases as it approaches maturity" which is known as Samuelson hypothesis or maturity effect. Clark (1973) found that assets' returns are drawn from joint distribution of volume and prices which are conditional on current information. Hence, price changes (returns) and trading volume are driven by the same information signifying positive relation between them. Later on, these variables were studied formally with modern statistical tools for various commodity futures. Samuelson hypothesis or maturity effect was first examined by Rutledge (1976) by considering volatility as absolute daily price change using linear regression, found the hypothesis to be valid for silver and cocoa but not for wheat and Soy-bean oil futures. Dusak-Miller (1979) computed correlation between volatility and time to maturity and found significant negative relation between the two variables for live cattle futures contracts for the period 1964-1972. Castelino and Francis (1982) found empirical evidence towards maturity effect for Wheat, Corn, Soy-bean, Soy-bean Meal, Soy-bean Oil and Copper Contracts for the period of 1960 to 1971.Volume-Volatility dynamics were studied in a more formal way by Tauchen and Pitts (1983) terming this relationship as Mixed Distribution Hypothesis (MDH) by assuming information arrival rate is independently identically distributed.

Maturity effect was studied by Anderson (1985) using both nonparametric and parametric tests and found it to be present in Oats, Soybean oil, Live cattle, and Cocoa futures but not in wheat, corn, soybean and silver contracts. Chamberlain (1989) found that Samuelson hypothesis was applicable to debt instruments but not for commodities. However, in the studies of Leistikow (1989), Board and Sutcliffe (1990) and Yang and Brorsen (1993) for stock index futures support for Samuelson hypothesis was weak. Bessembinder and Seguin (1993) studied open interest as proxy for market depth along with time to maturity and volume as factors influencing volatility for currencies, metals, agricultural commodities, financial contracts. Chen et.al (1999) found contradictory results to Samuelson hypothesis and observed decreasing volatility as contract approaches maturity. Walls (1999) who studied maturity effect and volatility volume dynamics together for electricity futures found maturity effect to be present in contracts but no relation between volume and volatility. Allen and Cruickshank (2000) found the hypothesis to be applicable for majority of futures contracts traded at Sydney, London and Singapore futures exchanges. Black and Tonks (2000) used multi-period futures model to test Samuelson hypothesis and found the hypothesis did not hold when the output uncertainty was resolved before maturity. Girma and Mougoue (2002) studied open interest and volume separately as determinants of volatility using GARCH models. They observed that the lagged volume and open interest provide significant explanation for futures volatility. Xin et.al (2003) found that past volatility and trading volume had positive effect while open interest had negative effect on volatility with seasonal effect in the Chinese futures market. Gao and Wang (2005) developed a new framework to study volatility dynamics of commodity futures maturing at different delivery dates. The framework incorporated time-to-delivery, storability, seasonality and conditional volatility effects. The corn futures provided evidence in favour of the theory of storage and the presence of the Samuelson effect. Kenourgios and Ketavatis (2011) in their study on index futures found positive relationship between volatility and volume and negative between volatility, open interest and TTM.Jongadsayakul (2015) studied determinants of silver futures price volatility in Thailand Futures Exchange based on conditional volatility estimates and found no significant relationship between volatility and TTM, negative relationship with volume and positive relationship with open interest. Kadioğlu et.al (2016) in their study on determinants of volatility for currency futures traded at Istanbul exchange found support for maturity effect and mixed distribution hypothesis.

Pati (2006) studied relation between volatility, volume, time to maturity (Samuelson hypothesis) for nifty index futures. He concluded that the Samuelson hypothesis did not hold for futures price volatility but rate of information arrival proxied by volume and open interest were important determinants of volatility. Balcombe (2009) found that volatility in oil prices, exchange rate and stock level and yields influenced agricultural prices. Karali and Thurman (2010) investigated the volatility in grain prices and found it to be significantly influenced by seasonality and time to maturity. Verma and Kumar (2010) studied Samuelson hypothesis for wheat and pepper futures and found the hypothesis to be applicable to majority of contracts. They cited negative co-variance between spot price and net carry cost as the reason for this effect. Past volatility, stock and yield were found to be affecting volatility in a study by Balcombe (2011). Gupta and Rajib (2012) tested Samuelson hypothesis with trading volume and open interest for commodities traded at MCX and failed to find support in favour of the hypothesis for majority of contracts. They found that volatility was influenced by trading volume but there were other factors which influenced volatility other than time to maturity and volume. Chauhan et.al (2013) found volatility spillover effect from spot price to futures price for Chana and Guar seeds futures. Taskin and Kapucugil-ikiz (2013) investigated determinants of volatility for currency futures and found time to maturity, trading volume and open interest influenced the volatility of the contracts. Regardless of the definition of volatility there is ample empirical evidence that the volatility of time series keeps fluctuating.

Sekhar et al (2018) studied the agricultural commodity price volatility in relation to the inflation for the Indian market. The volatility- inflation dynamics shows that the commodities with higher elasticity demand and lack of storage capacity have high volatility in their prices. Vu et al (2020) studied the volatility spill over effect between the oil and agricultural prices. The panel data analysis shows that bio fuel production and exchange rate affects the agricultural prices. Bouri et al (2021) studied the volatility among the fifteen agricultural commodities. The results supported strong to moderate level of volatility between the energy and agricultural commodities. Moderate connectedness between agricultural commodities. They argued macroeconomic variables to affect the volatility interconnectedness. Maréchal (2021) rejects Samuelson hypothesis but supports the theory of storage for study on the agricultural commodities.

The review of literature indicates number of studies on financial futures but limited studies on commodity futures.

3. Methodology

3.1 Data and Series formation

The study considers the most liquid eight agricultural commodities being traded at NCDEX. The selected commodities are Barley, Chana, Coriander, Jeera, Gur, Soyabean, Soya Oil and Turmeric. The source of data is the NCDEX website which is the warehouse of the data. The variables which are considered are daily closing spot prices, futures prices, trading volume and open interest of selected commodities for the time period of financial year 2009-10 to financial year 2014-15. In the futures market more than traded at the same time, there is issue of overlapping of the data. To avoid this issue pooling of the data is done where the futures prices closer to expiration date will provide better estimate for future spot prices is taken as it considers more information.

3.2 Statistical techniques:

This study considers conditional volatility to estimate the historical volatility. The main advantages of conditional volatility are that it can estimate volatility clustering wherein large changes tend to be followed by large changes and small changes tend to be followed by small changes (Mandelbrot; 1963). This method is proposed by Engle and Bollerslev (1986). It is a measure of historical volatility which is estimated as conditional variance of residuals. In time series analysis the variance of error terms is not constant which is violation of the assumption of Classical Linear Regression Model (CLRM). In such situations conditional volatility is used to estimate the various parameters. The acronym ARCH stands for Auto Regressive Conditional Heteroscedasticity wherein the term "heteroscedasticity" refers to changing volatility. However, it is not the variance itself which changes with time according to an ARCH model; rather, it is the change in the conditional variances The ARCH (q) model for the series is defined by specifying the conditional distribution of error terms given the information available up to time $t - 1$. It consists of the knowledge of all the available values of the series and anything which can be computed from these values like innovations. In principle, it may even include the knowledge of the values of other related time series and anything else which might be useful for forecasting and available by time $t - 1$.

Development of conditional heteroskedastic models by Engle (1982) captures the time varying volatility which is a common feature of commodity futures. As per autoregressive conditional heteroskedasticity (ARCH) conditional volatility is simple quadratic function of the lagged values of the innovations.

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \quad (1)$$

Where $\varepsilon_t = \sigma_t z_t$ and z_t is i.i.d random variable with zero mean and constant variance.

This ARCH model was extended by Bollerslev (1986) to overcome the requirement of many parameters and higher order q. A general GARCH model is

$$h_t = \omega + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} \quad (2)$$

Where ω is mean ε^2_{t-1} is the news about volatility from the previous period measured as lag of the squared residual (ARCH term) and h_{t-j} is past period estimated variance.

These models were further modified to capture the informational asymmetry and leverage effect. Asymmetric GARCH models are applicable to understand the informational asymmetry and leverage effect where a positive shock has less effect on the conditional variance compared to a negative shock. This was introduced by Glosten et.al (1993), they showed that asymmetric adjustment was an important consideration with asset prices. The model is of the form

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2 + \lambda u_{t-1}^2 I_{t-1} \quad (3)$$

Where, *I* is a dummy variable that takes the value of 1 when the shock is less than 0 (negative) and 0 otherwise.

The exponential GARCH (EGARCH) was developed by Nelson (1991), the model was given as

$$\log \sigma_t^2 = \omega + \beta \log \sigma_{t-1}^2 + a \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \quad (4)$$

The logarithmic form of the conditional variance implies that the leverage effect is exponential and forecasts of the variance are non-negative. The presence of leverage effects can be tested by the hypothesis that $\gamma > 0$. If $\gamma \neq 0$, the impact is asymmetric.

APGARCH model was developed by Ding (1993). This specification introduces asymmetric effects in the transitory equation which is given by

$$\begin{aligned} R_t &= x_t \pi + \varepsilon_t \\ q_t &= \omega + \alpha(q_{t-1} - \omega) + \gamma(\varepsilon_{t-1}^2 - \sigma_{t-1}^2) + \theta_1 z_{1t} \\ \sigma_t^2 - q_t &= \beta(\varepsilon_{t-1}^2 - q_{t-1}) + \beta_1(\varepsilon_{t-1}^2 - q_{t-1}) d_{t-1} + \beta_2(\sigma_{t-1}^2 - q_{t-1}) + \theta_2 z_{2t} \end{aligned} \quad (5)$$

Where, z_{1t} and z_{2t} are the exogenous variables and *d* is the dummy variable indicating negative shocks. $\beta_1 > 0$, which implies transitory leverage effects in the conditional variance.

4. Result and Discussion

Adopting the methodology of Johnson (1998) and Allen and Cruishank (2002) the nearest contract to maturity was included to study volatility determinants. Conditional volatility requires heteroskedasticity or ARCH effect to be present in the data. ARCH-LM test is used to examine the presence of conditional heteroskedasticity. For conditional volatility modelling, it is necessary to estimate exact lags in the mean equation and order of ARCH (p) and GARCH (q). The residuals should not exhibit serial correlation, conditional heteroscedasticity and non-linear dependence.

4.1 Conditional Volatility model

The model selection criteria for a variety of GARCH (p, q) for futures prices of Commodities are given in table 1. The conditional volatility model has been selected based on the Akaike Information Criteria (AIC). The selected model of the commodities are presented in the table below (Table 1).

Table 1: AIC values of the selected conditional volatility model (authors calculation)

Barley	**AR (1)-EGARCH (1,1)**	**8.93**
Chana	EGARCH (1,0)	10.43
coriander	EGARCH (2,2)	12.3
Gur	EGARCH (2,2)	8.3
Jeera	AR (1) EGARCH (1,1)	
Soya bean	EGARCH (2,1)	6.64
Soy oil	EGARCH (2,2)	13.63
Turmeric	EGARCH (2,1)	13.46

Source: Processed by author

4.2 Summary Statitics of Volatility

Table 2: Summary statistics of estimated volatility (Source: author's calculation)

	Volatility-Barley	**Volatility-Chana**	**Volatility-coriander**	**Volatility-Jeera**	**Volatility-Gur**	**Volatility-Soyabean**	**Volatility-Soya oil**	**Volatility-Turmeric**
Mean	481.31	2388.27	27448.13	303.21	2309.75	45.20	76342.92	46910.20
Median	411.4	1889.39	11160.22	267.92	2202.45	44.61	39838.37	40287.08
Max	23016.3	7898.06	1594640.00	6435.15	16742.10	231.68	412539.20	163256.60
Min	238.51	501.95	1439.42	42.81	2047.71	25.73	4910.90	9748.77
Std. Dev.	609.56	1485.91	69099.59	297.60	537.08	8.42	84159.62	25527.16
Skewness	31.19	1.09	13.88	10.47	17.87	8.07	1.94	1.15
Kurtosis	1125.64	3.41	259.64	169.29	437.30	154.83	6.11	4.10
Jarque-Bera	88.33	4110.21	4445222.00	1927782.00	1340.94	164.66	1283.70	436.51
p-value	0	3.80E-09	0.000	0.000	0.000	0.000	0.000	0.000

Source: Processed by author

Table 2 reports the descriptive statistics of open interest, volume and conditional volatility estimated by selected model. Volatility for barley futures has high range with minimum volatility of 238.51 and maximum of 23016.33 for the period. It is highly leptokurtic and positively skewed. Volatility for Chana futures has high range with minimum volatility of 501.95 and a maximum of 7898.06. The series is highly leptokurtic with positive skewness. Volatility for coriander futures has high range with minimum volatility of 1439.4 and maximum of 1594640.00 which is highly leptokurtic with positive skewness. Volatility for

Gur futures has high range with minimum volatility of be 42.80 and maximum of 303.20 units. It is highly leptokurtic with positive skewness. Volatility for Soya oil futures has high range with minimum volatility of 4911.00 and a maximum of 412539.20 units. Volatility for soya bean futures has high range with minimum volatility of 25.73 and a maximum of 231.68 units for the period. Volatility for turmeric futures has high range with minimum volatility of 9748.77 and a maximum of163256.6units. All the variables are non-normal as per Jarque-Bera statistics rejecting the null hypothesis of normality (p = 0.00).

Table 3: Results of the multiple regression (source: authors calculation)

	coeff.- (Barley)	**coeff.- (Chana)**	**coeff. - (Coriander)**	**coeff.- (Jeera)**	**coeff.- (Gur)**	**coeff.- (Soyabean)**	**coeff.- (Soya oil)**	**coeff.- (Turmeric)**
intercept	213.53** (105.10)	45.15 (60.54)	-894.02 (666)	3006.06*** (189.60)	47.85 (59.34)	0.36 (2.89)	-0.378 (2.89)	808.96 (2.89)
TTM	3.17*** (0.83)	4.60*** (0.97)	205.98** (16.37)	– 12.48*** (2.59)	– 1.87* (1.10)	– 0.03* (0.02)	– 136.06* (0.02)	– 45.47* (30.17)
log Volume	41.47*** (13.39)	50.01*** (8.35)	2920.98*** (116.28)	81.21 *** (17.08)	42.98 *** (10.03)	0.63 *** (0.212)	1314.70** (553)	447.85** (422.2)
open Interest	28.55* (17.17)	55.09* (9.43)	2202.62* (151.37)	152.35*** (22.35)	21.03** (10.71)	– 0.59* (0.344)	– 44.70* (60.5)	– 294.57* (349.2)
Vol (-1)	0.33*** (0.02)	0.98*** (0.00)	0.82*** (0.01)	0.01*** (0.02)	0.23*** (0.02)	-0.98*** (0.004)	-0.970*** (0.00)	-0.96*** (0.008)

Source: Processed by author

Samuelson (1965) proposed that futures price volatility will increase as the futures contract maturity date approaches. He further asserted that a stock's price is a set of discounted value of future dividends, generated by stochastic process. The futures price fluctuation is martingale process, as the contract approaches maturity there is little information about the future spot price of the commodity or future weather conditions which result in more transactions and price fluctuations as current market price must converge to the spot price. The findings of this study provide evidence in support this hypothesis.

The positive relationship between volume and volatility can be attributed to sequential arrival of information which supports a dynamic relationship wherein past volume provides information on current absolute returns changes and past absolute returns change contains information on current volume (McMillan and Speight, 2002). As per MDH positive relationship between volume and volatility can be explained through information innovation. Tauchen & Pitts (1973) explains that returns are generated by combination of distribution and information arrival. This combination of the two causes momentum in the squared residuals of the daily returns and autoregressive nature of conditional volatility. Since information arrival cannot be observed, trading volume is considered as a proxy to information flow in the market. Any unexpected information affects both trading volume and volatility contemporaneously. Therefore, it is expected to have positive relationship between volatility and volume. In general, both sequential arrival hypothesis and MDH support positive and contemporaneous relationship between volume and volatility. The findings of this study support the theoretical positive relation between volume and volatility. Volume is a determinant of futures price volatility for all the commodities under this study similar to the findings of Balcombe (2009); Asche et.al. (2016)

Open interest is the number of unsettled contracts at the end of the day. It is considered as proxy for market depth as it reflects the willingness of traders to risk their capital in futures market. A high level of open interest creates a situation that reduces pressure from prices where trading provides new information, so theoretically relation between open interest and volatility should be negative. This relation is supported by the findings of this study wherein all the commodities under study have statistically significant negative relation with volatility. Open interest is a determinant of futures price volatility for all the commodities under this study similar to the findings of Allen and Cruishank (2000).

5. Conclusion

There have been considerable efforts on understanding the price dynamics of storable commodities. The relationship between prices and the fundamentals of demand and supply remains a challenge for policy analysts and market participants. The volatility in agricultural commodity prices is a major concern for the welfare of the farmers who are highly vulnerable and face long term disruptive consequences even on account of short-term crop price fluctuations. It has been observed that irrational speculative-driven bubbles create price volatility in futures market that affects spot prices.

Determinants of futures price volatility are studied for eight selected agricultural commodities, namely, Barley, Chana, Coriander, Gur, Jeera, Soyabean, Soya oil and Turmeric. The price series are non-stationary and do not have trend unlike Buccola (1989) who observed a trend in agricultural prices. The returns on the prices are stationary and show presence of heteroscedasticity that is estimated with GARCH (p, q) and EGARCH (p, q) models with different combinations of p and q. To select the appropriate conditional heteroscedasticity model AIC values have been considered. The estimated values indicate presence of leverage effect in the volatility of all the commodities under the study. Hence, volatility is asymmetric for all the commodities wherein the magnitude of impact of negative news on volatility is higher than impact of positive news, further it shows clustering effect in all the commodities.

Regression method has been used to study the relationship between volatility and time to maturity, trading volume and open interest and the results support the theoretical relationship. It is found that volatility has negative relationship with time to maturity and open interest supporting Samuelson hypothesis or maturity effect. The positive relationship between volatility and volume as explained by MDH is applicable to all the commodities under study. The future volatility is higher than current volatility except for turmeric. The findings of the study show that the risk in Indian commodity futures market is inherent and not subject to manipulations considering open interest, volume and time to maturity.

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