Volatility Dynamics with Volume and Open Interest : An Empirical Study in the Indian Commodity Market

** Shashi Gupta*
*** Himanshu Choudhary*
**** D. R. Agarwal*

Abstract

This paper examined the relationship between price volatility, volume, and open interest in eight Indian commodity futures; two commodities belong to the agriculture sector, and the remaining six belong to the non agriculture sector. To study the price volatility and its stylized facts like persistence, leverage, clustering in commodity futures, GARCH(1,1) model with adequate autoregressive terms was used. The focus of this study was to examine the volatility persistence in commodity futures return volatility considering the asymmetric effect. ARMA(1,1)–EGARCH(1,1) model augmented by exogenous variables contemporaneous(current) and lagged volume and open interest either separately or jointly was used for estimation. This paper found evidence of leverage effect for castor seed and crude oil. The results of the paper indicated that current volume reduced the volatility persistence more than lagged volume. However, the GARCH effect did not vanish completely. However, the volume and open interest were ineffective in explaining the GARCH effect for energy commodities, which implies the inefficiency of the EGARCH model, which is later confirmed by the statistical significant value of LB-Q statistics. Open interest as the exogenous variable in conditional variance equation did not reduce the volatility significantly. Hence, it is a prima facie evidence that market information proxy by volume explained the persistence of volatility with asymmetric effect. The empirical results verified that there is a significant relationship between return, volatility, and current volume in the variance equation. Open interest cannot explain the persistence of volatility individually, but it is significant when integrated with volume. The research findings of this paper have important implications for market traders, government, regulatory bodies, and hedgers.

Keywords: **volatility, persistence, EGARCH, GARCH, asymmetric effect**

JEL Classification: C5, C55, G3, G39

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Volatility dynamics is the answer of many questions of financial market participants. Valuation of financial asset and hedging depends on the volatility dynamics. Volatility, as explained by Figlewski (1997), is the risk resulting from any deviation from its mean. People investing in the capital market desire to gauge this risk (volatility) in order to maximize their benefit. Various models have been developed from time immemorial to cater to the risk minimization need of investors. The effectiveness of any volatility model is determined by the accuracy with which it can forecast volatility. There are some stylized facts about volatility that should be considered while designing an efficient model. Persistence or volatility clustering (Mandelbrot, 1963), leverage effect are well documented stylized facts. Persistence, as explained by Taylor (2005), is a phenomenon in which markets experience periods of high volatility and periods of low volatility, wherein, high volatility leads to high dispersion of returns and vice-versa. Mandelbrot (1963) has reported the evidence that the large changes in the price of assets are often followed by other large changes while small changes are often followed by small

* *Research Scholar,* ITM University, Gurgaon. E-mail : shashigupta085@gmail.com
** *Associate Professor,* ITM University, Gurgaon. E-mail : dr.himanshu.c@gmail.com
*** *Professor of Emeritus,* ITM University, Gurgaon. E-mail : dragarwal@itmindia.edu

changes. This characteristic, termed as volatility clustering, was reaffirmed by Baillie, Bollerslev and Mikkelsen (1996), Chou (1988) and Schwert (1989).

Black (1976) introduced the concept of leverage effect in context of financial time series data. Leverage effect confers a negative correlation between changes in stock price and changes in volatility. Under leverage effect, volatility tends to be more after a negative shock as compared to positive shock of similar magnitude (Poon, 2005 and Christie, 1982). ARCH and GARCH models provide an effective framework to study price volatility considering the stylized facts of volatility. Presence of ARCH effect in financial return is based on the theoretical tenet of the arrival of new information. Rate of arrival of information is not measurable, so some researchers (Lamoureux & Lastrapes, 1990; Anderson, 1996) have proxied trading volume as the rate of arrival of information. Trading volume has also proxied as the heterogeneity in investor's opinion and beliefs. Relationship between price volatility and volume is explained by the two well documented theories i.e. Mixture of distribution hypothesis (MDH) (Clark, 1973; Tauchen & Pitts, 1983) and Sequential information arrival hypothesis (SIAH) (Copeland, 1976; Jennings, Starks, & Fellingham, 1981). Clark (1973) postulated that volatility and trading volume show positive relationship because of joint dependence of an underlying common factor i.e. rate of information flow to the market. MDH suggests that there is simultaneous response of both price and volume to the common factor which is termed as mixing variable. Copeland (1976) explained the SIA on the assumption that any information that arrives in market flows sequentially among traders. When all traders receive the information, a new equilibrium price is settled. This hypothesis implies that positive relationship between trading volume and price variability could be measured over the period of information arrival.

Tauchen and Pitts (1983) extended the MDH, argue that there is disagreement between traders regarding valuation due to information arrival, so the larger the disagreement between traders, the larger the volatility and volume.

Microstructure of financial market hinges on the rate of arrival of information, trading volume, open interest and volatility. Open interest is explained as the total outstanding long and short positions in futures contract while volume represents the number of contracts traded in a period. Open interest is a crucial variable in futures markets, which indicates trading activity. The informational role of volume and open interest and their relationship with price changes (volatility) has got much attention of scholars. Kamara (1993) has proxied open interest as hedging activities. Bessembinder and Seguin (1993) proxied the open interest for the market depth and found negative relationship between open interest and volatility for eight futures market. Open interest has been modeled in different ways by different scholars like a proxy for hedgers' opinion (Kamara, 1993), hedging demand, market depth (Bessembinder & Seguin, 1993) and divergence of traders (Bessembinder, Chan, & Seguin, 1996). Liew and Brooks (1998) suggest that there is informational relationship between volatility and open interest. Ragunathan and Peker (1997) show that positive open interest shocks have more impact on volatility than negative shocks. This also leads to the conclusion that market depth does have an effect on volatility.

Review of Literature

Relationship among price volatility, trading volume and open interest has been extensively investigated in developed countries for equity and futures market. A large number of studies support the existence of MDH, i.e. positive correlation between price volatility and volume. Karpoff (1987) provided a broad literature review on the relationship between trading volume and price volatility in equity and futures market. He found the positive relationship between volume and price change in only equity market, but positive relationship between absolute price and volume in both equity and futures market. Mubarik and Javid (2010) extensively studied the return, volume and volatility relationship at market and firm level for 70 KSE listed firms by using Granger causality test and EGARCH model. They found the empirical evidence that inclusion of trading volume in conditional volatility equation does not diminish the persistence of volatility for majority of the stocks. The results also suggested the lead-lag pattern between return volatility and trading volume.

Researchers have used different models and techniques to determine the relationship among volume, open interest and volatility. Mc Carthy and Najand (1993) investigated currency futures using state space model and found no relationship between price variability and volume. Similar result was found by James and Edmister (1983) and Wood, Mclnish, & Ord (1985) in equity market. Foster (1995) found the positive relationship between contemporaneous volume and price volatility for crude oil futures by using GARCH(1,1) and Generalized Methods of Moments models and confirmed the existence of MDH in Crude oil futures. He also found that there is significant relationship between lagged volume and price volatility. Fung and Patterson (1998) investigated the dynamic relationship among volume and price volatility in the presence of open interest by using VAR and found volumes play a predictive role in determination of price volatility and that volume and open interest are not endogenously determined.

A number of researches have been conducted in developed countries. Lamoureux and Lastrapes (1990) studied the persistence of price variance for US market considering daily trading volume as proxy of the rate of information arrival in the variance structure of GARCH (1,1). He found that inclusion of contemporaneous volume as exogenous factor reduces the volatility persistence of futures market. Girma and Mougoue (2002) suggested that current trading volume and open interest do not remove the GARCH effect in three out of the four energy product spreads traded in New York Mercantile Exchange (NYMEX). Watanabe (2001) conducted a study with Nikkei 225 stock index futures and found the significant negative relation between volatility and expected open interest. However, the results provide evidence that the relation may vary with regulation. Lee and Swaminathan (2000) conducted a study on the firms listed with NYSE and American Exchange (AMEX) to find out the relationship between monthly returns and daily trading volume. He found that trading volume helps in predicting the return in equity market. Bekaert and Wu (2000) supported these findings and added that a relatively greater response is generated to negative shocks in volatility than to positive shocks of an equal magnitude and evidenced speed of information transmission in markets. Thus, the findings of past studies are strong indications of informational role of volatility in the markets, which could be used by investors to earn abnormal profit.

Time and again considerable efforts have been devoted to study the impact of volume and open interest on price volatility in emerging market. Basci, Ozyildidrim, and Aydogan (1996) conducted a study in Turkish market and found the cointegration relation between the price level and volume. Saatcioglu and Starks (1998) conducted a study in Latin America and found the positive relation between price changes and volume. Their finding evidenced the positive price-volume relation and a causal relationship from volume to stock price changes.

Volume is an important statistic for market participants, regulators and futures exchanges. Chan, Fung, and Leung (2004) conducted a study in four commodity futures (soyabean, copper, mungbeans and wheat) in Chinese commodity market and found positive relationship between volume and volatility and negative relationship between open interest and volatility. Liu, Zhong, and Mei (2005) found the large trading volume is an important determinant of volatility. Xiangli and Shouyang (2015) studied the correlation among return, volume and open interest in Chinese commodity futures market and found that impact of open interest on volatility and volume is weak but they found strong correlation between volume and absolute return.

Of late, the emerging futures market of India has been the interest area for researchers and investors because of improved capital market, improved trading settlements, computerized system, effective corporate governance and transparent and effective disclosure standards. A number of researches have been done to investigate the relationship between volume-open interest and volatility but very few have been attempted in emerging markets like India.

Deo, Srinivasan, and Devandhen (2008) questioned the dynamic relation among trading volume, volatility and price change in Asia-Pacific stock market between 2004 -2008 and found the evidences of a contemporaneous relation between trading volume and absolute value of stock returns. Moreover, they report a causal relation between stock return and trading volume. Thus their findings support both MDH and SIAH. Kumar and Pandey (2010) studied about the impact of volume and open interest in selected eleven commodities of Indian commodity market. They found the positive relationship between lagged unexpected volume and volatility. They also found that open interest data is not a proxy of market depth in Indian commodity market. Salman (2002) investigated return, volume and volatility relationship in Istanbul Stock Exchange on Index data from 1992 to 1998. He reported a positive contemporaneous relation between return and trading volume, when the volume is taken as a proxy for the information arrival into market. Sabri (2004) tested the various predicting factors of stock return volatility by using monthly data of five different emerging markets including Turkey, Mexico, Malaysia, Korean and South Africa. According to his findings, trading volume could be an important source to predict return volatility in Turkey. Relationship among volume, open interest and volatility has been investigated in the past, but to the best of my knowledge individual commodity futures are not adequately researched because of their recent introduction in the Indian financial market.

Pati and Rajib (2010) conducted a study to investigate the volume-volatility relationship for NSE Nifty index futures and found that there is substantial reduction in volatility persistence by using contemporaneous volume in conditional variance than by using lagged trading volume. Results obtained from the study conducted in emerging markets are somewhat different from the study conducted in developed countries. The most promising reason for these differences may be the loose standard of trading and unavailability of information to all the traders equally (inefficient market). Gupta and Rajib (2012) studied the influence of volume, open interest and time to maturity on return volatility. By using GARCH family model, their study concluded that trading volume has significant impact on volatility compared to the time-to-maturity or open interest. Maitra (2014) studied the impact of expected and unexpected volume and open interest on volatility in Indian commodity market. He found that unexpected volatility and open interest has positive relationship with volatility, and the unexpected component of volume has greater impact than the expected component of trading volume. Whereas, expected open interest is negatively related to volatility. The present study tried to bridge this gap and extent the present literature on commodity futures in emerging market in two important ways. Firstly, it used the Garch family models to find the relation between trading activities and price volatility keeping in mind the leverage effect. Secondly, a good understanding of price variability helps traders and hedgers to formulate superior trading and hedging strategies. The results of this study are important for hedgers and speculators who trade in commodity futures to lock in their profit as they get better understanding of the sources of variability in futures prices.

Data and Preliminary Analysis

We conducted the present study with daily futures prices, volume and open interest of eight selected commodities, out of which two belong to the agricultural sector and six belong to non- agricultural sector.

Table 1. Details of Data Period and Spot Market Related to Individual Commodities

Commodities	Futures Market	Data Period	Spot Market
Castor Seeds	NCDEX	March2004 to Nov 2014	Disa
Guar Seeds	NCDEX	May 2004 to Nov2014	Jodhpur
Copper	MCX	March 2005 to Dec 2014	Mumbai
Nickel	MCX	March 2005 to Dec 2014	Mumbai
Gold	MCX	July2007 to Dec2014	Ahmedabad
Silver	MCX	June 2005 to Dec 2014	Ahmedabad
Crude Oil	MCX	March 2005 to Dec 2014	Mumbai
Natural Gas	MCX	March 2005 to Nov 2014	Hazira

Agricultural and non-agricultural data were collected form NCDEX and MCX websites respectively. Data span over a period of almost 10 years from March 2004 to November 2014. Exchanges were chosen on the basis of volume of transactions. Near month futures prices were taken for the study, and switched to the next month maturing contract one week prior to expiration date to avoid any maturity effect. When the futures contracts approach to maturity, traders shift to the next month expiry contract, resulting in dramatic increase in trading activities of next month contract. Thus, by eliminating expiry week data and shifting to next month contact one week before the expiry, futures prices were taken from the most liquid contracts to avoid any maturity effect in data. Details of data period and commodities are mentioned in the Table 1.

Natural logarithms of price series have been considered as the most consistent measure of variation of price changes in the past. Hence, for present analysis the price series has been converted in the return series as follows:

Table 2. Descriptive Statistics of Commodity Futures Return, Volume, and Open Interest

		Castor seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
Mean	Return	0.108	0.128	0.115	0.02	0.127	0.142	0.036	-0.014
	VOL	7.98	10.691	10.169	8.429	9.936	10.136	10.357	9.077
	OI	9.247	10.84	9.501	7.887	9.259	9.348	9.42	8.593
Median	Return	0.023	0.062	0.06	0	0.064	0.105	0.078	-0.071
	VOL	7.473	10.903	10.853	9.211	10.382	10.558	10.753	9.394
	OI	8.889	10.999	9.817	8.737	9.358	9.444	9.486	8.812
Maximum	Return	163.66	13.313	27.135	11.5965	18.698	17.835	12.667	21.184
	VOL	12.416	13.254	12.264	12.036	11.919	12.301	12.833	12.26
	OI	12.487	12.38	10.811	11.15	9.998	10.294	11.241	11.201
Minimum	Return	-11.081	-59.413	-38.106	-18.78	-11.729	-21.5507	-9.439	-11.901
	VOL	2.303	3.401	0.693	0	5.749	6.009	4.511	0
	OI	5.347	6.721	1.609	0	6.293	6.611	6.613	2.996
Std. Dev	Return	3.855	2.295	2.503	2.797	1.638	2.688	1.77	2.59
	VOL	1.939	1.516	1.89	2.819	1.239	1.327	1.728	1.987
	OI	1.485	1.056	0.96	2.535	0.464	0.493	0.747	1.393
Skewness	Return	34.602	-7.26	-2.198	-0.992	2.525	0.061	0.086	0.514
	VOL	0.577	-1.1415	-1.393	-1.309	-1.373	-1.438	-0.842	-0.824
	OI	0.616	-1.21	-1.982	-1.844	-1.914	-1.223	-0.491	-0.644
Kurtosis	Return	1461.37	195.467	71.77	14.111	35.736	21.105	6.818	7.146
	VOL	2.603	4.968	4.471	4.051	3.768	4.146	3.986	3.435
	OI	2.639	4.637	9.158	5.262	8.986	5.669	3.4	2.923
Jarque- Bera	Return	1.97E+08	3660253	225288.8	1114.61	57510.41	13507.64	1592.28	1642.77
	VOL	166.487	893.517	478.086	798.623	426.568	395.401	308.846	261.671
	OI	183.93	954.47	2583.029	1878.888	2648.143	540.934	122.328	149.986
Heteroscadasticity test									
LB-Q^2 return		0.036**	0.004*	0.05*	0.012*	0.042**	-0.032*	0.072**	0.009*
Volume		0.651**	0.558**	0.534**	0.638**	0.101**	0.291**	0.629**	0.691**
Open Interest		0.694**	0.744**	0.675**	0.677**	0.507**	0.457**	0.642**	0.595**

** and * represent 1% and 5% levels of significance, respectively.

$$R_F = \ln \left(\frac{P_{F,t}}{P_{F,t-1}}\right)$$

where,

$P_{f,t}$ and $P_{F,t-1}$ are current and previous day daily closing value of select commodities futures price, respectively. R_F is the return series of selected commodities futures price series.

Volume data and open interest data of particular commodity futures are extracted from respective chosen exchange. Trading volume has been proxied by different ways in the literature. Epps and Epps, (1976) and Gallant, Rossi, and Tauchen (1992) considered total number of share traded as the measure of volume. Campbell and Hentschet (1992) have considered aggregate turnover (total no of shares/total number of share outstanding) as the measure of volume. In this paper we have considered daily turnover as a measure of trading volume.

Table 2 presents the descriptive statistics of futures return, volume and open interest series of all commodities under consideration. Natural log series of volume and open interest was considered for empirical analysis. Mean return varies from -0.0141 to 0.141741. The highest return is of silver while the lowest mean return is of natural gas, which is negative. A perusal of Standard deviation of all commodities suggests that the futures return of castor seed are the most volatile. Measure of skewness and kurtosis suggests that all the commodities are positively skewed except guar seed, copper and nickel, which are negatively skewed. Return series of castor seed is more skewed and highest peaked as compared to others, which indicates that there is a great percentage of small deviations from mean return and even a greater percentage of extremely large deviations from mean return. Most investors perceived such kind of behavior as increasing risk. Volume and open interest for all the commodities except for castor seed are negatively skewed and display significantly lower values for excess kurtosis.

Significant Jarque-Bera statistics indicate the non-normal behavior of unconditional distributions of futures return, volume and open interest (Fama, 1965 ; Stevenson & Bear, 1970). Stationarity of all the commodities is examined by using Augmented Dicky Fuller test (ADF) [Results of ADF are not shown here, could be provided on request] for return, volume and open interest series. ADF tests suggest that futures price, volume and open interest series are stationary and integrated of order one, that is, $I(1)$. The result of ADF rejects the null hypothesis (non stationarity) for all the series and accepts the alternative hypothesis of stationarity.

Ljung-Box (LB-Q) statistics, shown in Table 2, are calculated to test the serial correlation in returns, volume and open interest of all the commodities. All values of LB-Q statistics of returns, volume and open interest are statistically significant indicating the presence of serial correlation. Serial correlation in volume and open interest series of all the commodities signifies the mixed distribution hypothesis (MDH). The significant autocorrelation in squared returns exhibits the stylized fact of volatility clustering. Bollerslev (1986) proposed the GARCH model where conditional variance is modeled as a function of previous own lagged values and previous squared error. GARCH model with heavy tailed innovation efficiently forecasts the downside risk of returns.

➬ **Model Description :** The initial analysis of commodity futures return series are showing stylized facts like time- varying volatility, excess kurtosis and non normal distribution. Significant heteroscedasticity indicated by LM-Q statistics suggest the use of GARCH model. Literature supports using GARCH specifications to characterize the presence of serial correlation (Pati & Rajib, 2010; Lamoureux & Lastrapes, 1990). Thus, the present study uses GARCH framework to determine the relationship between volume, open interest and volatility. The first step in GARCH modeling is to accommodate the sufficient lagged value of autoregressive (AR) and moving average (MA) which remove any predictability associated with them (Pagan & Schwert, 1990; Engle and Ng, 1993). Akaike information criterion (AIC) and Bayesian information criterion (BIC) has been used to specify the mean equation with ARMA (1,1) and variance equation as GARCH(1,1). Generalized error distribution (GED) of the error term is used for the estimation of GARCH model (Nelson, 1991). GED-GARCH model disposes the leptokurtosis, fat-tailed behavior of financial time series (Gao, Zhang, Zehan, & China, 2012).

Considering distributional assumption, maximum-likelihood method is used to estimate GARCH models.

Following ARMA(1,1) - GARCH(1,1) model is used to estimate the time varying volatility.

Mean equation $R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 \varepsilon_{t-1} + \varepsilon_t$ ---------------------------- (1)

Variance Equation $\sigma^2_t = \phi + \alpha\varepsilon^2_{t-1} + \beta\sigma^2_{t-1}$ -------------------------- (2)

Restrictions imposed by GARCH model: $\phi \geq 0, \alpha \geq 0, \beta \geq 0$

R_t is the return of individual commodity futures at time t; ε_t is the conditional error term which follows the GED distribution with mean zero and variance σ^2_t. α and β are the ARCH and GRCH terms respectively which can be defined as the coefficients which measure the impact of recent news and old news on volatility respectively. Sum of α and β indicates the persistence of volatility. Large value of GARCH coefficient indicates the high volatility persistence while the large value of ARCH coefficient signifies less persistence. As GARCH model incorporates squared value of error term, it fails to explain the leverage effect in the model. Thus, for further examination of individual commodities we undertake EGARCH model proposed by Nelson (1991).

In EGARCH model positive and negative shocks are illustrated as good or bad news by Engle and Ng (1993). Equation 3 and 4 represent the mean and variance equation respectively for ARMA(1,1) EAGRCH(1,1) model

Mean equation $R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 \varepsilon_{t-1} + \varepsilon_t$ ---------------------------- (3)

Variance Equation $Ln(\sigma^2 t) = \omega + \varphi \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma^2_{t-1}}} - \sqrt{\frac{2}{\pi}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma^2_{t-1}}} + \beta \ln(\sigma^2_{t-1})$ ------------------ (4)

Coefficient γ is the leverage term which shows the asymmetric impact on volatility. The impact is asymmetric if the coefficient $\gamma \neq 0$ and is significant. If $\gamma < 0$, it shows leverage impact, and the persistence of volatility is measured by the term β. To investigate the impact of volume and open interest separately equations 5 and 6 are used.

$$Ln(\sigma^2 t) = \omega + \varphi \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma^2_{t-1}}} - \sqrt{\frac{2}{\pi}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma^2_{t-1}}} + \beta \ln(\sigma^2_{t-1}) + \delta_1 V_1 \text{ ------------------ } (5)$$

$$Ln(\sigma^2 t) = \omega + \varphi \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma^2_{t-1}}} - \sqrt{\frac{2}{\pi}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma^2_{t-1}}} + \beta \ln(\sigma^2_{t-1}) + \delta_1 OI_t \text{ ------------------ } (6)$$

Equation 7 and 8 represent the EGARCH equations for conditional volatility with contemporaneous volume and open interest and lagged volume and open interest, respectively :

$$Ln(\sigma^2 t) = \omega + \varphi \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma^2_{t-1}}} - \sqrt{\frac{2}{\pi}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma^2_{t-1}}} + \beta \ln(\sigma^2_{t-1}) + \delta_1 V_t + \delta_2 OI_t \text{ ------------------ } (7)$$

$$Ln(\sigma^2 t) = \omega + \varphi \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma^2_{t-1}}} - \sqrt{\frac{2}{\pi}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma^2_{t-1}}} + \beta \ln(\sigma^2_{t-1}) + \delta_1 V_{t-1} + \delta_2 OI_{t-1} \text{ ------------------ } (8)$$

Empirical Analysis and Results

Table 3 presents the estimated coefficients of ARMA (1,1) - GARCH (1,1) model without any variance regressors in the conditional variance equation. In the mean equation the coefficients α_1 and α_2 are statistically significant at 1% for copper, nickel, gold, and silver which signifies that conditional mean depends on its previous value and previous error term.

Table 3. Estimations of ARMA (1,1)-GARCH(1,1) Model

	Castor seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
α_0	0.0297	0.05633*	0.524**	0.04971*	0.0515**	0.1060**	0.0857**	-0.0598
α_1	0.2037*	0.2818**	0.2917**	-0.6172**	0.5446**	0.9691**	-0.53513*	0.14398**
α_2	0.28964**	-0.32302**	-0.2741**	0.5954**	-0.566**	-0.9561**	0.54149*	-0.12329**
ϕ	0.03689**	0.1012**	0.06901*	0.4522**	0.0255*	0.0764*	0.0222*	0.06774*
α	0.08093**	0.0908**	0.0181*	0.2078**	0.031**	0.0297**	0.0437**	0.0312**
β	0.9031**	0.8911**	0.9623**	0.7609**	0.954**	0.9555**	0.9497**	0.9589**
Persistent								
(α + β)	0.984	0.982	0.981	0.969	0.984	0.985	0.994	0.99
Half Life	43 days	38 days	35 days	22 days	44 days	47 days	107 days	70 days
Standardized residual diagnostic								
ARCH-LM(24)	0.0011	0.0398	0.0621	3.237	0.0952	0.964	1.458*	1.4217*
LB-Q(24)	21.971	22.4	19.908	5.42	14.319	24.631	25.382	15.22
LB-Q^2(24)	1.91	0.7604	1.608	0.048	2.086	24.273	36.45	35.638

** and * represent 1% and 5% levels of significance, respectively.

The results show that ARCH term, α (the coefficient on the lagged squared residual term) and GARCH term, β (the coefficient on the lagged conditional variance) of the conditional variance equation are statistically significant for all the eight commodities. Persistence of volatility is measured by the summation of α and β which is quite high (greater than .98). Sum value of ARCH and GARCH is less than 1 in all commodity futures which indicates that return volatility will not move indefinitely upwards or downwards, thus, confirming mean reversion behavior in case of all commodity futures. Eventually the return volatility will come down to a mean level.

A further measure of persistence in a volatility model is the "half- life" of volatility. Half- life of volatility is defined as the time taken for the volatility to move halfway back towards its unconditional mean following a deviation from it. The half- life is a better explanation of persistence as it quantifies it in terms of exact days required for volatility to come back to its average. Zivot and Wang (2006) proposed a formula to calculate half -

Table 4. Estimations of ARMA (1,1)-EGARCH(1,1) Model

	Castor seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
c	0.0183	52.776	0.0266	-0.0021	-0.235**	0.1149**	0.0829**	-0.051
θ_1	0.0178	0.999**	-0.555**	0.0306	1.0001**	0.9028**	0.8574**	0.1416
θ_2	0.0418	-0.997**	0.5487**	-0.0332	-1.004**	-0.886**	-0.847**	-0.124
ϕ	-0.0247**	-0.065**	2.5401**	-0.0521	-0.053**	-0.0245	-0.62**	-0.038**
α	0.074**	0.1174**	0.0201**	0.6067**	0.1046**	0.1211**	0.0942**	0.0712**
γ	-0.0518**	0.0624**	0.0132**	0.172	0.0241	0.0264	-0.0249*	-0.0165
β	0.9687**	0.9830**	0.998**	0.8605**	0.9796**	0.9716**	0.9922**	0.992**
Standardized residual diagnostic								
ARCH-LM(24)	0.0011	0.047	0.6912	1.1294	0.1142	1.357	1.57	1.587
LB-Q(24)	12.003	20.44	20.95	4.078	14.67	22.69	27.58	14.87
LB-Q^2(24)	0.418	0.321	0.885	0.0667	2.489	33.98	37.78	39.694

** and * represent 1% and 5% levels of significance, respectively.

Table 5. Estimations of ARMA (1,1)-EGARCH(1,1) with Current Volume

	Castor seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
c	0.0116	0.0304	0.0572**	0.0630**	0.0678	0.0836**	0.0805**	-0.0528
θ_1	-0.0165	-0.5767**	0.3006**	-0.6850**	0.5233**	-0.2976	-0.4063	0.142
θ_2	0.0827	0.5989**	-0.2914**	0.6691**	-0.5530**	0.3121	0.4131	-0.1245
ϕ	1.3256**	1.9211**	0.8078**	-0.0208**	-1.5602	-0.0221	-0.0569**	-0.0387**
α	0.1075	0.054	0.1504*	0.0554**	0.2971**	0.3062**	0.0931**	0.0712**
γ	-0.0676*	0.0633*	0.0002	-0.0121	-0.1954	-0.0126	-0.0244*	-0.0177
β	-0.4301**	-0.5732**	-0.3268**	0.9921**	-0.2838**	-0.2397**	0.9917**	0.9921**
δ_1	9.26E-06**	4.58E-06**	1.44E-05**	-2.22E-07*	5.42E-05**	3.73E-05**	-4.78E-08	2.88E-08
Standardized residual diagnostic								
ARCH-LM(24)	0.045143	0.0034	0.041	0.01046	0.2418	0.135	1.73	1.66
LB-Q(24)	19.36	24.22	21.876	9.003	27.316	59.429	26.83	14.89
LB-Q^2(24)	1.144	0.1355	5.087	0.2443	6.196	54.465	41.905	41.711

** and * represent 1% and 5% levels of significance, respectively.

life as given below:

$L_{half} = \ln(1/2) / \ln(\omega+\gamma)$

wherein,
ln is Natural logarithm,
ω is ARCH term,
γ is GARCH term.

We have found that half life time for commodities range from 22 to 107 days. Highest half life is for energy commodities (107 and 70 days) and the least is for industrial products (11 days and 35 days). LB-Q return, LB-Q squared return has insignificant statistical value for all the commodities except ARCH-LM which has significant statistical value for energy commodities futures. Insignificant statistical value implies acceptance of the null hypothesis of no serial correlation for all the commodities futures which implies that GARCH model is a perfect fit. Literature shows that because of some exogenous variables conditional volatility persists. Hence, inclusion of these exogenous factors in the model may decrease the volatility persistence. According to Kyle (1985), Williams and Wright (1991), and Karali and Thurman (2008) persistence in volatility is the result of market reaction to news. Assumptions of GARCH model restrict the model behavior toward bad or good news. We have used ARMA (1,1)-EGARCH(1,1) model to study this asymmetric behavior of volatility.

Table 4 reports the estimates of the coefficients of ARMA (1, 1) – EGARCH (1,1) model. The asymmetric parameter γ is negative and statistical significant for castor seed and crude oil which confirms the leverage impact, which implies that variance tends to fall when return innovations are negative i.e. negative news have a greater impact on volatility than positive news of same magnitude. While asymmetric parameter γ is positive and statistical significant for guar seed and copper, it indicates that positive shocks cause same effect on variance as negative shocks. Since β, coefficient of volatility persistent, is positive and statistical significant for all the commodity futures, it indicates the current period volatility is highly impacted by the previous period's volatility. Diagnostic test of Ljung – Box (Q) test and ARCH-LM test has been applied to check the robustness of the EGARCH(1,1) model. The values of Q and Q^2 statistics accept the null hypothesis of no serial correlation for all commodity futures and indicate that ARMA(1,1)-EGARCH(1,1) model is well fitted to capture the leverage effect of innovations on volatility. ARCH –LM statistics confirms the presence no serial correlation among the residuals.

Table 6. Estimations of ARMA (1,1)-EGARCH(1,1) with Current Open Interest

	Castor seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
C	0.032	-0.2083	0.0456**	-0.0332	0.0015**	0.09978**	0.0828**	-0.0532
θ1	-0.0123	1.004**	0.2917**	-0.5945*	1.001**	-0.249	0.4594	0.1429
θ2	0.1039	-0.9974**	-0.2784**	0.6124**	-1.0033**	0.2638	-0.4433	-0.1252
ϕ	0.0014	-0.0562**	-0.0022**	0.02209	-0.3401**	-0.0139	-0.0603**	-0.0396**
α	0.0391	0.1009**	0.0627**	0.1097**	0.12483**	0.1118**	0.0938**	0.07118**
γ	0.0186	0.0681**	-0.0227	-0.0241**	-0.0648**	0.0287	-0.0238*	-0.0176
β	0.9796**	0.9931**	0.9852**	0.93625**	0.7057**	0.9719**	0.9919**	0.992**
δ1	-3.36E-08	-6.49E-08	-9.40E-08**	-3.91E-08**	0.0001**	-4.89E-07	-8.27E-08	2.11E-07
Standardized residual diagnostic								
ARCH-LM(24)	0.022584	0.135	0.2641	0.00359	1.2916	1.305	1.587*	1.81*
LB-Q(24)	12.887	11.88	23.309	5.727	41.389	26.342	26.205*	14.794
LB-Q^2(24)	0.5455	0.2441	6.771	0.0854	37.78	32.831	38.123	45.218*

** and * represent 1% and 5% levels of significance, respectively.

➪ **Price Volatility and Contemporaneous Volatility and Open Interest Separately :** Tables 5 and 6 show the estimates of ARMA(1,1)-EGARCH(1,1) for all the eight commodities taken into study. Results of Table 5 show the presence of significant autoregressive process and moving average of first order for guar seed, copper, nickel and gold. This indicates that last one period commodity futures returns and error term influence future return. Variance equation of the EGARCH model is hypothesized to be the function of daily rate of information proxy by daily trading volume (equation 5). Asymmetric coefficient, γ is negatively significant for castor seed and crude oil and positively significant for guar seed. The current volume coefficient is significant positive for all the commodities futures except for energy futures. The results suggest the positive association between volatility and trading current volume. β value is significant for all the commodities but less than 1, signifies the volatility persistence and mean reversion. Coefficient value of δ_1 represents that current volatility is significant for all the commodities except energy commodities which signifies that volume has no explanatory power for crude oil and natural gas. Inclusion of current volume in the model leads to substantial reduction in volatility persistence except for nickel futures (from 0.8605 to 0.9921). However, for energy commodities no change is found in persistence of volatility. The results reflect the contribution of volume in explaining the time varying conditional volatility which supports the MDH theory. This finding is in line with the results of Najand and Yung (1991), Foster (1995), and Kumar et al. (2010) but in contradiction with the results of Lamoureux and Lastrapes (1990). The insignificant value of LB-(Q) test and ARCH-LM test indicates that no serial correlation is present in the residual values of the model. Thus model is a perfect fit.

The results of Table 6 reveal that for five out of eight commodities, the current open interest value is not statistically significant. Open interest has explanatory power for copper, nickel and gold, whereas, the inclusion of current open interest does not have any significant impact on the market persistence for all commodities except for nickel and gold futures. The volatility persistence has reduced significantly (from 0.9796 to 0.7057) for gold futures and increased significantly for nickel futures (from 0.8605 to 0.0.9852). The reasonable cause for this behavior of open interest may be the ineffectiveness of hedging in Indian commodity market. Indian commodity is used by market participants more for speculative purpose, which is evidenced by the reduction in volatility persistence by considering current trading volume. The significant negative value of open interest for industrial goods (Copper and nickel) indicates that an increase in open interest mitigates the volatility. It is interesting to note that open interest which is generally used as proxy for market depth has no significance in Indian commodity futures. These findings are in inline with Kumar et al.(2010). The insignificant value of LB-(Q) test and ARCH-

Table 7. Estimations of ARMA (1,1)-EGARCH(1,1) with Lagged Volume

	Castor seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
c	0.0318	0.0620*	0.0524**	0.0628**	0.0668**	0.0942**	0.0803**	-0.0528
θ_1	-0.0123	0.0577	0.2912**	-0.707**	-0.7898**	-0.2729	-0.4136	-0.9360**
θ_2	0.1033	-0.0514	-0.2731**	0.6917**	0.7679**	0.2871	0.42043	0.9386**
ϕ	-4.82E-05	-0.0642**	-0.0139	-0.0171*	-0.0475**	-0.0259	-0.0571**	-0.0381**
α	0.0398	0.1168**	0.0653**	0.0587**	0.0986**	0.1102**	0.0928**	0.07004**
γ	0.0191	0.0549**	-0.0181	-0.0128	0.0285	0.0285	-0.024*	-0.0177
β	0.9793**	0.9816**	0.989**	0.990**	0.981**	0.971**	0.9917**	0.99238**
δ_1	-2.25E-08	-1.08E-08	-2.02E-07**	-3.29E-07*	-4.95E-08	2.59E-07	-4.34E-08	2.29E-08
Standardized residual diagnostic								
ARCH-LM(24)	0.020571	0.032	0.0012	0.0101	0.1151	1.4545	1.718*	1.686*
LB-Q(24)	12.732	25.927	27.954	8.7004	13.685	25.479	26.671	16.402
LB-Q^2(24)	1.43	0.1569	6.2603	0.2341	2.528	36.237	41.617**	42.148**

** and * represent 1% and 5% levels of significance, respectively.

Table 8. Estimation of ARMA(1,1)-EGARCH(1,1) Model with Lagged Open Interest

	Castor Seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
c	0.0323	0.0897**	0.0598**	0.0664**	0.0596**	0.0998**	0.0829**	-0.0531
θ_1	-0.0123	0.3995	0.2878**	-0.2825	0.6671**	-0.2925	0.4594	-0.9362**
θ_2	0.1038	-0.3878	-0.2786**	0.2604	-0.681**	0.30601	-0.4433	0.9386**
ϕ	0.0009	-0.0738**	-0.001	0.0169	1.9329**	2.5823**	-0.06004**	-0.03902**
α	0.0396	0.1322**	0.0636**	0.0991**	0.4358**	0.5169**	0.09381**	0.07013**
γ	0.0184	0.0645**	-0.0234	-0.0167	-0.0593	0.0509	-0.02373*	-0.0178
β	0.9796**	0.9813**	0.9847**	0.9527**	0..9767**	0.978	0.99186**	0.99201**
δ_1	-3.32E-08	-1.14E-08	-9.73E-07**	-3.09E-06**	-0.00017	-0.00012**	-9.33E-08	1.97E-07
Standardized residual diagnostic								
ARCH-LM(24)	0.02258	0.034	0.086	0.0041	1.411	1.549	1.5906*	1.831**
LB-Q(24)	12.887	21.84	23.604	6.65	25.781	38.05	26.202	16.334
LB-Q^2(24)	0.5455	0.1159	6.922	0.0968	40.827	42.695	38.173*	45.640**

** and * represent 1% and 5% levels of significance, respectively.

LM test indicates that no serial correlation is present in the residual values of the model. Thus the model is a perfect fit for all the commodities futures except crude oil futures because of significant value of LB-Q statistics and ARCH-LM test.

In conclusion, we can say that when contemporaneous volume and open interest are included separately as explanatory variables in the variance equation, current volume has a significant explanatory power over current open interest for the volatility of the futures return. Yang et al. (2004) found the long term relationship between price volatility and open interest and suggested that open interest does not cause futures price volatility while futures price is the source of open interest.

➭ **Price Volatility and Lagged Volume and Open Interest Separately:** According to Najand and Yang (1991), if the futures prices and volume are jointly determined, then GARCH model may have some simultaneity bias. To

Table 9. Estimation of ARMA (1, 1)-EGARCH(1,1) Model with Contemporaneous Volume and Open Interest

	Castor Seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
C	-0.0176	0.060446*	0.046467*	0.07143**	0.066085**	0.095565**	0.082125**	-0.0523
θ_1	-0.0281	-0.875118**	0.291778**	0.822418**	0.672556**	-0.2565	0.4426	0.1419
θ_2	0.0978	O.879786**	-0.27759**	-0.81147**	-0.70302**	0.2688	-0.4264	-0.1238
ϕ	1.3068**	1.6941**	1.412416**	2.140104**	-2.01239**	O.83077**	-0.05901**	-0.03785**
α	0.0669	0.163703**	0.0983	0.219411**	0.327179**	0.167117*	0.090451**	0.067566**
γ	0.0383	0.104086**	-0.034	0.0197	-0.21064**	0.0033	-0.02684*	-0.0119
β	-0.1500	-0.1229	-0.058	-0.275118**	-0.32286**	-0.0361	0.99329**	0.99242**
δ_1	2.3E-05**	-1.80E-05**	2.16E-05**	3.02E-05**	3.76E-05*	-8.49E-05**	-9.05E-08*	-2.58E-07*
δ_2	-1.20E-05**	1.14E-05**	-8.23E-05**	-0.00012**	5.33E-05**	3.86E-05**	0	8.61E-07*
Standardized residual diagnostic								
ARCH-LM(24)	0.0622	0.087	0.0031	0.0022	0.4831	1.671	1.686	1.785
LB-Q(24)	17.609	20.334	22.28	16.715	31.134	50.206	27.805	14.49
LB-Q^2(24)	1.54	0.0886	5.875	0.0552	12.343	40.508	41.28	44.11

** and * represent 1% and 5% levels of significance, respectively.

Table 10. Estimation of ARMA(1,1)- EGARCH(1,1) Model with Lagged Volume and Open Interest

	Castor Seed	Guar Seed	Copper	Nickel	Gold	Silver	Crude Oil	Natural Gas
c	0.03608	0.0892**	0.0470**	0.00047	0.0664**	0.10006**	0.0822**	-0.0523
θ_1	-0.0116	0.9326**	0.2891**	0.9931**	-0.826**	-0.241	0.4482	0.1423
θ_2	0.1049	-0.9356**	-0.292**	-0.997**	0.806**	0.2548	-0.4321	-0.1242
ϕ	0.0115	-3.15E-2*	-0.00154	0.0347*	1.496**	1.9745**	-0.058**	-0.0376**
α	0.0358	1.03E-01**	0.0610**	0.1258**	0.3595**	0.4002**	0.0898**	0.0674**
γ	0.0159	0.0594**	-0.0222	-0.0294**	-0.0348	0.0598	-0.0261*	-0.0118
β	0.9523**	0.9633**	0.991**	0.930**	0.2799*	0.2962*	0.9921**	0.9923**
δ_1	3.59E-07	3.09E-07**	-2.13E-08	-8.37E-07**	-0.0001**	-0.0001**	-7.71E-08	-2.70E-07**
δ_2	-2.27E-07	-4.38E-07**	-8.71E-07	-3.39E-06**	6.72E-06*	4.86E-06	2.81E-07	8.87E-07*
Standardized residual diagnostic								
ARCH-LM(24)	0.027733	0.012	0.071	0.00437	0.7882	1.312	1.676*	1.778*
LB-Q(24)	13.44	22.48	22.45	5.479	24.098	39.511	27.45	14.459
LB-Q^2(24)	0.668	0.114	5.929	0.1307	21.226	35.801	40.969**	43.85**

** and * represent 1% and 5% levels of significance, respectively.

remove these biases, lagged value of volume and open interest is included as exogenous variable in the variance equation.

Table 7 shows the estimations of unrestricted ARMA(1,1) EGARCH (1,1) model for the all the eight commodities taken into study when lagged volume is included as explanatory variable. Coefficient of lagged value of volume (δ_1) is significant for industrial commodities only and does not induce any significant change in persistence of volatility except for nickel (from 0.8605 to 0.990).

As shown in Table 8, coefficient of lagged value of open interest (δ_1) is significant for industrial commodities futures and silver futures also. The inclusion of open interest in conditional volatility does not show any significant change in the volatility persistence except for nickel. In nickel futures the volatility persistence has increased from 0.8605to 0.9527. The model is a perfect fit for all the commodities futures except crude oil futures as shown by the insignificant value of LB-Q statistics and ARCH-LM test.

➩ **Price Volatility, Volume, and Open Interest Together:** Table 9 depicts the joint effect of contemporaneous volume and open interest on price volatility. Coefficient values of contemporaneous volume (δ_1) and open interest (δ_2) are significant for all the commodities except crude oil, for which open interest is not significant. Volatility persistence has reduced drastically for all the commodities expect energy goods for which volatility persistence remains the same.

Table 10 show the results of ARMA(1,1) – EGARCH(1,1) with lagged volume and open interest taken as exogenous variable. Coefficient value of lagged volume (δ_1) and open interest (δ_2) are significant for all the commodities except castor seed, copper, and crude oil. For silver futures lagged value is significant but open interest has insignificant statistics. However, in silver futures, lagged volume achieves statistical significance at 1% level. The result shows that volatility persistence has reduced drastically for precious commodities but for energy futures volatility persistence remains the same.

Thus, it appears that compare to lagged volume and open interest, contemporaneous volume and open interest are showing greater power to reduce volatility persistence. Volume and open interest are not showing any impact on the persistence of energy futures either jointly or separately which implies that the traders cannot predict the futures prices based on the previous prices/ Volatility. This also indicates the market efficiency for energy futures in India. These findings imply that inclusion of open interest with volume may provide better understanding of price variability (Bessembinder & Seguin, 1993), but open interest which is generally used as proxy for market depth, does not play any significant role in explaining the price volatility in Indian futures market.

Conclusion

In the present paper, ARMA-GARCH and ARMA-EGARCH models are used with GED distribution to examine the time varying volatility dynamics for eight commodity futures. ARMA–GARCH and ARMA- EGARCH model give empirical evidence of the presence of volatility dynamics like persistence, volatility clustering and mean variance and leverage effect in the Indian commodity futures respectively. Out of eight commodities, only two commodity futures (castor seed and crude oil) are showing leverage effect, which implies that negative news increases volatility more as compared to positive news of same magnitude. It has been argued in the past that constraint of a costly short sale is responsible for the asymmetric effect in equity markets. Absence of any such constraint of short sales in commodity futures is the plausible reason of absence of asymmetric effect in commodity futures. When current volatility is included as exogenous variable in EGARCH model, the coefficient γ shows the amplifying effect as more commodities futures (guar seed, gold ,copper ,silver) are showing leverage effect.

Industrial metal, guar seed and gold futures show the autoregressive nature of return. Results of the paper indicate that current volume reduces the volatility persistence more than lagged volume does. Open interest as the exogenous variable in conditional variance equation does not reduce volatility significantly. However, current open interest provides significant reduction in persistence of volatility when entered with current volume in the conditional variance equation. Hence it indicates that market information proxy by volume, explains the GARCH effect, persistence of volatility and also supports the existence of MDH. Current (lagged) volume and open interest are ineffective in explaining the GARCH effect for energy commodities which implies the inefficiency of EGARCH model which is later confirmed by the statistical significant value of LB-Q statistics. The empirical results verify that there is significant relationship between return, volatility and volume when current volume is integrated in variance equation. The present result is in line with the previous findings of Bessembinder and Senguin (1993), and Kumar and Pandey (2010).

Research Implications

The present study is significant for market traders, government and regulatory bodies. The results of the study have practical implications for market traders, as they can reduce their futures price volatility substantially by taking into consideration current volume. A significant positive volume-price volatility relationship poses a significant challenge in front of regulators to curb speculative trading.

Limitations of the Study and Scope for Future Research

(1) More commodities and a larger span of period can be used to empirically analyze the relationship among volume, open interest and volatility.

(2) More advance econometric tools can be used to find a suitable model for Energy futures commodities.

(3) Insignificant relationship between open interest and futures volatility poses questions about the motive beind trading activities. Further research is required to answer these questions

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