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ASYMMETRIC VOLATILITY OF NET CONVENIENCE YIELD: EVIDENCE FROM INDIAN COMMODITY FUTURES MARKETS

Abstract:

(NCY). It asserts that the positive NCY should have higher volatility as compared to negative NCY. This paper investigates asymmetric volatility behavior of NCY in Indian commodity futures markets. We model NCY as EGARCH process which captures the asymmetry in volatility of the series. The mean equation of NCY is modeled as autoregressive process with month and period dummies. We also include volatility of the spot prices as explanatory variable. Our results of the asymmetric behavior of NCY indicate that the theory of storage is not valid in Indian commodities market. In most of the agricultural commodities, we do not find asymmetric behavior; the negative shock to NCY increases the volatility of NCY rather than decreasing it. This result contradicts the implications of the theory of storage. In other words, when the spot prices are higher than the futures prices (backwardation), the volatility of spread is higher than volatility of spread when spot prices are lower than the futures prices. Only in case of crude oil, positive NCY has higher volatility than negative NCY.

Keywords:

Convenience yield, Asymmetric volatility, EGARCH, The theory of storage, Indian Commodity Futures Markets

JEL Classification: C22, G13

1. Introduction

Commodity price formation and relationship between spot and futures prices have long been an important aspect of investigation by researchers. Pindyck (2001) argued that for storable commodities, spot price, futures price and price of storage (convenience yield) are simultaneously decided by the equilibrium in all three markets namely spot market, storage market and futures markets. However, apart from these basic economic factors affecting supply and demand of commodity and storage market, futures market structure (kind of participation- speculative or hedging); risk test of participants in the futures markets and different expectation about the futures prices may also affect the spot and futures prices. Hence, there are two popular postulates which explain the difference between spot and futures prices of a particular commodity. These are the theory of storage and the theory of normal backwardation.

The theory of normal backwardation asserts that futures price is a downward biased estimate of the expected spot price and this may result in positive risk premium (Keynes, 1930). This risk premium arises because of differences in positions of hedgers and speculators. If hedgers are net short, or risk aversion of the short hedgers is more than the long hedgers, the futures price will be downward biased estimate of the expected spot price. The decrease in the futures price relative to the expected spot price at maturity is referred to as *normal backwardation*. On the other hand, the theory of storage explains the difference between spot and futures prices in terms of interest forgone in storing a commodity, storage cost and convenience yield on inventory. The convenience yield is equal to the stream of implicit benefits which the processors or consumers of a commodity receive from holding a marginal unit of inventory of the commodity. These benefits may arise because the inventory may provide some productive value as when it is an input to the production of another commodity or there may be a convenience yield from holding inventory to meet unexpected demand. The theory is based on no-arbitrage condition between keeping physical inventory as compared to buying a futures contract for future delivery of the commodity.

Initially, Kaldor (1939) put forth the concept of convenience yield and asserted that the marginal value of convenience declines as inventory increases. It is argued that the convenience yield is a hyperbolically decreasing function of the level of inventory (Fama and French, 1987). This implies that the convenience yield declines with increases in inventory but at a decreasing rate. The typical behavior of convenience yield and its relationship with inventory under various regimes of demand and supply explain the behavior of the spot prices, futures prices and their difference. The backwardation and contango in the market is explained by convenience yield. Fama and French (1987 & 1988) pointed out that the convenience yield, which declines with inventory at decreasing rate, is the main reason behind the seasonal change from contago to backwardation in the futures market. If the net convenience yield (NCY[1]) is large then the interest cost, futures prices will be lesser than the spot price and this phenomenon is called normal backwardation. If net convenience yield is zero or negative then the futures price exceeds the spot price and spot price will equal the discounted futures prices. This phenomenon is called contango. So understanding convenience yield is important to understand the spread between spot and futures.

1.1 Empirical Testing of the Theory of Storage

The theory of storage is tested by two methods: direct method and indirect method. The direct test uses stock level to proxy inventory level and explicitly model inventory effect on convenience yield. It directly tests the hypothesis that convenience yield (CY) on inventory falls as aggregate inventory increases but at decreasing rate. Working, (1948, 1949), Brennan, (1958), Telser, (1958), Gray and Peck (1981), Thompson (1986), Lien (1987), Cho and McDougal (1990), Heaney (1998), Gao and Wang (2004) and others researched used stock level as proxy of inventory and modeled convenience yield to test the theory of storage. The direct method suffers from the problem of measurement of stocks of inventory. There are difficulties in defining aggregate inventory data due to variation in consumption, production, international trading, etc. Gray and Peck (1981) argued that the price of storage is determined by the current stock rather than general level of stock. Weymer (1966) demonstrated that the expected level of stocks between two distant futures contract is most important in determining the price of storage. In absence and accuracy of storage data, and defining actual measurement of stock of inventory, indirect method is used to test the theory.

The indirect test investigates the behavior of NCY by examining the relative variation of spot and futures prices rather than by examining the inventory-convenience yield relation directly. It asserts that the relative variation of spot and futures prices is also a function of inventory and therefore CY. When inventory is low, the variation in spot prices is higher than the futures prices. Also futures and spot prices have roughly the same variability when inventory is high. Indirect test of the theory of storage uses interest adjusted basis (IAB) first introduced by French, 1986; or NCY and/or interest and storage adjusted basis (Ng and Pirrong, 1994).

In their seminal work, Fama and French (1986) used interest adjusted basis or net convenience yield as a proxy as follows:

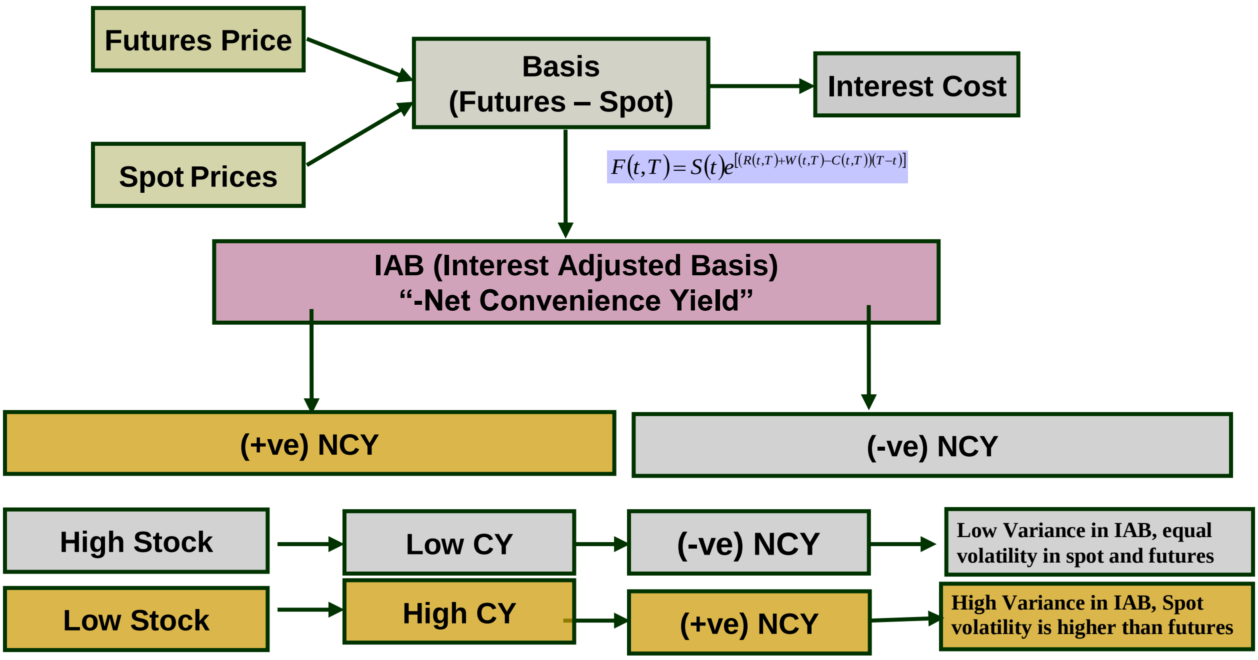
$$[F(t,T)-S(t)]/S(t)-R(t,T)=[W(t,T)-C(t,T)]/S(t) \quad (1)$$

The left hand side of equation [1] is called the interest adjusted basis (IAB) or net convenience yield (NCY). It is equal to the difference between the relative warehouse cost, and the relative convenience yield. They assume that the marginal warehousing

[1] The net convenience yield (NCY) is the difference of convenience yield and storage cost.

costs are roughly constant so variation in convenience yield dominates variation in storage cost. As inventory falls, the convenience yield becomes positive and larger, and probably higher than the warehousing cost. It makes the IAB (NCY) negative (positive). At higher inventory levels, convenience yield falls to zero and IAB (NCY) becomes positive (negative). So author used the sign of IAB as a proxy for high (+ve) and low (–ve) inventory.

Figure 1: Indirect Test of Theory of Storage



The theory of storage asserts that any demand and supply shocks can be adjusted through inventory. The variation in NCY depends on the way inventory adjust to transmit price effects of shocks through time. In different inventory conditions, NCY will behave differently. The NCY widens as inventory fall down and should show high variability. Higher inventory level allows higher inventory response and lower variation in current and expected prices. Hence NCY with be low and has less variation. Therefore, the theory of storage explains asymmetry of volatility of NCY when it is positive and negative. The volatility of NCY should be high when it is positive as compared to when NCY is negative. French (1986) used the IAB as proxy of inventory and tested the asymmetric volatility of IAB for industrial metals- aluminum, copper, lead, tin, and zinc. Authors calculated the IAB and divided the data into two parts-positive and negative IAB and variation in IAB was calculated separately. They found support of asymmetric volatility in IAB for all industrial metals.

Many studies applied the same proxy to test the theory of storage in different commodities. Apostolos, and Vaughn (1994) tested the theory of storage in energy markets and found that the IAB of crude oil was slightly more volatile when IAB was positive than when it was negative. The results suggest that the theory holds for heating oil and unleaded market but not for crude oil market. Serletis and Hulleman (1994) used futures prices for crude oil, heating oil and unleaded gasoline traded on NYMEX and found that theory of storage held for energy market. Serletis and Shahmoradi (2006) tested the theory of storage using indirect test for North American natural gas markets and confirmed that the theory of storage is valid for natural gas market.

Recently, some of the studies in this area found that the convenience yield shows mean-reversion/persistence and also possesses time varying volatility pattern. It also has seasonal variation, as convenience yield of agricultural commodities becomes positive and high just before harvest. Some of the studies includes Mazaheri (1999); Gao and Wang (2004), Ates and Wang (2005), Benavides (2005), Modjtahedi and Movassagh (2005), and Wei and Zhu (2006). Mazaheri (1999) modeled CY as ARFIMA-GARCH process and used EGARCH and the Glosten-Jagannathan-Runkle (GJR) volatility models to capture the asymmetric variability of CY. He found that CY shows asymmetric volatility which is in accordance with the theory of storage. Gao and Wang (2005) proposed a "unified test" that incorporates aspects of both direct and indirect tests to validate the theory of storage. Authors used six metal futures contracts (copper, lead, zinc, aluminum, tin and nickel) traded on London Metal exchange (LME) and three metals contracts (copper, silver and gold) futures traded on the New York Mercantile Exchange (NYMEX) and found that volatilities of six metal traded on LME and NYMEX copper IAB (NCY) have strong negative asymmetric pattern while negative asymmetric pattern was absent in basis of gold and silver traded on NYMEX. They suggested that even if inventory data is available, an asymmetric volatility term in conditional variance function of NCY should be incorporated to model dynamic behavior of the daily NCY of storable commodities. Ates and Wang (2005) studied the same for natural gas market and found found that during the low inventory periods, sudden increase in demand increases the volatility of CY. The asymmetric property of NCY disappeared when inventory and weather in used as explanatory variables in the conditional variance equation. Modjtahedi and Movassagh (2005) also studied the natural gas futures and modeled NCY as GARCH process with inventory data as explanatory variable in conditional mean equation. They found partial support of the theory of storage that the NCY is convex in the storage level for the short run delivery but becomes concave for the long run. Wei and Zhu (2006) modeled CY as a function of spot price shock, spot price volatility and gas storage shock and found that the price and storage variable statistically affect the CY. Siaplay et al. (2012) used basis in a regression model and found that the basis provides better signal for store or sell decisions as compared to spot and futures prices. However, Barone-Adesi, Geman, and Theal (2014) analyzed the gold futures and found that inventory is negatively related to lease rate and convenience yield is better explained through lease rate than interest adjusted basis.

To sum up, it can be concluded that indirect method of testing the asymmetric behavior of NCY has been extensively applied in developed market and non-agricultural commodities. Also, it has been found that convenience yield follows mean-reverting and seasonal behavior and its volatility has time varying nature (ARCH effect). In an emerging market, understanding asymmetric nature of convenience yield or testing the implication of the theory is important because of different returns and microstructure characteristics. The characteristics of emerging markets are very different from that of developed markets. Emerging markets are characterized by low liquidity, thin trading, and consequentially returns exhibit higher sample averages, low correlations with developed market returns, non-normality, better predictability, higher volatility, and small samples for research (Antoniou and Ergul; 1997 and Bakaert and Harvey; 1997). It is usually assumed that the emerging market exhibit higher price variability and poor information processing (Tomek, 1980; Carter, 1989). In this context, Indian commodity futures markets with recent origin and low volume of trade provide an opportunity to investigate these issues in emerging market context.

In the year 2003, three national commodity exchanges in India were setup with modern electronic trading platform. Since the inception of national commodity exchanges, the volume and value of futures trade has increased manifold. Despite the phenomenal growth, many a times Indian commodity futures markets have been criticized for their alleged destabilizing effect on spot market through manipulative and speculative activity. Given the criticism, it is important to understand the convenience yield characteristics and its relationship with spot and futures prices in Indian futures market. It will hopefully help in explaining various policy related issues as well as help the traders (hedgers and speculators) to understand the functioning of an emerging futures markets.

In order to fill the research gap, this paper investigates the asymmetric behavior of volatility of NCY for eleven commodities including agricultural commodities, industrial metals, precious metals and energy commodities. We have analyzed the behavior of one month convenience yield, and two month convenience yield (details are given in section 2) for all agricultural and non-agricultural commodities. We model conditional mean equation of NCY as autoregressive process with monthly dummies to capture seasonal behavior in the NCY. The conditional volatility equation is model as EGARCH process which tests the asymmetric response of NCY. One should expect difference in the behavior of convenience yield of agricultural commodities, which possess high storage and transaction costs and are less tradable as, compared to non-agricultural commodities which are more responsive to global information and have less storage and transaction cost (especially precious metals Gold and Silver).

2. Data and Methodology

In this study, the asymmetric volatility of NCY is examined for four agricultural commodities- Soybean, Maize, Castor seed, and Guar seed, three industrial metals- Aluminum, Copper and Zinc, two precious metals- Gold and Silver, and two energy commodities- Crude oil and Natural gas, traded on Indian national commodity exchanges. Details of the data period and source of data are given in Table 1. We also divide the data into two non-overlapping sub-periods of almost two years each. The first sub-period from year 2004 to 2006, represents the early phase of the national commodity exchanges and characterized by low futures trading volume and market depth and the second sub-period from year 2007 to 2008, is characterized by relatively high futures trading volume and high market depth.

Convenience yield is unobserved but can be estimated through futures and spot prices by using cost of carry model[2]. We estimate the near month convenience yield (NCY_1) and next to near month by near month convenience yield (NCY_2) from near month and next to near month futures and spot prices. We prepare the near month futures time series and next to near month futures time series on rolling basis, i.e. when the near month contract approaches maturity, we select data from the next maturing contract. We also remove the maturity week data from the near month futures series to remove the maturity bias.

Table 1: Details of Commodity, Data Period and Source

Commodity		Data-Period	Future Market	Spot Market
Agricultural	Soybean	09/01/2004 to 10/20/2008	NCDEX	Indore
	Maize	01/05/2005 to 10/20/2008	NCDEX	Nizamabad
	Castor Seed	09/21/2004 to 10/20/2008	NCDEX	Disa
	Guar Seed	04/12/2004 to 09/19/2008	NCDEX	Jodhapur
Precious Metals	Gold	05/02/2005 to 09/30/2008	MCX	Ahmedabad
	Silver	05/02/2005 to 09/30/2008	MCX	Ahmedabad
Industrial	Aluminium	02/01/2006 to 09/30/2008	MCX	Mumbai

[2] $F(t,T) = S(t)e^{[(R(t,T)+W(t,T)-C(t,T))(T-t)]}$ where, F(t,T) is the futures price at time t for delivery of a commodity at T, S(t) is the spot price at time t, R(t,T) is the risk free interest rate, W(t,T) is the marginal storage cost and C(t,T) is the convenience yield.

Metals	Copper	07/04/2005 to 11/20/2008	MCX	Mumbai
	Zinc	04/03/2006 to 09/30/2008	MCX	Mumbai
Energy	Crude Oil	05/02/2005 to 09/30/2008	MCX	Mumbai
	Natural Gas	07/21/2006 to 09/30/2008	MCX	Mumbai

2.1 Modeling Asymmetric Volatility of Net Convenience Yield

Our methodology consists of indirect test of theory of storage when inventory data is not available. To test the asymmetric volatility of convenience yield, we follow EGARCH specification as follows:

$$ncy_t = \alpha_0 + \sum_{i=1}^{p} \beta_t ncy_{t-i} + \delta g(\sigma_t) + \sum_{i=1}^{12} M_i + \varepsilon_t \text{ or,}$$

$$\varepsilon_t \approx N(0, h_t^2) \qquad [2]$$

$$\log(h_t^2) = a_0 + b \log(h_{t-1}^2) + c_1 |\varepsilon_{t-1}/h_{t-1}| + c_2 (\varepsilon_{t-1}/h_{t-1}) + \sum_{i=1}^{12} M_i$$

In the above model, the conditional mean equation of net convenience yield (ncy_t) is modeled as an AR process and its conditional variance equation is modeled as an EGARCH process. It is plausible that the seasonal demand and supply conditions of commodities make NCY seasonal. To capture the seasonal effect in the NCY, we use seasonal dummies (M_i) in the conditional mean equation. The effect of spot volatility on conditional mean equation is also captured by including the spot volatility as an exogenous variable in the conditional mean equation of NCY as suggested by Heinkel, Howe, and Hughes (1990), Milonas and Thomadakis (1997), and Routledge, Seppi and Spatt (2000).

To test the hypothesis whether the volatility of NCY is higher in the low inventory period as compared to high inventory period, we test whether the coefficient c_2 is positive and significantly different than zero. We test the asymmetric volatility of convenience yield for near month NCY, and next to near month NCY. The same is also tested for the entire sample period and the two-sub-periods.

3. Results and Discussions

The asymmetric behavior of NCY is modeled in the EGARCH framework and parameters are estimated through maximum-likelihood estimates. We use 10 lags of NCY to capture all possible autoregressive coefficients of NCY[3]. Table 2 and Table 3 report the parameter estimates for the near month NCY and next to near month NCY respectively. The mean of NCY of all commodities in the entire period and both the sub-periods have significant and negative autocorrelation coefficient. These correlations are significant at higher lags for agricultural commodities. It shows the importance of considering higher lags of NCY while investigating the asymmetric volatility behavior. Otherwise, it may increase variance of the residual and bias the test. The high and negative autocorrelations of NCY indicate that the inventory (which gives rise to convenience yield) cannot adjust immediately and hence any demand and supply shock would result is high NCY and its significant autoregressive characteristics.

In the conditional variance function, the coefficient of $(\varepsilon_{t-1}/h_{t-1})$ are significant and negative for agricultural commodities. The result is opposite to what is expected and contradicts the implications of theory of storage for agricultural commodities. On the other hand, the coefficient is mostly insignificant at 1% significance level for most of the non-agricultural commodities except for the energy commodities, where the coefficients are positive. In the first sub-period, when futures trading activity was relatively less, the coefficients are mostly insignificant for most of the commodities. However, in the second sub- period we find negative and significant coefficient for agricultural and positive for energy commodities. Similar results are found when the NCY of the next to near month futures are analyzed.

The results of asymmetric volatility of NCY in Indian commodity markets are very interesting and reveal very important characteristics NCY. For agricultural commodities and most of the non-agricultural commodities, any negative (positive) shock increases (decreases) the volatility of NCY which is contradictory to the results of developed futures markets. As NCY is derived from the cost of carry model, the volatility of NCY mathematically depends upon the volatility of spot prices, futures prices and their correlation. The mechanics of spot market, storage market and futures markets suggests that when inventory is less (positive NCY), the spot market should be more volatile than the high inventory condition (negative NCY). Also, when inventory is less, the correlation between spot and futures prices decreases (because of less supply of arbitrage) and the volatility of spot prices should be higher than the futures prices (because futures prices carry long run expectations), the volatility of NCY should be higher, ceteris paribus, than when inventory is high. We further analyzed the spot volatility in both scenarios (positive and negative NCY) separately and found that spot volatility is surprisingly low when NCY

[3] We apply different lag lengths in estimation but the results are similar.

is positive. Also, in both scenarios, the spot volatility dominates the futures volatility and the ratio of spot to futures volatilities varies from 2 to 5. Hence, decrease in the spot volatility at the time of backwardation is the important reason for less volatility of positive NCY. The decrease in volatility in spot and futures markets can be attributed to low volume of trade in these markets.

Table 2: Parameter Estimates of EGARCH Model for Near Month NCY

(a) For the Entire Period

Commodity	α_0	sum of β	δ	a_0	b	c_1	c_2
Soy Bean	-0.052	-0.839	-4.73**	-1.02**	0.72**	0.88**	-0.01
Maize	-0.085	-0.936	1.60**	-0.91**	0.98**	0.72**	-0.20**
Castor Seed	-0.063	-0.858	346.06**	-1.76**	0.63**	0.60**	-0.25**
Guar Seed	-0.185	-0.835	4.52	-0.95**	0.58**	0.74**	-0.46**
Gold	-0.003	-0.754	-35.85**	-0.88	1.41**	0.81**	-0.13
Silver	-0.008	-0.498	29.95**	-0.46**	0.83**	0.94**	0.08*
Aluminium	0.012	-0.477	-16.17**	-0.64**	0.51**	0.86**	-0.28**
Copper	0.006	-0.324	-21.68*	-0.32**	0.80**	0.96**	-0.05*
Zinc	-0.053	-0.280	170.61**	-0.61	0.60	0.71	0.09
Crude Oil	0.093	-0.072	-216.84**	-0.75**	0.57**	0.71**	0.25**
Natural Gas	-0.120	-0.192	8.82**	-1.32**	0.65**	0.52**	0.13**

** and * denote significance of the parameters 1 and 5% significance level respectively

(b) For the First Sub-period

Commodity	α_0	sum of β	δ	a_0	b	c_1	c_2
Soy Bean	-0.038	-0.708	-12.54**	-0.96**	0.70**	0.87**	-0.01
Maize	-0.084	-1.009	-11.30**	-0.78**	1.27**	0.84**	-0.13**
Castor Seed	-0.399	-0.981	533.69**	-2.96**	0.95**	0.42**	-0.05
Guar Seed	-0.209	-0.833	-6.60**	-0.77	0.11	0.83**	-3.35
Gold	0.032	-0.310	-75.31**	-1.80**	1.48**	0.67**	0.12
Silver	0.043	-0.136	-22.92**	-0.45**	0.80**	0.97**	-0.09
Aluminium	4.000	-0.456	48.99**	-1.93**	1.53**	0.51**	0.01
Copper	0.019	-0.676	-24.16**	-0.26**	1.07**	0.93**	0.22**
Zinc	-0.292	-0.056	517.16**	-0.45**	1.06**	0.86**	-0.07
Crude Oil	0.059	-0.085	-209.03**	-5.67**	0.60**	-0.33**	-0.05
Natural Gas	-0.234	0.596	-49.53**	0.07	0.01	1.00**	411.22**

** and * denote significance of the parameters 1 and 5% significance level respectively

(c) For the Second Sub-period

Commodity	α_0	sum of β	δ	a_0	b	c_1	c_2
Soy Bean	0.018	-0.704	-0.22	-1.12	0.85	0.76	-0.06
Maize	-0.219	-0.896	-6.09**	-1.53**	0.80**	0.61**	-0.49**
Castor Seed	-0.060	-0.756	280.86**	-1.60**	0.56**	0.68**	-0.40**
Guar Seed	-0.108	-0.851	74.51**	-0.69**	0.62**	0.83**	-0.14*
Gold	0.003	-0.027	60.65**	-0.25**	0.83**	0.91**	0.09

Silver	-0.025	-0.236	40.83**	-0.41**	0.95**	0.96**	0.09
Aluminium	4.000	-0.095	6.65**	-8.56**	0.57**	-0.84**	-0.04
Copper	0.009	0.043	-33.10**	-0.34**	0.75**	0.90**	-0.06
Zinc	0.027	-0.061	33.67**	-2.67**	0.93**	0.25*	-0.02
Crude Oil	0.122	-0.093	-228.92**	-0.66**	0.53**	0.88**	0.44**
Natural Gas	-0.019	0.020	5.46**	-3.26**	0.34**	0.03	0.29

** and * denote significance of the parameters 1 and 5% significance level respectively

Table 3: Parameter Estimates of EGARCH Model for Next to Near Month NCY

(a) For the Entire Period

Commodity	α_0	sum of β	δ	a_0	b	c_1	c_2
Soy Bean	1.476	-0.996	-3.73	-0.57**	0.90**	0.86**	-0.09**
Maize	-0.194	-0.855	18.10**	-0.77**	1.42**	0.75**	-0.13**
Castor Seed	-0.228	-0.962	459.23**	-1.66**	0.87**	0.62**	-0.18**
Guar Seed	-0.408	-0.908	-2.71	-0.62**	0.14	0.84**	-3.78
Gold	-0.072	-0.957	5.80**	-0.65**	0.70**	0.87**	0.07
Silver	-0.015	-0.608	34.81**	-0.42**	0.81**	0.91**	-0.09**
Aluminium	-0.011	-0.700	-15.22**	-0.79	0.67	0.80	-0.32
Copper	0.074	-0.809	-60.38**	-0.35**	0.87**	0.91**	0.09*
Zinc	-0.040	-0.467	146.43**	-0.75**	0.66**	0.77**	-0.08
Crude Oil	0.010	-0.829	-78.62**	-0.90**	0.81**	0.74**	0.21**
Natural Gas	-0.312	-0.794	-6.12	-0.48**	0.35**	0.82**	-0.74**

** and * denote significance of the parameters 1 and 5% significance level respectively

(b) For the First Sub-period

Commodity	α_0	sum of β	δ	a_0	b	c_1	c_2
Soy Bean	-0.078	-0.708	-6.06**	-0.68**	0.96**	0.84**	-0.18*
Maize	-0.198	-0.934	26.77**	-0.58	1.41**	0.81**	-0.11*
Castor Seed	-0.161	-0.881	931.70**	-1.55**	0.99**	0.64**	-0.14*
Guar Seed	-0.516	-0.930	-3.79	-0.45**	0.06	0.88**	-8.85
Gold	0.035	-0.898	-178.21**	-0.48**	0.67**	0.91**	0.10
Silver	-0.001	-0.799	37.97	-0.43**	1.11**	0.91**	0.08
Aluminium	1.588	-1.009	23.16**	-0.40	0.72	0.88	-0.12
Copper	0.060	-0.863	-28.29**	-0.35**	1.17**	0.91**	0.07
Zinc	0.267	-0.105	-277.28**	-0.55**	1.00**	0.82**	-0.07
Crude Oil	0.016	-0.583	-122.51**	-4.05**	0.63**	-0.03	-0.09
Natural Gas	-2.598	-0.954	3.16	-0.27**	0.18	0.86**	-3.32

** and * denote significance of the parameters 1 and 5% significance level respectively

(c) For the Second Sub-period

Commodity	α_0	sum of β	δ	a_0	b	c_1	c_2
Soy Bean	0.006	-0.77	1.89	-0.68**	1.04**	0.84**	0.00
Maize	-0.290	-0.82	13.38**	-1.91**	2.03**	0.47	-0.15
Castor Seed	-0.237	-0.95	290.71**	-3.09**	1.03**	0.33**	-0.27**
Guar Seed	-0.358	-0.81	159.17**	-0.86**	0.33**	0.81**	-1.52*
Gold	-0.025	-0.58	329.79**	-2.03**	1.96**	0.62**	-0.07

Silver	-0.034	-0.38	17.34**	-0.71**	1.32**	0.85**	-0.15
Aluminium	0.031	-0.63	13.92**	-1.14**	0.69**	0.73**	-0.25**
Copper	0.001	-0.27	-29.81*	-0.41**	0.93**	0.90**	-0.05
Zinc	-0.066	-0.13	113.78**	-2.29**	1.01**	0.35**	-0.13
Crude Oil	0.037	-0.79	128.00**	-1.07	1.04	0.68	0.26
Natural Gas	-0.051	-0.63	-20.89**	-0.62	0.22	0.79	-0.89

** and * denote significance of the parameters 1 and 5% significance level respectively

We divide the data into positive and negative NCY and find that in most of the agricultural commodities, the standard deviation of NCY is high when it is positive as compared to when it is negative. However, when autocorrelation and seasonality is removed from the NCY, we find opposite results. Indian futures markets are linked with international markets (Kumar and Pandey, 2012) and therefore Indian futures prices may be reflecting expected global inventory condition rather than local inventory conditions. On the other hand, Indian spot markets of agricultural commodities which are characterized by high transaction cost are slow to respond to global as well as local information. Hence, we find insignificant asymmetric of NCY in case of non-agricultural commodities and opposite asymmetry for agricultural commodities

4. Conclusions

The theory of storage predicts that the volatility of net convenience yield increases as it become positive. Positive and volatile NCY arises when inventory is less and market encounters demand and supply shocks. This paper investigates asymmetric volatility behavior of NCY in Indian commodity futures markets. In this paper, NCY is modeled as EGARCH process which captures the asymmetry in volatility of NCY. To enhance the robustness of the estimates, the mean equation of NCY is modeled as autoregressive process with month dummies and spot volatility is also included as an explanatory variable.

Our results of asymmetric behavior of net convenience yield indicate that the implications of the theory of storage are not valid in Indian commodities market. In most of the commodities, we do not find asymmetric behavior of NCY except for crude oil. In case of agricultural commodities, we find contradictory results that any negative shock to NCY increases the volatility of NCY rather than decreasing it. Our results contradict the results found in developed futures marktets. In other words, when the market is in backwardation, volatility of NCY is lower as compared to volatility of NCY in contango market. It is also found that the volatilities of spot and futures prices are low when market is in backwardation as compared to higher volatility in the *contango* period. Less speculation and lower volume of trade in the futures markets and restricted supply in the pre-harvest period in the spot market would be the reasons for less volatility of NCY in the backwardation period. Also, Indian commodity futures markets are linked with international markets and may be reflecting global supply demand conditions than local. Hence, our results do not support even contradict the implications of the theory of storage.

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