VOLATILITY MODELING, SEASONALITY AND RISK-RETURN RELATIONSHIP IN GARCH-IN-MEAN FRAMEWORK: THE CASE OF INDIAN STOCK AND COMMODITY MARKETS

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This paper provides an empirical study of volatility, risk premium and seasonality in risk-return relation of the Indian stock and commodity markets. This investigation is conducted by means of the General Autoregressive Conditional Heteroscedasticity in the mean model (GARCH-in-Mean) introduced by Engle *et al.* (1987). A systematic approach to model volatility in returns is presented. Volatility clustering and asymmetric nature is examined for Indian stock and commodity markets. The risk-return relationship and seasonality in risk-return are also investigated through GARCH-in-Mean modeling in which seasonal dummies are used for return as well as volatility equation. The investigation has been made on market index S&P CNX Nifty for a period of 18 years from January 1990 to December 2007. Gold prices from 22nd July 2005 to 20th February 2008 and Soybean from October 2004 – December 2007 are also considered. The stock and commodity markets returns show persistence as well as clustering and asymmetric properties. Risk-return relationship is positive though insignificant for Nifty and Soybean where as significant positive relationship is found in the case of Gold. Seasonality in risk and return is also found which advocates the asymmetric nature of return, i.e. negative correlation between return and its volatility.

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1. INTRODUCTION

Volatility acquired a central role in derivative pricing and hedging, risk management, and optimal portfolio selection. Understanding and forecasting volatility remains an active and challenging area of research in the finance. Researchers in this area focus on the different properties of the return series as its time varying conditional moment, volatility clustering, asymmetric pattern, and long persistence. Volatility clustering in returns implies that small (large) price changes follow small (large) price changes of either signs. Asymmetric nature of volatility indicates that returns and conditional volatility are negatively correlated.

It has been found that stock markets show time varying volatility with clustering effect. They also have asymmetric mature and have log memory i.e. the autocorrelation of volatility up-to long time horizon are significant. A large part of the research in this area focuses on the relationship between stock volatility and stock returns. Similar to stock market, commodity market also shows time varying volatility with clustering and asymmetric effect. They also have long memory in return. Testing of effectiveness of price behavior and risk management of stock and commodity markets are upon the assumption of volatility of the prices as well as returns.

1.1 RISK-RETURN RELATIONSHIP

The relationship between the return on an asset and its volatility as a proxy for risk has been an important topic in financial research. However, there is wide controversy regarding the type of relationship, whether relationship is positive or negative. Baillie and DeGennarro (1990) assert that most asset-pricing models postulate a positive relationship between a stock portfolio's expected returns and volatility. On the other hand, many researchers also modeled stock return volatility as negatively correlated with stock returns (Black, 1976; Cox and Ross, 1976; Bekaert and Wu, 2000; Whitelaw, 2000). Bekaert and Wu (2000) reported the asymmetric volatility in the stock market and negative correlation between return and conditional volatility.

Risk- return relationship in commodity market is also widely studied. Dusak (1973) examined the existence of risk premium within the context of the Capital Asset Pricing Model. She viewed the futures price as consisting of two components: an expected risk premium and a forecast of a forthcoming spot price. According to this concept, futures contract should depend on the extent to which the variations in prices are systematically related to variation in return on total wealth. She found that the systematic risks of the three commodity contracts investigated were not significantly different from zero.

Carter, Rausser and Schmitz (1983) modified Dusak's study by allowing systematic risk to be stochastic and to be a function of speculators' actual net position. They estimated non market and systematic risk as time varying parameter to incorporate seasonality in commodity market. They found the evidence of systematic risk and non-market risk that varies seasonally. By using a combined stock and commodity index as proxy for the market portfolio, they found nonzero estimates of systematic risk for most of the speculative return series they examined. In case of commodity, the risk-return relationship is also studied with seasonality.

1.2 SEASONALITY IN RETURN AND RISK

In equity market, year end effect or "tax loss selling" hypothesis is well reported. It is argued that investors sell their stock in the month of December (Tax month) to book losses in order to reduce their taxes. Selling of stocks put downward pressure on the prices. As soon as the tax month ends market corrects and stock prices rise. It gives higher return in the month of January. Wachtel (1942) was the first to point out the seasonal effect in the US markets. Various other works also supported this effect in the USA market (Rozeff and Kinney, 1976; Keim, 1983; Reinganum, 1983). The seasonal effect has been found in Canada (Berges, McConnell, and Schlarbaum, 1984; Tinic, Barone-Adesi and West, 1990) Japan (Aggarwal, Rao and Hiraki, 1990) Australia (Officer, 1975; Brown, Keim, Kleidon and Marsh, 1983), and UK (Lewis, 1989).

For commodities there is seasonality in demand and supply. For instanc the spot price of agricultural commodities usually increases before harvest and falls after harvest. Seasonals in demand and supply can generate seasonals in inventories. Inventory seasonals generate seasonals in the marginal convenience yield and in the basis. Because of this pattern, the basis is positive when the futures contract matures in the current crop year and negative when the futures contract matures in the next crop year.

There would exist seasonality in returns or variances if the average returns were not same in all periods. The importance of monthly seasonality lies in the challenge that it is an indicator of market efficiency or informational efficiency. Ideally, seasonality in spot prices is not likely to influence the futures return because they represent foreseeable fluctuations that are taken into account when market participants set futures prices. On the other hand modern portfolio theory (Markowitz) indicates that the compensation required by speculators in any period would be proportional to the contribution of each contract to the risk of speculators' portfolios. During Months of high (low) production, long positions on agricultural future contracts would reduce (induce) the Portfolio risk because of negative correlation between prices and speculators' return as shown in Figure 1.

		Return to Portfolio	
Season		Low	High
	High Prod.	Positive Contribution	
	Low Prod.		Negative Contribution

Figure 1: Production cycle and return to portfolio

Seasonality in return negate the weak form of market efficiency, which states that stock prices are random and it is not possible to predict stock price and return movements using past price information. The understanding of seasonality risk and returns should help financial managers, financial analysts and investors to develop appropriate strategy.

1.3: MODELING APPROACH

In time series modeling approach, after the seminal work of Engle (1982), time variation in second or higher order moments is incorporated and a new group of time series models named Auto Regressive Conditional Heteroscedasticity (ARCH) and later generalized by Bollerslev (1986), Generalized Auto Regressive Conditional Heteroscedasticity (GARCH), are being used to model time varying volatility. These models consider non-linearity in the mean equation. They are able to explain the volatility clustering and persistence in the volatility. Because of their quadratic form, they are not able to consider some of the important properties of the financial data like asymmetric pattern of the volatility. Financial series shows asymmetric nature where the conditional variance tends to respond asymmetrically to positive and negative shocks in errors. Asymmetric property of the volatility is incorporated in the other GARCH family models such as Exponential GARCH or EGARCH (Nelson, 1991), Quadratic GARCH or QGARCH Sentana (1995), the GJR models (Glosten, Jagannathan and Runkle, 1993), Threshold GARCH or TGARCH (Davidian and Carroll, 1987) etc.

After GARCH family volatility models, the research in the area of risk-return relationship also became active. Inference from early studies may not be reliable because variance modeling in past studies does not consider the asymmetric and time varying properties. Recently, studies have typically used GARCH-Mean models (Engle et al., 1987) to allow for time-varying behavior of volatility.

The empirical results in this area are also mixed. Most of the research found insignificant relationship but both positive and negative relationship between return and conditional volatility. Baillie and DeGennarro (1990) found a positive but insignificant relationship in the US stock market. In contrast, Nelson (1991) reported a negative but insignificant relationship between expected returns and the conditional variance of the US stock market. The empirical findings are still remaining inconclusive. The GARCH-in-Mean model is very sensitive to its specification.

There is relatively less empirical research on stock return volatility in the emerging markets. In the Indian context, ARCH/GARCH model and its various extensions have been used by Karmakar (2005, 2006), Kaur (2002, 2004), Pandey (2005), Pattanaik and Chatterjee (2000) and Thomas (1995, 1998). Shenbagaraman (2003) has examined the impact of introduction of index futures and options on the volatility of underlying stock index in India using a GARCH model. We have not been able to find any papers that have investigated the risk-return relationship and seasonality in the Indian commodity market.

In the present work, an attempt has been made to understand the dynamics of spot return and its volatility for stock as well as commodity market in India. Volatility clustering and its asymmetric nature are examined. The risk and return relationship and seasonality are investigated in GARCH-in-Mean approach. The rest of the paper is organized as follows: Section 2 explains the data set used and its properties, Section 3 explains the empirical methodology, Section 4 reports the empirical findings and finally, Section 5 concludes.

2. DATA SET USED AND ITS PROPERTIES

The data used here consists of the daily stock closing price index of S&P CNX Nifty, a value-weighted stock index of National Stock Exchange (www.nseindia.com), Mumbai, derived from prices of 50 large capitalization stocks, published by NSE India for the period from 1 January 1990 to 28th December 2007. Gold and Soybean spot prices are also analyzed. Daily closing prices of commodities are collected from National Commodity & Derivatives Exchange (NCDEX), India (http://www.ncdex.com). Soybean and Gold data set extends over the period October 2004 – December 2007 and from 22nd July 2005 to 20th February 2008 respectively. We have used near month future prices as a proxy for spot prices for commodities because spot prices are not reliable and effected by many national and international policies. The percentage return of the asset is defined as

$$R_t = \ln\left({p_t}/{p_{t-1}} \right) \times 100$$

Where, R_t is logarithmic daily percentage return at time t and P_{t-1} and P_t are daily price of an asset at two successive days t-1 and t respectively.

2.1 DAILY RETURNS CHARACTERISTICS

Daily return from S&P CNX Nifty, Gold and Soybean are analyzed and summary statistics are presented in Table 1. Spot price and return are shown in Figure 1.

Table 1: Descriptive Statistics

a) Nifty

Month	*N*	*Mean*	*Median*	*Max*	*Min*	*SD*	*CV*	*Kurtosis*	*Skewness*
Jan	339	0.0278	-0.0053	5.1708	-3.7721	1.3692	4932.9181	1.1245	0.3373
Feb	332	0.2549	0.1542	9.9339	-5.9924	1.6636	652.6995	6.4142	0.9824
Mar	341	-0.0791	-0.0184	5.9960	-6.6457	1.5112	-1909.6775	2.5848	-0.2158
Apr	319	-0.0319	0.0204	7.5394	-7.7099	1.6445	-5158.5369	5.7875	0.0802
May	348	0.0067	0.0636	11.6434	-11.7272	1.8066	27155.6121	12.0625	-0.3274
Jun	351	0.1484	0.0461	7.0420	-4.8749	1.4266	961.0197	3.3405	0.4709
Jul	374	0.0962	0.0776	6.1098	-4.6454	1.2716	1322.3108	2.3092	0.0427
Aug	360	0.1653	0.1332	3.8683	-4.0794	1.1552	699.0410	1.2493	-0.0144
Sep	365	0.0540	0.0505	4.0549	-5.5000	1.2747	2360.9254	2.8112	-0.4669
Oct	345	-0.0130	-0.0377	6.9574	-8.1963	1.4598	-11272.6094	4.9482	-0.0258
Nov	350	0.0788	0.1340	4.7815	-3.8772	1.2089	1533.9663	1.8677	0.0963
Dec	342	0.1658	0.1799	4.4007	-5.4504	1.2184	734.9370	2.6844	-0.3483
All	4166	0.0735	0.0720	11.6434	-11.7272	1.4277	1942.6441	6.1083	0.0625

b) Gold

Month	N	Mean	Median	Max	Min	SD	CV	Kurtosis	Skewness
Jan	62	0.2491	0.1546	2.8120	-3.0651	0.9352	375.3693	2.9388	-0.0660
Feb	55	0.0219	0.1103	1.8448	-2.1160	0.8431	3844.3742	0.6483	-0.4120
Mar	44	0.0119	0.0593	2.3685	-2.8827	0.7753	6501.2549	4.9055	-0.6858
Apr	39	0.0992	0.1170	2.3479	-1.9601	0.8527	859.6061	1.2442	-0.1599
May	44	0.0679	-0.0282	2.8854	-4.8563	1.1973	1764.3387	6.6315	-0.9405
Jun	42	-0.2716	-0.0457	3.9321	-6.6752	1.4612	-537.9579	9.7790	-1.7526
Jul	48	0.1825	0.0811	2.3945	-1.4466	0.6976	382.3278	2.1694	0.8262
Aug	62	0.0826	0.0435	1.8150	-2.1790	0.5962	721.7472	3.9997	-0.2537
Sep	60	0.0433	0.0585	1.4537	-2.1903	0.7373	1702.4682	0.9966	-0.5145
Oct	64	0.1054	0.1264	1.4364	-2.2794	0.6312	598.7507	2.3436	-0.7247
Nov	63	0.1630	0.1086	2.3920	-1.6099	0.7195	441.4742	1.4086	0.2805
Dec	62	0.0738	0.0500	1.4775	-3.4126	0.7839	1061.7038	5.6170	-1.3629
All	645	0.0786	0.0691	3.9321	-6.6752	0.8580	1091.6865	9.3003	-1.0426

c) Soybean

month	N	Mean	Median	Max	Min	SD	CV	Kurtosis	Skewness
Jan	60	-0.0204	-0.0976	2.8287	-2.1158	0.7118	-3490.7284	4.3584	0.9146
Feb	57	0.0737	0.0699	2.8862	-1.3710	0.6457	876.4309	5.5835	1.1336
Mar	63	0.1254	0.1178	2.4349	-1.5655	0.6337	505.2885	2.7763	0.8204
Apr	56	-0.0387	-0.0636	2.3426	-1.5050	0.6426	-1658.8603	2.5859	0.6817
May	66	-0.0167	-0.0117	1.8914	-1.7972	0.7531	-4505.8878	0.1850	0.1365
Jun	63	-0.1035	-0.2083	2.1018	-1.7697	0.7373	-712.3887	0.5369	0.2869
Jul	61	-0.0056	-0.0578	1.5399	-1.5552	0.6325	-11246.7733	0.1302	0.1419
Aug	65	-0.0554	-0.0646	1.8214	-1.8605	0.6426	-1159.8668	1.3461	0.2899
Sep	60	-0.1500	-0.1844	1.9956	-1.6766	0.7051	-470.0404	1.1122	0.6636
Oct	82	0.0610	0.0569	2.6457	-3.5669	0.9851	1615.6570	1.8225	-0.2273
Nov	83	0.0180	0.0000	2.3509	-2.1691	0.9516	5292.0100	-0.2308	0.1972
Dec	85	0.0598	0.1491	2.3758	-2.5758	0.8246	1379.1365	1.4516	-0.2932
All	801	-0.0005	-0.0078	2.8862	-3.5669	0.7626	-150362.7684	1.5784	0.2270

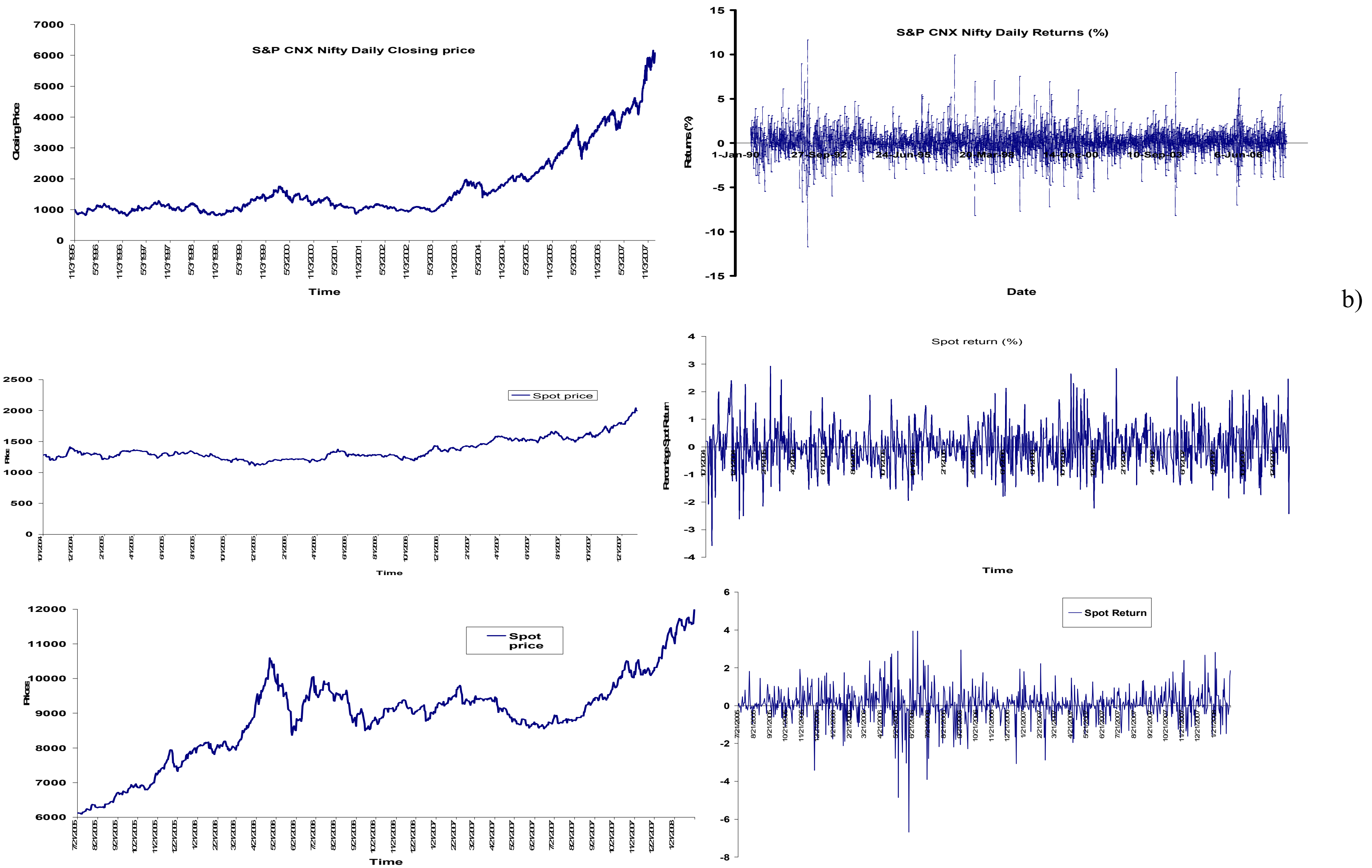

Figure1: Spot prices and he return series of Nifty, Soybean and God (in sequence)

There are wide variations of returns across months for all the assets. Nifty returns for the months of March, April, and October are negative. The maximum average return occurs in the month of February and minimum occurred in the month of March. Gold returns are positive for all months except June. The maximum average return is found in the month of January and June shows minimum. In case of Soybean return most of the months show negative return except February, March, October, November and December. Index returns show negative skewness for six months and positive for other six months. Gold shows negative skewness in most of the months and Soybean return are positively skewed. Nifty and Gold returns show leptokurtic (kurtosis >3) distribution for five months, but Soybean shows platykurtic distribution.

The index has small average positive return and an average standard deviation of 1.43 percent, implying average annualized volatility of 22.5 percent. The Gold has also positive return with average annualized volatility of 13.5 percent, where as Soybean has average negative return with average annualized volatility of 12.0 percent.

2.2 TIME DEPENDENCE AND LONG MEMORY IN RETURN

The serial autocorrelation of the returns series is examined to test the randomness as well as the stationarity. The autocorrelation check for white Noise is performed for all return series[1] and presence of significant autocorrelation in the series is inconsistent with weak form of market efficiency. Autocorrelation function of the return series falls off quickly as the number of lags increase. This is a typical behavior in the case of a stationary series. The PACF of the return series does not indicate any large spikes. The ADF test was performed to test the stationarity of the series and is presented in Table 2.

[1] See appendix A

Table 2: Augmented Dickey-Fuller Unit Root Tests

	Type	Lags	Rho	Pr < Rho	Tau	Pr < Tau	F	Pr > F
Nifty	**Zero Mean**	10	-3602.74	0.0001	-19.17	<.0001	--	--
	Single Mean	10	-4177.59	0.0001	-19.44	<.0001	188.93	0.001
	Trend	10	-4182.48	0.0001	-19.44	<.0001	188.94	0.001
Soybean	**Zero Mean**	10	-727.109	0.0001	-8.51	<.0001	--	--
	Single Mean	10	-724.225	0.0001	-8.5	<.0001	36.2	0.001
	Trend	10	-1077.25	0.0001	-8.74	<.0001	38.22	0.001
Gold	**Zero Mean**	10	-160.074	0.0001	-6.03	<.0001	--	--
	Single Mean	10	-185.812	0.0001	-6.23	<.0001	19.43	0.001
	Trend	10	-186.267	0.0001	-6.22	<.0001	19.41	0.001

2.3 VOLATILITY CLUSTERING AND NONLINEAR DEPENDENCE IN DAILY RETURN

In order to check the presence of volatility clustering, we analyzed the autocorrelation of squared returns. Squared returns of the series are shown in Figure 2. We also checked the autocorrelation of the squared series for white Noise[2]. All the squared return series showed substantially autocorrelation up-to higher lag as compared to return series. The autocorrelation coefficients of the series are significant for more than 40 lags.

The presence of volatility clustering and time-varying characteristics of volatility can be modeled as ARCH/GARCH-type conditional volatility models. The presence of "ARCH effect", Portmanteau Q-Test and Lagrange Multiplier Test is performed on data set of Nifty, Soybean and Gold daily returns. In the mean equation only intercept is used and number of lags included is 10. Results of the test are presented in Table 3. All the return series showed ARCH effect.

[2] See appendix B

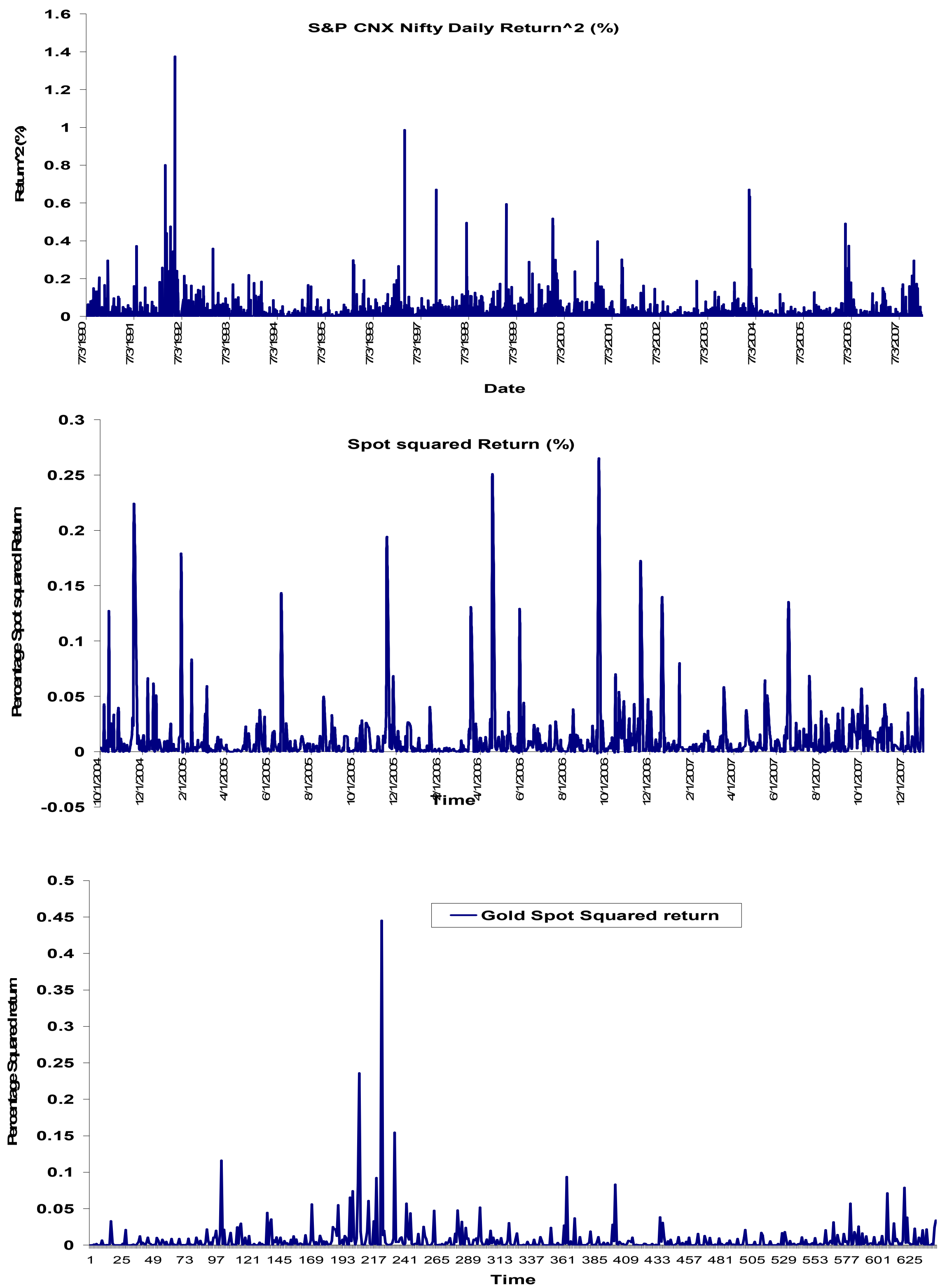

Figure1: Squared returns of the of Nifty, Soybean and God (in sequence)

Table 3: Portmanteau Q-Test and Lagrange Multiplier Test statistics on Soybean daily spot and futures return

Q and LM Tests for ARCH Disturbances												
	Soy bean				Nifty				Gold			
Order	Q	Pr >Q	LM	Pr > LM	Q	Pr >Q	LM	Pr > LM	Q	Pr >Q	LM	Pr > LM
1	5.24	0.022	5.27	0.022	314.26	<.0001	314.08	<.0001	2.39	0.122	2.39	0.1218
2	6.68	0.035	6.38	0.041	340.93	<.0001	314.18	<.0001	3.08	0.2143	2.95	0.2291
3	7.98	0.046	7.45	0.059	365.53	<.0001	327.13	<.0001	3.21	0.3607	3.14	0.3703
4	9.70	0.046	8.74	0.068	392.09	<.0001	335.81	<.0001	9.34	0.0531	9.43	0.0513
5	9.88	0.079	8.77	0.119	470.32	<.0001	380.72	<.0001	9.63	0.0863	9.50	0.0906
6	22.11	0.001	20.25	0.003	508.38	<.0001	383.75	<.0001	13.85	0.0314	12.97	0.0435
7	23.34	0.002	20.62	0.004	518.57	<.0001	383.90	<.0001	15.38	0.0314	14.17	0.0482
8	23.80	0.003	21.88	0.005	537.39	<.0001	390.06	<.0001	15.40	0.0518	14.52	0.0692
9	24.12	0.004	22.59	0.007	551.75	<.0001	391.08	<.0001	15.40	0.0805	14.52	0.1051
10	28.03	0.002	25.14	0.005	568.99	<.0001	393.70	<.0001	47.92	<.0001	43.97	<.0001
11	28.85	0.002	25.40	0.008	612.04	<.0001	409.83	<.0001	48.75	<.0001	43.97	<.0001
12	30.77	0.002	25.92	0.011	664.13	<.0001	423.99	<.0001	49.57	<.0001	44.20	<.0001

3. METHODOLOGY

This section deals with the methodology used to model return volatility. Conditional volatility model and their different specification to model volatility are explained. Risk-return and seasonality models used to capture seasonality are also described.

3.1 CONDITIONAL VOLATILITY ESTIMATION

The return series of the index exhibits time varying volatility i.e. ARCH effect. Conditional volatility models (ARCH family) incorporate time varying characteristics of second moment and non-linearity in the mean equation explicitly. Various conditional volatility models have been proposed in the literature. Here, ARCH, GARCH and EGARCH models are explored.

3.1.1 ARCH MODEL

Engle (1982) proposed the ARCH (q) model is given by

$$R_t = u_{t-1} + \varepsilon_t$$

$$\varepsilon_t \mid \psi_{t-1} \sim N(0, \sigma_t^2)$$

$$\varepsilon_t = z_t \sigma_t \text{ and } z_t \sim N(0,1)$$

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

Where, R_t is daily stock return, u_{t-1} is the conditional mean, Ψ_{t-1} is the information set in time t-1, and ε_t is the error term of the mean equation which is serially uncorrelated with mean zero. But the conditional variance of ε_t equals σ_t^2, which is a function of q past squared returns. For the ARCH model to well defined, the parameters of conditional variance equation should satisfy: $\alpha_0 \rangle 0$ and $\alpha_i \geq 0$. Here, the mean equation is modeled as intercept term and error term. The problem with the ARCH (q) type model is the estimation of number of lags (q) in the variance equation.

3.1.2 GARCH MODEL

Bollerslev (1986) proposed GARCH (p,q) model in which volatility at time t is not only affected by q past squared returns but also by p lags of past estimated volatility. GARCH model removed the problem of estimation of lags 'q' because GARCH (1,1) is equivalent to ARCH (∞).The specification of a GARCH (p,q) is given by

$$R_t = u_{t-1} + \varepsilon_t$$

$$\varepsilon_t \mid \psi_{t-1} \sim N(0, \sigma_t^2)$$

$$\varepsilon_t = z_t \sigma_t \text{ and } z_t \sim N(0,1)$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_J \sigma_{t-j}^2$$

For GARCH model the restriction on the conditional variance parameters are:

$\alpha_0 \rangle 0$, $\alpha_i \geq 0, \beta_j \geq 0$ and $\alpha_i + \beta_j = 1$. GARCH model does not consider the asymmetric property of return. i.e. negative relationship between return and conditional volatility.

3.1.3 EGARCH MODEL

Asymmetric property of the volatility is incorporated in the other GARCH family models called Exponential GARCH or EGARCH. In the EGARCH model, the conditional variance depends upon both the size and the sign of lagged residuals. Nelson (1991) proposed EGARCH models which incorporates leverage effect and observed asymmetric volatility changes with the change in return sign. The specification of EGARCH (1,1) model are given by

$$R_t = u_{t-1} + \varepsilon_t$$

$$\varepsilon_t \mid \psi_{t-1} \sim N(0, \sigma_t^2)$$

$$\varepsilon_t = z_t \sigma_t \text{ and } z_t \sim N(0,1)$$

$$\log \sigma_t^2 = \alpha_0 + \alpha_1 (\phi Z_{t-1} + \gamma [|z_{t-1}| - E|Z_{t-1}|]) + \beta_1 \log \sigma_{t-1}^2$$

The restrictions of the parameters are same as for GARCH model. It is the extension of GARCH model where conditional variance has different effect on positive and negative return.

3.2 RISK-RETURN RELATIONSHIP, GARCH-in-Mean APPROACH

Recently, studies have typically used GARCH-In-Mean models (Engle et al., 1987) to allow for time-varying behavior of volatility. The specification of a GARCH (p,q)-Mean is given by

$$R_t = u_{t-1} + \delta \sigma_t + \varepsilon_t$$

$$\varepsilon_t \mid \psi_{t-1} \sim N(0, \sigma_t^2)$$

$$\varepsilon_t = z_t \sigma_t \text{ and } z_t \sim N(0,1)$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_J \sigma_{t-j}^2$$

In the above model the conditional mean is an explicit function of the conditional variance.

Seasonality in the return series are also modeled in GARCH-In-Mean framework. To capture the effect of month, month dummies are used in both mean and GARCH specification. The model is given by

$$R_t = u_{t-1} + \sum_{i=1}^{11} \gamma_i D_i + \delta\sigma_t + \varepsilon_t$$

$$\varepsilon_t \mid \psi_{t-1} \sim N(0, \sigma_t^2)$$

$$\varepsilon_t = z_t \sigma_t \text{ and } z_t \sim N(0,1)$$

$$\sigma_t^2 = \alpha_0 + + \sum_{i=1}^{11} \theta_i D_i + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_J \sigma_{t-j}^2$$

$where\ \mathrm{D_i}$ are month dummies in return and volatility.

4. RESULTS AND DISCUSSIONS

In this section, we report the empirical findings of volatility structure of the Indian stock and commodity market. Risk-return relationship and seasonality in these markets is also presented.

4.1 VOLATILITY MODELING

After identifying the ARCH effect in the spot return of all series, different GARCH (p, q) and EGARCH (p, q) models are tested. Results of Nifty are presented in Table 4 and 5.

Results of the GARCH model indicates a time varying volatility having long memory for Indian market. GARCH (1, 1) is the best fitted model having lowest AIC value. Asymmetric nature of the volatility is tested by various EGARCH specifications. The results of the EGARCH model suggest the asymmetric volatility pattern in the market (theta >0 and significant).

Table 4: Results from GARCH (p=1, 2 and q=1, 2) model on Nifty returns

Variable	GARCH (1,1)	GARCH (2,1)	GARCH (1,2)	GARCH (2,2)
Intercept	0.0968**	0.0967**	0.0967**	0.0967**
ARCH0	0.0725**	0.0756**	0.0705**	0.1348**
ARCH1	0.0979**	0.1022**	0.1040**	0.0998**
ARCH2	--	--	-0.008594**	0.0815**
GARCH1	0.8690**	0.8092**	0.8723	0.0000467
GARCH2	--	0.0541	--	0.7571**
AIC	14103.4882	14105.3499	14105.2954	14107.2608
**(*) significant at 1% (5%)				

Table 5: Results from EGARCH (p=1, 2 and q=1, 2) model on Nifty returns

Variable	EGARCH (1,1)	EGARCH (2,1)	EGARCH (1,2)	EGARCH (2,2)
Intercept	0.0726**	0.0720**	0.0719**	0.0779**
EARCH0	0.0410**	0.0460**	0.0375**	0.0825**
EARCH1	0.2261**	0.2564**	0.2682**	0.2570**
EARCH2	--	--	-0.0570*	0.1960**
EGARCH1	0.9543**	0.7748**	0.9587**	-0.0319**
EGARCH2	--	0.1744**	--	0.9357**
THETA	-0.1463**	-0.1469	-0.1463**	-0.1836**
AIC	14083.9054	14083.4476	14082.617	14050.8769
**(*) significant at 1% (5%)				

The appropriate model appears to be the EGARCH (5, 5) having significant asymmetric volatility effect as well as heteroscedasticity up-to 5 lags (Table 6). All parameters in the EGARCH (5, 5) model are significant. The value of theta is negative which suggests that the conditional variance is an asymmetric function of past innovations and increasing proportionately more during market declines.

Table 6: Results from EGARCH (5,5) model on Nifty returns

Variable	EGARCH (5,5)
Intercept	0.0438**
EARCH0	-0.003443
EARCH1	0.4898**
EARCH2	0.5426**
EARCH3	-0.1326

EARCH4	-0.3556**
EARCH5	-0.1378
EGARCH1	-0.4057**
EGARCH2	0.6052**
EGARCH3	-0.1631
EGARCH4	0.1641**
EGARCH5	0.695**
THETA	-0.2714
AIC	1509.63295
**(*) significant at 1% (5%)	

Similarly various GARCH and EGARCH specifications are tested on Soybean data and best fitted model is selected (Table 7-8).

Table 7: Results from GARCH (p, q) model for Soybean spot return

Variable	GARCH (1,1)	GARCH (1,2)	GARCH (1,3)	GARCH (2,1)	GARCH (2,2)
Intercept	0.006146	0.0103	0.00568	0.006114	-0.00118
ARCH0	0.0129*	0.0270*	0.0109*	0.0155*	0.0613*
ARCH1	0.0593**	0.1375**	0.0996**	0.0727*	0.1178**
ARCH2	--	-0.0457	-0.006827	--	0.1184**
ARCH3	--	--	-0.0394	--	--
GARCH1	0.9215**	0.8761	0.9302**	0.6908	1.27E-10
GARCH2	--	--	--	0.2136	0.6842
AIC	2111.0852	2117.9494	2113.94	2112.5599	2120.8415
**(*) significant at 1% (5%)					

Table 8: Results from EGARCH (p, q) model for Soybean spot return

Variable	EGARCH (1,1)	EGARCH (1,2)	EGARCH (2,1)	EGARCH (2,2)	EGARCH (5,1)	EGARCH (5,2)
Intercept	-0.017**	-0.017**	-0.017**	-0.017	-0.016	-0.016
EARCH0	-0.005	-0.004	-0.006	-0.01	-0.007	-0.028
EARCH1	0.1569**	0.237**	0.193**	0.138**	0.263**	0.294**
EARCH2	--	-0.089**	--	0.171**	--	0.272**
EGARCH1	0.9805**	0.983	0.746**	-0.008	0.946**	"-0.2**
EGARCH2	--	--	0.231	0.97**	-0.519	0.417**
EGARCH3		--	--	--	0.072	-0.204**
EGARCH4	--	--	--	--	0.427	0.118
EGARCH5	--	--	--	--	0.047	0.793**
THETA	-0.308**	-0.312**	-0.309**	-0.302**	-0.351**	-0.303**
AIC	2103.476	2103.385	2104.534	2103.063	2090.333	2084.186
**(*) significant at 1% (5%)						

Results of the GARCH model indicate a time varying volatility having long memory. GARCH (1, 1) is the best fitted model having lowest AIC value. The results of the EGARCH model suggest the asymmetric volatility pattern in the market (theta >0 and significant). The appropriate model appears to be the EGARCH (5, 2) having significant asymmetric volatility effect as well as heteroscedasticity up-to 5 lags. The value of theta is negative which suggests that the conditional variance is an asymmetric function of past innovations and increasing proportionately more during market declines.

Time varying and asymmetric estimation of Gold through GARCH and EGARCH modeling also confirms the same. Results are presented in Table 9-10.

Table 9: Results from GARCH (p, q) model for Gold spot return

Variable	GARCH (1,1)	GARCH (1,2)	GARCH (1,3)	GARCH (2,1)	GARCH (2,2)
Intercept	0.0692*	0.1048**	0.1048**	0.0786*	0.0786*
ARCH0	0.0182**	0.5723**	0.5722**	0.7362	0.7362
ARCH1	0.0589**	0.197**	0.197**	0.0000514	0.0000519
ARCH2	--	0.0655**	0.0655**	--	0.0000278
ARCH3	--	--	-6.18E-06	--	--
GARCH1	0.9170**	-0.00000000015**	0.0000943	1.10E-06	7.29E-17
GARCH2	--	--	--	-3.02E-13	1.66E-06
AIC	1548.8634	1616.40001	1618.4	1639.91707	1641.9103
**(*) significant at 1% (5%)					

Table 10: Results from EGARCH (p, q) model for Gold spot return

Variable	EGARCH (1,1)	EGARCH (1,2)	EGARCH (2,1)	EGARCH (2,2)
Intercept	0.0627**	0.068	0.0647*	0.0617*
EARCH0	0.007148*	-0.6912**	0.009858	0.0145*
EARCH1	0.0728**	0.3517**	0.0995*	0.0395
EARCH2	--	0.4912**	--	0.1298**
EGARCH1	0.9934**	-0.9082**	0.657	0.0411
EGARCH2	--	--	0.3341	0.941**
THETA	0.4527	-0.2983*	0.4225	0.2781
AIC	1543.02523	1571.45156	1544.89941	1544.3116
**(*) significant at 1% (5%)				

In this case also GARCH (1,1) model is best fitted model with high volatility persistence (92%). EGARCH (5,5) model best describes the asymmetric effect (Table-11) which signifies the negative correlation between Gold return and its volatility.

Table 11: Results from EGARCH (5,5) model on Gold returns

Variable	EGARCH (5,5)
Intercept	0.0693**
EARCH0	0.2031**
EARCH1	0.2946**
EARCH2	0.2737**
EARCH3	0.2794**
EARCH4	0.1317**
EARCH5	0.2597**
EGARCH1	-0.1428**
EGARCH2	-0.3229**
EGARCH3	0.3096**
EGARCH4	0.0463*
EGARCH5	0.8799**
THETA	-0.1374**
AIC	14003.3853
** significant at 1%	

4.2 SEASONALITY AND RISK AND RETURN RELATIONSHIP:

Risk-return relationship and seasonality in the return and variance is captured through GARCH-in-Mean approach where dummies in mean and variance are used to identify seasonal effect. GARCH (1,1)-in-Mean model is used. Results of the parameter estimates are shown in Table 12.

Symmetric GARCH (1,1)-in-Mean shows insignificant but positive risk-return relationship in Indian stock and Soybean market. In case of Gold, positive and significant (1%) risk return relationship is found. The mean coefficient (DELTA) is positive for all three series. In India, assets seem to be priced by the standard pricing model where positive risk return relationship is established. Most asset-pricing models postulate a positive relationship between a stock portfolio's expected returns and volatility. Baillie and DeGennarro, (1990) also found insignificant but positive risk relationship in the US market.

Table 12: Risk-return relationship and seasonality in return and risk

	Nifty		**Soybean**		**Gold**	
Variable	**Estimate**	**Pr > |t|**	**Estimate**	**Pr > |t|**	**Estimate**	**Pr > |t|**
Intercept	0.1133	0.1757	0.2044	**0.0069**	-0.0281	0.8419
D1 (return)	-0.1727	**0.0517**	0.1307	0.5133	0.0946	0.5048
D2 (return)	-0.0484	0.647	0.1318	0.6198	-0.1808	0.2096
D3 (return)	-0.2768	**0.0076**	0.1324	0.2262	-0.1215	0.4023
D4 (return)	-0.1422	0.0913	0.1371	0.6077	-0.0173	0.9047
D5 (return)	-0.0575	0.4796	0.1414	0.2033	-0.125	0.5304
D6 (return)	-0.008456	0.9144	0.1393	0.0992	-0.6321	0.1542
D7 (return)	-0.126	0.1071	0.126	0.4799	0.0192	0.8708
D8 (return)	-0.0257	0.7503	0.1272	0.5626	-0.1236	0.2473
D9 (return)	-0.1379	0.0997	0.1394	0.0891	-0.0676	0.6006
D10 (return)	-0.1611	**0.0728**	0.1422	**0.02**	-0.0588	0.6233
D11 (return)	-0.0594	0.4912	0.1456	**0.0114**	0.008916	0.9416
ARCH0	0.0449	<.0001	1.64E-10	<.0001	0.292	<.0001
ARCH1	0.1005	<.0001	0.014	0.0013	0.3859	<.0001
GARCH1	0.8614	<.0001	0.0184	<.0001	4.53E-20	1
DELTA	**0.0725**	**0.2641**	**0.2363**	**<.0001**	**0.276**	**0.1493**
D1 (volatility)	0.0588	**0.0005**	0.008484	0.1968	0.3818	**0.0019**
D2 (volatility)	0.1788	**<.0001**	0.007872	0.6493	0.318	**0.0131**
D3 (volatility)	0.0171	0.4086	0.005647	0.5624	0.0702	0.4373
D4 (volatility)	0.0483	**0.0068**	0.007087	**0.0002**	0.0793	0.3399
D5 (volatility)	0.0141	0.3245	0.0122	0.0928	0.4575	**0.0064**
D6 (volatility)	-6.52E-20	1	0.009776	0.2305	1.8103	**<.0001**
D7 (volatility)	0.049	**0.0002**	9.13E-11	1	0.0194	0.8089
D8 (volatility)	4.64E-19	1	0.006882	**0.0055**	3.94E-23	1
D9 (volatility)	0.0637	**<.0001**	0.009698	0.7524	0.1679	**0.0585**
D10 (volatility)	0.033	**0.0036**	0.0158	**<.0001**	0.00685	0.9274
D11 (volatility)	0.0287	**0.0343**	0.0205	0.7085	0.1032	0.1962

We have taken December as a reference and seasonality in risk and return is measured through dummies. It is found that in January, March and November, returns are significantly lower than December for Nifty. On the other hand, volatility in return of Nifty are higher for the January, February, April, July, September, October, and November. Soybean does not show seasonality in return in most of the months (except October and November) but seasonality in volatility is found in April, August and October. Higher volatilities in these months are accompanied by higher return. Gold also does not exhibit seasonality in return but in some months volatilities are higher than December. Returns in these months are lower although insignificant.

Nifty return shows asymmetric nature. i.e. most of the dummies in volatility equation are positive but their return in the corresponding months shows negative return as compared with reference month December. Gold also has asymmetric property. Some of the dummy in volatility equation (Jan, Feb, May, June, Sep) are significant and show higher volatility; however returns are not significant higher than reference month, December. In case of Soybean the return do not exhibit asymmetric nature when compared with reference December. The return in the month of October and November are higher and corresponding volatility was also higher.

5. CONCLUSIONS

The non-linear relationship in return structure is investigated through time series modeling approach (GARCH and EGARCH models) on stock market index S&P CNX Nifty, and on commodity market (Gold and Soybean). Volatility clustering, asymmetric properties, risk-return relationship and seasonality in risk and return are investigated for Indian stock and commodity market.

It is found that in Indian commodity and stock market, returns shows persistence in the volatility and clustering and asymmetric properties. Similar kind of result was found by Karmakar (2005, 2006), Kaur (2002, 2004), and Pandey (2005) for Indian stock market.

For symmetric conditional volatility structure GARCH (1,1) is found to be more appropriable for Nifty, Gold and Soybean. The asymmetric conditional volatility structure EGARCH (5,5) is found to best to explain the time varying volatility structure in Nifty and Gold market. EGARCH (5,2) is best fitted model for Soybean market.

Risk-return relationship is analyzed using symmetric GARCH (1, 1)-in-Mean with seasonals dummies in risk and return equation. Gold shows significant positive risk- return relationship where as Nifty and Soybean, positive but insignificant relationship was found. This finding is consistent with most asset-pricing models which postulate a positive relationship between a stock portfolio's expected returns and volatility

Seasonality in return and volatility is explored through GARCH-in-Mean approach. Soybean does not show seasonality in return where as seasonality is found in NIFTY returns. Volatility shows seasonal effect in all the cases. Seasonals in return raises question about the efficiency of the Indian stock and commodity markets.

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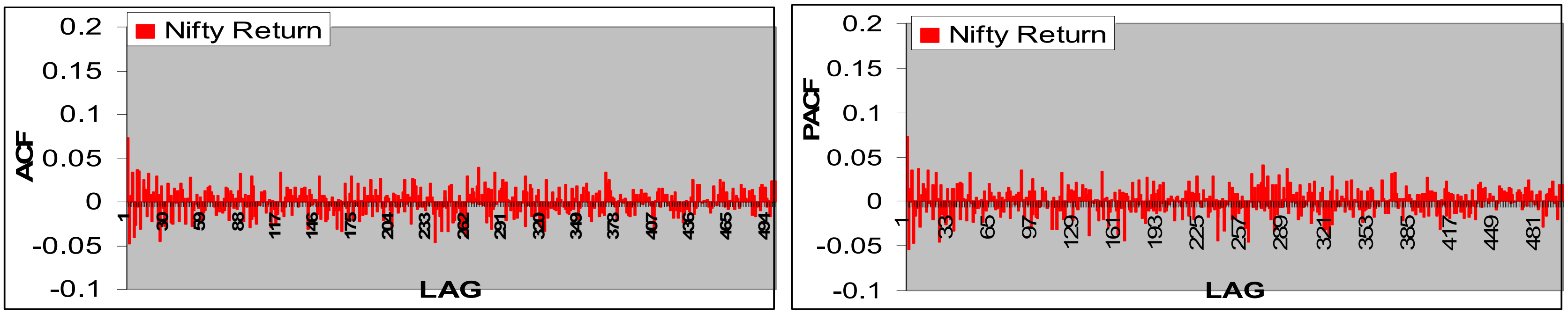
Appendix A



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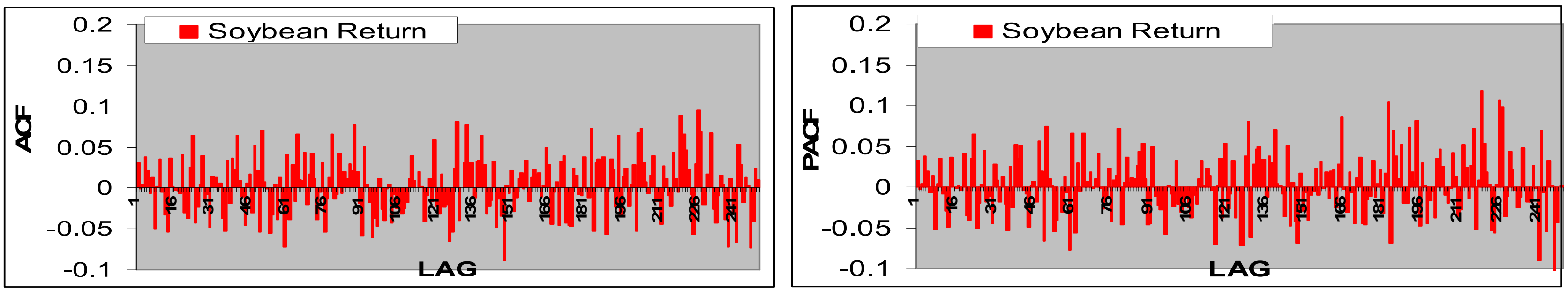

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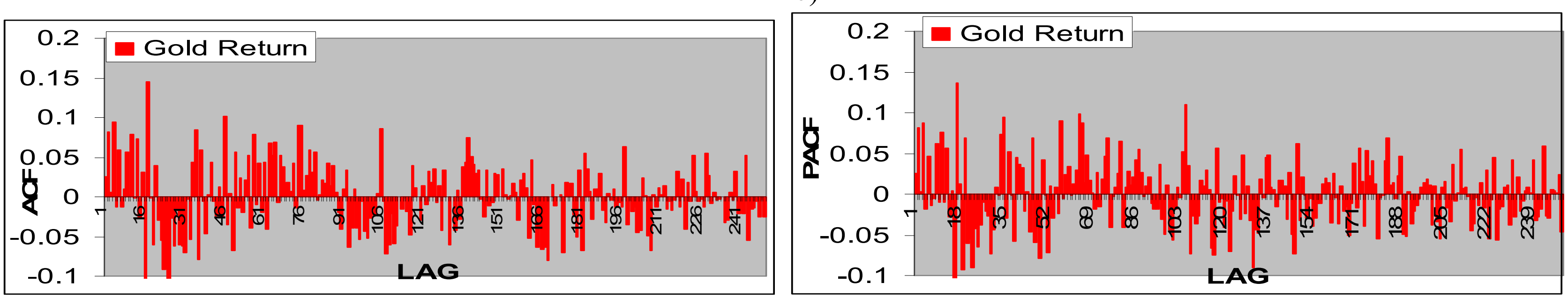


c)

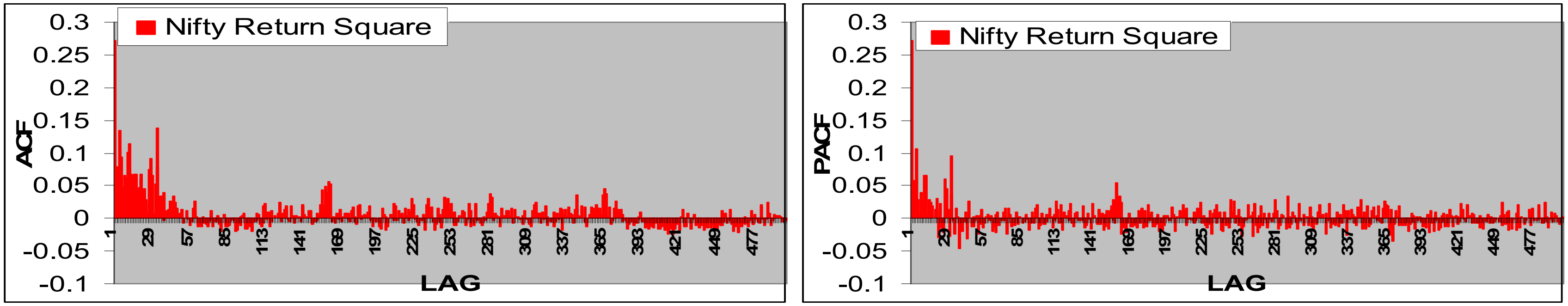
Figure 1: ACF & PACF of Spot return of a) Nifty b) Soybean c) Gold

Table 1: Autocorrelation Check for White Noise for Nifty, Soybean and Gold

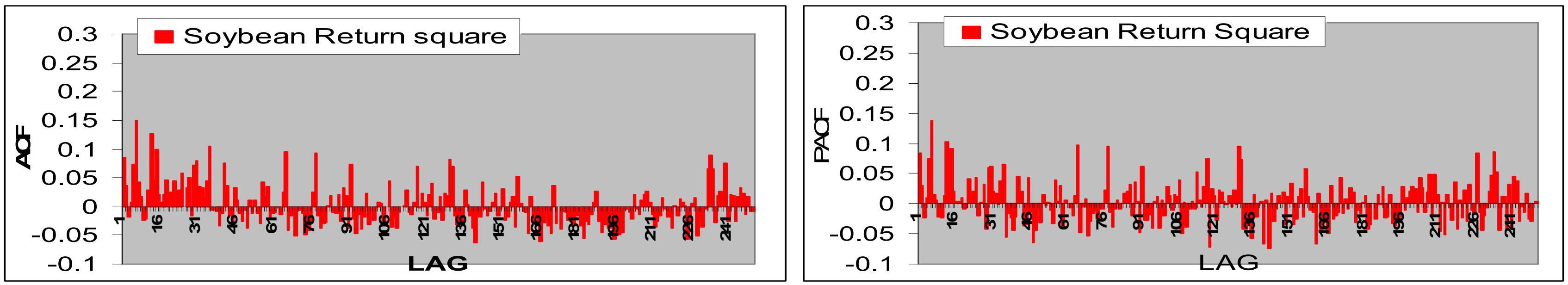
Autocorrelation Check for White Noise									
	Nifty			Soybean			Gold		
To Lag	Chi-Square	DF	Pr > ChiSq	Chi-Square	DF	Pr > ChiSq	Chi-Square	DF	Pr > ChiSq
6	44.21	6	<.0001	2.37	6	0.8826	12.98	6	0.0433
12	61.81	12	<.0001	6.36	12	0.8971	19.27	12	0.0821
18	72.63	18	<.0001	9.72	18	0.9408	49.61	18	<.0001
24	79.74	24	<.0001	17.89	24	0.8082	62.37	24	<.0001
30	99.49	30	<.0001	21.5	30	0.8717	78.62	30	<.0001
36	109.58	36	<.0001	24.92	36	0.9178	94.4	36	<.0001
42	115.66	42	<.0001	30.73	42	0.9008	99.59	42	<.0001
48	119.53	48	<.0001	35.31	48	0.9133	108.59	48	<.0001
54	127.25	54	<.0001	43.88	54	0.8356	115.18	54	<.0001
60	130.8	60	<.0001	50.05	60	0.8167	124.24	60	<.0001
66	134.83	66	<.0001	56.41	66	0.794	135.45	66	<.0001
72	137.16	72	<.0001	59.79	72	0.8473	140.12	72	<.0001
78	140.55	78	<.0001	63.89	78	0.8752	155.38	78	<.0001
84	143.98	84	<.0001	68.79	84	0.885	159.04	84	<.0001
90	152.15	90	<.0001	74.61	90	0.8789	163.25	90	<.0001
96	158.07	96	<.0001	82.62	96	0.833	169.66	96	<.0001
102	167.02	102	<.0001	85.88	102	0.8744	176.32	102	<.0001
108	169.65	108	0.0001	88.91	108	0.9097	189.24	108	<.0001
114	174.76	114	0.0002	90.61	114	0.9479	193.52	114	<.0001
120	185.07	120	0.0001	94.46	120	0.9589	197.61	120	<.0001
126	188.42	126	0.0003	99.14	126	0.9631	199.97	126	<.0001

132	191.23	132	0.0006	107.58	132	0.9412	205.42	132	<.0001
138	194.45	138	0.0011	113.9	138	0.9337	215	138	<.0001
144	200.1	144	0.0014	118.97	144	0.937	220.7	144	<.0001
150	206.86	150	0.0014	126.57	150	0.9179	223.28	150	<.0001
156	211.83	156	0.002	127.81	156	0.9521	224.61	156	0.0003
162	217.79	162	0.0023	129.56	162	0.9714	230.74	162	0.0003
168	225.08	168	0.0022	132.87	168	0.9789	247.46	168	<.0001
174	231.95	174	0.0022	138.33	174	0.9785	252.25	174	<.0001
180	238.16	180	0.0024	141.22	180	0.9853	256.61	180	0.0002
186	241.94	186	0.0036	147.69	186	0.9824	265.36	186	0.0001
192	247.04	192	0.0045	151.57	192	0.9859	267.51	192	0.0003
198	253.31	198	0.0048	155.89	198	0.9879	272.87	198	0.0003
204	257.82	204	0.0063	164.49	204	0.9806	277.51	204	0.0005
210	260.33	210	0.0103	165.74	210	0.9893	284.48	210	0.0005
216	264.41	216	0.0137	168.83	216	0.9924	285.2	216	0.0011
222	273.66	222	0.0103	177.49	222	0.9875	288.87	222	0.0017
228	277.05	228	0.0146	188.02	228	0.9752	294.81	228	0.0019
234	280.02	234	0.0211	192.42	234	0.9782	295.68	234	0.0039
240	291.18	240	0.0133	196.98	240	0.9805	299.27	240	0.0055
246	298.71	246	0.0121	201.74	246	0.9821	306.23	246	0.0054

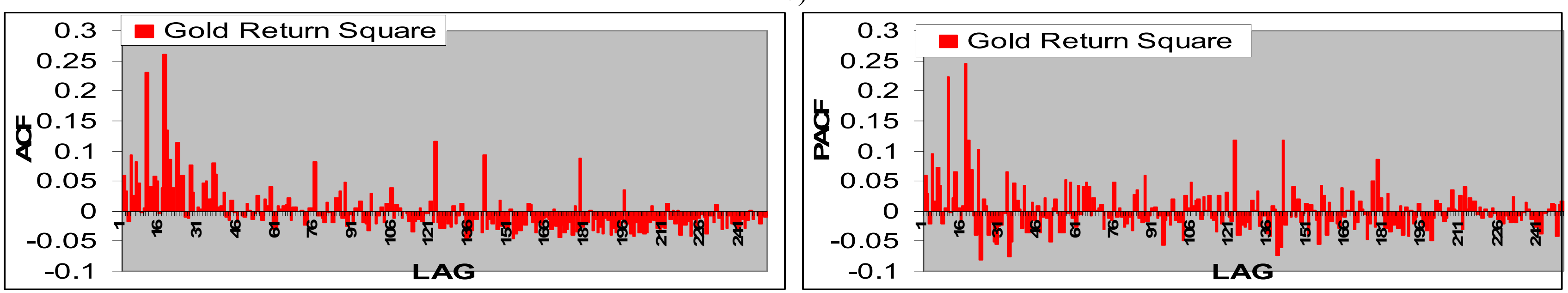
Appendix B



a)



b)



c)

Figure 2: ACF & PACF of spot return square of a) Nifty b) Soybean c) Gold

Table 2: Autocorrelation Check for White Noise on Return Square for Nifty, Soybean and Gold

Autocorrelation Check for White Noise									
	Nifty			Soybean			Gold		
To Lag	**Chi-Square**	**DF**	**Pr > ChiSq**	**Chi-Square**	**DF**	**Pr > ChiSq**	**Chi-Square**	**DF**	**Pr > ChiSq**
6	495.7	6	<.0001	29.25	6	<.0001	13.84	6	0.0315
12	650.12	12	<.0001	44.85	12	<.0001	52.18	12	<.0001
18	750.4	18	<.0001	56.57	18	<.0001	114.35	18	<.0001
24	806.77	24	<.0001	62.48	24	<.0001	131.58	24	<.0001
30	886.17	30	<.0001	74.23	30	<.0001	136.44	30	<.0001
36	1015	36	<.0001	85.94	36	<.0001	144.55	36	<.0001
42	1026.39	42	<.0001	92.33	42	<.0001	148.2	42	<.0001
48	1035.24	48	<.0001	94.7	48	<.0001	148.82	48	<.0001
54	1037.09	54	<.0001	96.15	54	0.0004	149.54	54	<.0001
60	1041.91	60	<.0001	99.55	60	0.001	152.48	60	<.0001
66	1043.61	66	<.0001	108.06	66	0.0008	153.19	66	<.0001
72	1044.94	72	<.0001	110.42	72	0.0024	154.06	72	<.0001
78	1046.36	78	<.0001	120.96	78	0.0013	159.2	78	<.0001
84	1049.74	84	<.0001	123.45	84	0.0033	160.57	84	<.0001
90	1051.08	90	<.0001	126.4	90	0.0069	163.92	90	<.0001
96	1054.83	96	<.0001	133.58	96	0.0068	165.52	96	<.0001
102	1058.31	102	<.0001	135.03	102	0.0159	166.92	102	<.0001
108	1060.74	108	<.0001	138.06	108	0.0271	168.5	108	0.0002
114	1065.72	114	<.0001	139.75	114	0.051	169.93	114	0.0005
120	1067.42	120	<.0001	143.7	120	0.0692	170.56	120	0.0017

126	1070.9	126	<.0001	145.87	126	0.1088	183.5	126	0.0006
132	1075.77	132	<.0001	154.69	132	0.0862	185.04	132	0.0016
138	1076.18	138	<.0001	157.18	138	0.1261	189.48	138	0.0024
144	1079.86	144	<.0001	162.02	144	0.1448	199.02	144	0.0016
150	1081.42	150	<.0001	162.77	150	0.2249	201.79	150	0.0031
156	1093.8	156	<.0001	165.02	156	0.295	206.22	156	0.0044
162	1135.93	162	<.0001	168.51	162	0.3469	208.57	162	0.008
168	1137.24	168	<.0001	172.51	168	0.3897	210.2	168	0.015
174	1138.17	174	<.0001	176.9	174	0.4246	215.17	174	0.0184
180	1140.52	180	<.0001	178.53	180	0.5169	225.3	180	0.0123
186	1144.16	186	<.0001	182.29	186	0.5632	228.51	186	0.0183
192	1146.52	192	<.0001	185.23	192	0.6239	233.72	192	0.0214
198	1148.05	198	<.0001	190.92	198	0.6281	237.73	198	0.0281
204	1152.51	204	<.0001	191.6	204	0.7236	243.89	204	0.0293
210	1156.47	210	<.0001	192.62	210	0.7996	246.97	210	0.0409
216	1157.85	216	<.0001	194.23	216	0.8537	248.59	216	0.0634
222	1164.43	222	<.0001	195.54	222	0.8993	253.12	222	0.0743
228	1166.88	228	<.0001	199.48	228	0.9138	255.56	228	0.1015
234	1174.55	234	<.0001	209.98	234	0.8686	257.19	234	0.1425
240	1178.36	240	<.0001	214.52	240	0.8802	260.32	240	0.1755
246	1185.91	246	<.0001	216.41	246	0.9133	261.71	246	0.2346