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Testing the Hedging Effectiveness of Index and Individual Stock Futures Contracts: Evidence from India

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Abstract

Present study attempts to estimate hedging effectiveness in Indian equity futures market using NIFTY50 index futures and its 17 composite stock futures (out of 50 stocks). The study uses near month futures contracts from their respective date of inception until March 31, 2017. The study applies eight methods, proposed in the literature, to estimate optimal hedge ratio namely; Naïve, Ederington's OLS, ARMA-OLS, VAR, VECM, GARCH, EGARCH, and TARCH. It is observed that OLS hedge ratio provides highest hedging effectiveness, whereas lowest hedging effectiveness is given by Naïve and time-varying models. The above observations imply that constant hedging is more efficient than dynamic hedging which is consistent with the findings of Wang et al (2015) and Bonga and Umoetok (2016).

Keywords: Equity Futures Market, GARCH, Hedging Effectiveness, OLS, Optimal Hedge Ratio

JEL Classification: C1, C5, G11, G17

Introduction

Hedging is considered to be a primary function of derivatives market, and futures' contracts have been widely used by investors in managing the price risk involved in underlying assets. Previously, futures market was mainly used for managing price risk in agricultural commodities only; however, more recently, it is being used by a different class of investors trading in equities, bonds, currencies, and other financial securities.

The co-movement and long-term equilibrium relationship between spot and futures market (Kawaller et al., 1987) enable hedger to offset price fluctuations in underlying asset prices by taking opposite position in both spot and futures market. However, in reality, the absence of a perfect correlation between spot and futures market (Stoll and Whaley, 1990) due to presence of lead-lag relationship during the short-run[1] gives rise to basis risk (Figlewski, 1984; Castelino, 1992). Due to the presence of basis risk, the number of futures' contracts required to hedge a given spot position departs from unity and, therefore, requires an optimal hedge ratio to be estimated in order to achieve superior hedging effectiveness (according to specific objective function to be optimized).

An analysis of hedging literature suggests three different hedging theories, i.e., conventional hedging theory, working's hedging theory, and portfolio hedging theory. The conventional/traditional/naive hedging theory assumes that investor is averse to both, risk and price movement in futures, and cash market is perfectly correlated; therefore, it suggests that an equal number of futures as well spot exposures is required in inverse direction in order to hedge portfolio. However, this theory fails to incorporate the impact of basis risk. Therefore, contradicting the naïve hedging theory, Working (1953)

[1] Herbst et al. (1987), Stoll and Whaley (1990), Martikainen et al. (1995)

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proposed that hedger acts as a speculator who wishes to maximize his profits at any level of risk by speculating on the basis. However, this theory failed to leave its impact because hedgers cannot always maximize their wealth at any level of risk. Subsequently, Johnson (1960), Stein (1961), and Ederington (1979) developed a portfolio hedging theory. The optimal hedge ratio estimated within this framework is based upon the minimization of the variance of returns on hedged portfolio and, therefore, known as Minimum-Variance Hedge Ratio (MVHR) and is estimated as the ratio of covariance of cash and futures returns to the variance of futures returns

The minimum-variance hedge ratio/OLS hedge ratio suggested by Ederington (1979) has been popularly used due to its simplicity to compute and understand. However, it suffers from two limitations. Firstly, it ignores the time-varying nature of financial time series; secondly, it computes constant hedge ratio. Therefore, in order to address this issue, various econometric models like GARCH, EGARCH, TARCH, etc., have been proposed in literature which help in estimating time-varying hedge ratios. Henceforth, voluminous literature[2] supports time-varying hedge ratios over constant hedge ratios.

Although numerous studies claim superior performance of time-varying hedge ratios and despite a significant advancement in econometrics, a strand of literature observes that constant hedge ratios still dominate time-varying hedge ratios and, therefore, argues that econometric sophistication does not help to improve hedging effectiveness (Maharaj et al., 2008; Gupta and Singh, 2009;, and Wang et al., 2015). Especially, the superiority of Ederington's OLS hedge ratio over time-varying hedge ratio is prominent in literature (Lien et al., 2002; Moosa, 2003; Lien, 2005; Bhargava and Malhotra, 2007; Maharaj et al., 2008; Rao and Thakur, 2008; Awang et al., 2014).

Furthermore, Ederington (1979) suggested a measure of hedging effectiveness, based upon the portfolio theory approach to hedging proposed by Johnson (1960) and Stein (1961), according to which hedging effectiveness is measured as a proportionate reduction in standard deviation of returns from hedged portfolio and a hedge ratio that gives highest hedging effectiveness is popularly known as minimum-variance hedge ratio. Ederington's measure of hedging effectiveness has been widely appreciated in the literature (Park and Switzer, 1995; Holmes, 1995; Lypny and Powalla, 1998; Yang and Allen, 2004; Floros and Vougas, 2004, 2006; Bhargava and Malhotra, 2007; Bhaduri and Durai, 2008; Men and Men, 2008; Gupta and Singh, 2009; Pradhan, 2011; Hou and Li, 2013) mainly due to its simplicity to compute and understand.

Furthermore, it is observed that hedging effectiveness is highly affected by the presence of basis risk. The basis reflects the cost of carry which keeps on declining as asset reaches its maturity date (Figlewski, 1984; Hemler and Longstaff, 1991; Brailsford and Cusack, 1997; Wang, 2007). Therefore, hedge ratio and hedging effectiveness keep on increasing with decreasing time-to-expiry, thereby exhibiting negative relation with the basis risk (Figlewski, 1984). However, in short-run, due to mispricing of futures contracts[3] (Brailsford and Hodgson, 1997; Mackinlay and Ramaswamy, 1988; Yadav and Pope, 1990; Neal, 1996) basis deviates from equilibrium (as reflected by cost of carry model) which is then corrected by intervention of arbitrageurs in the market (Theobald and Yallup, 1997; Monoyios and Sarno, 2002).

In addition, voluminous literature observes the existence of positive relation between hedging effectiveness and hedge horizon (Ederington, 1979; Geppert, 1995; Holmes, 1995; Chou et al., 1996; Pennings and Meulenberg, 1997; Chen et al., 2002; Chen et al., 2004; In and Kim, 2006; Juhl et al., 2012). The economic rationale underlying is that basis risk tends to decline as the contract approaches expiry (Figlewski, 1984), thereby, leading to higher correlation between spot and futures (Chen et al., 2002). However, Howard and D'Antonio (1984) points out that hedging effectiveness does not always improve as correlation between spot and futures increases.

Further, it is observed that trading of futures contracts is highly popular in emerging markets, especially India which is evident from the fact that National Stock

[2] Myers, 1991; Park and Switzer, 1995; Aggarwal and Demaskey, 1997; Moschini and Myers, 2002; Harris and Shen, 2003; Pattarin and Ferretti, 2004; Kofman and McGlenchy, 2005; Floros and Vougas, 2006; Bhaduri and Durai, 2007; Lee and Yoder, 2007, Yang and Lai, 2009, Salles, 2013 and Hou and Li, 2013

[3] Probable reasons for mispricing of futures is found to be illiquidity, non-synchronous trading, market microstructure settings, return generation process, purpose of use of futures contracts, noise trading and violation of assumptions of cost of carry model. These factors gives rise to basis risk which deteriorates effectiveness of hedge.

Exchange of India (NSE) has been consistently ranked among top five markets of the world in terms of trading of equity futures contracts from the last decade[4]. However, to the best of our knowledge, there is dearth of literature examining the hedging effectiveness of index futures. Nonetheless, Bhaduri and Durai (2007), Rao and Thakur (2008), Gupta and Singh (2009), and Pradhan (2011) have all attempted to examine the hypothesis but these studies have mainly focused on examining a superior methodology for determining optimal hedge ratio by using index futures contracts. To the best of our knowledge, Gupta and Singh (2009) has the only attempt to estimate hedging effectiveness using individual stock futures by taking four years as sample period of the study. The present study attempts to estimate hedging effectiveness by taking a more comprehensive sample period of 17 years since the inception of the securities understudy until March 31, 2017.

Database and Research Methodology

As per the recommendation of L. C. Gupta Committee, trading of financial derivatives on Bombay Stock Exchange (BSE) and NSE commenced in June 2000. At present, trading of futures contracts on NSE is permitted on eight indices and 208 individual securities. As far as the present study is concerned, the sample size of the study comprises of NIFTY50 index and 17 individual stock futures which have been selected on the basis of their consistent trading history and high liquidity. The data have been collected for near month futures contracts of NIFTY50 index and 17 individual stock futures from official website of NSE, i.e., www.nseindia.com. The period of the study is from date of inception of respective indices until March 31, 2017 (Appendix A).

Unit-root Test

The estimation of hedge ratio is a statistical process, which involves regressing cash market returns on futures returns; therefore, prior to undertake any statistical procedures, it would be more important to examine the time series properties of data under investigation. The pre-requisite for time series analysis is to examine whether the series contain unit-roots. Augmented Dickey-Fuller (ADF) test has been applied for testing the presence of unit-roots and it is observed that both the series are non-stationary at levels and their log of first difference is stationary. Hence, log returns are used for further analysis in the study.

Estimation of Optimal Hedge Ratio

The futures and spot markets are linked to each other through arbitrage process (Stoll and Whaley, 1987) and the cost-of-carry model ensures the long-run relationship between both the markets. Assuming the above relationship, as suggested in the literature, hedging effectiveness of Indian equity futures market has been examined by using eight econometrical procedures (equation 2.1 through 2.9). The hedging effectiveness will be measured on the basis of variance reduction approach estimated through equation (2.10). Brief description of eight hedge ratio estimation models is as follows:

Naïve Hedge Ratio

Traditionally, cash and futures market was presumed to be perfectly correlated and therefore an equal number of futures' contracts was required to obtain a perfect hedge. Hence, it suggests an optimal hedge ratio of one. Since this methodology ignored basis risk, which is considered vital to the estimation of optimal hedge ratio, this theory failed to mark its presence in the literature.

Ederington's OLS Hedge Ratio

Based upon portfolio theory approach, Ederington (1979) suggested minimum-variance hedge ratio, which presumes strong and stable long-run relationship between two markets. Optimal hedge ratio is estimated as ratio of covariance of cash and futures market returns and variance of futures market returns as depicted in equation (2.1) and hedging effectiveness will depend upon the coefficient of R^2.

$$R_{s,t} = \alpha_0 + \beta_1 R_{f,t} + \varepsilon_t \qquad (2.1)$$

where

$R_{s,t}$ = Returns from cash market

$R_{f,t}$ = Returns from futures market

α_o = Intercept term

ε_t = Error term

[4] See NSE Fact Books for details (www.nseindia.com)

ARMA-OLS Hedge Ratio

The procedure suggested in equation (2.1) is economically justifiable and the estimated coefficient of β_1 is reliable only if the statistical properties of the estimation procedure are satisfied; otherwise, the estimated value would be biased. Literature on financial econometrics suggests that autocorrelation of financial time series has become a stylized fact, which implies that successive returns of one speculative asset are based upon their past values; hence, predictable. Hence, autoregressive orders of cash market returns are included in equation (2.1) and revised equation is presented in equation (2.2). The order of autoregressive terms included in equation (2.2) is decided on the basis of Schwartz Information Criteria (SI C).

$$R_{s,t} = \alpha_0 + \sum_{i=1}^{p} \alpha_i R_{s,t-i} + \beta_1 R_{f,t} + \varepsilon_t \qquad (2.2)$$

GARCH Hedge Ratio

Further, another stylized fact observed by the literature is that stock market returns observes volatility clustering, which implies that large price changes will be followed by large price changes and small price changes will be followed by small price changes. Vast amount of literature[5] observes that stock market returns are heteroskedastic, i.e., variance of error term is not constant. Estimation procedures suggested in equations (2.1) and (2.2) would be valid only if the variance of error term is constant; otherwise, the results would be spurious. Therefore, equation (2.2) will be estimated through Generalized Autoregressive Conditional Heteroscedasticity model (GARCH (p, q)) model and equation (2.3) will be estimated along with equation (2.2). The GARCH (p, q) model is given by equation (2.3),

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} + \upsilon_t \qquad (2.3)$$

EGARCH Hedge Ratio

Further, if stock returns are asymmetric and the interaction between old and new information observes leverage effect, EGARCH model as suggested in equation (2.4) may help to estimate an improved hedge ratio as compared to the hedge ratio estimated using GARCH procedure in equation (2.3).

$$h_t = \gamma_1 + \gamma_2 \left| \frac{\varepsilon^2_{t-1}}{h_{t-1}} \right| + \gamma_3 \frac{\varepsilon^2_{t-1}}{h_{t-1}} + \gamma_4 h_{t-1} \qquad (2.4)$$

TARCH Hedge Ratio

The EGARCH model, as discussed above, considers the leverage relationship between old and new information, but fails to segregate the impact of both negative and positive news upon market volatility. This is due to the fact that traders react differently to negative and positive news (Karpoff, 1987). Hence equation (2.4) will be modified to equation (2.5), where:

$$h_t = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \alpha_k \varepsilon_{t-1}^2 \xi_{t-i} + \sum_{j=1}^{p} \beta_j h_{t-j} + \upsilon_t \qquad (2.5)$$

where,

(i) $\xi_{t-i} = 1$, if $\varepsilon_{t-i} < 0$

(ii) $\xi_{t-i} = 0$, if $\varepsilon_{t-i} > 0$

The above equations assume that there is strong co-movement between both markets; whereas, as per cost of carry model, lead-lag relationship between two markets may exist. Hence, two more hedge ratios through VAR and VECM models have been estimated as discussed in sections 2.2.7 and 2.2.8, respectively.

VAR Hedge Ratio

VAR model takes into consideration theoretical relationship between spot and futures returns by simultaneously regressing the lagged returns of both variables. Hence, this methodology estimates optimal hedge ratio by considering the lead-lag relationship in the short-run. Equations (2.6) and (2.7) specify the estimation procedure of VAR methodology. The hedge ratio on the basis of VAR will be measured as $\sigma_{s,f} / \sigma^2 f$, where $\sigma_{s,f} = cov(\varepsilon_{ft}, \varepsilon_{st})$ and $\sigma^2 f = var(\varepsilon_{ft})$.

$$R_{s,t} = \sum_{i=1}^{M} \alpha_i R_{s,t-i} + \sum_{j=1}^{N} \beta_j R_{f,t-j} + \varepsilon_{st} \qquad (2.6)$$

$$R_{f,t} = \sum_{k=1}^{O} \alpha_k R_{s,t-k} + \sum_{l=1}^{P} \beta_1 R_{s,t-1} + \varepsilon_{ft} \qquad (2.7)$$

VECM Hedge Ratio

VECM model captures the long-run co-integration between spot and futures prices, which the VAR model

[5] Engle (1982), Bollerslev (1987), Myers (1991), Park and Switzer (1995), Pattarin and Ferretti (2004).

fails to. Therefore, if both the markets are co-integrated, optimal hedge ratio can be estimated using VECM model which simultaneously regresses the lagged returns of both the series as well as captures the error correction term. The estimation procedure of VECM is shown in equations (2.8) and (2.9). The optimal hedge ratio is estimated by using the same procedure as described in the above section.

$$R_{f,t} = \alpha_{0f} + \sum_{i=1}^{p} \alpha_{if}(F_{t-i} - S_{t-i}) + \sum_{j=1}^{q} \beta_f R_{f,t-j} + \sum_{k=1}^{m} \beta_f R_{s,t-k} + \varepsilon_{ft} \quad (2.8)$$

$$R_{s,t} = \alpha_{0s} + \sum_{i=1}^{p} \alpha_{is}(F_{t-i} - S_{t-i}) + \sum_{l=1}^{n} \beta_s R_{s,t-l} + \sum_{h=1}^{o} \beta_s R_{f,t-h} + \varepsilon_{st} \quad (2.9)$$

Estimation of Hedging Effectiveness

After estimating the optimal hedge ratio through above-mentioned statistical procedures, the hedging effectiveness of optimal hedge ratios estimated using eight econometric procedures will be computed on the basis of variance-reduction criterion suggested by Ederington (1979). The hedge ratio that gives the maximum variance reduction in the hedged portfolio would be proposed as an efficient hedge ratio.

As proposed by Ederington (1979), hedging effectiveness will be measured as proportionate decrease in the variance of hedged portfolio as shown in equation (2.10), where Var (H) and Var (U) represent variance of hedged and un-hedged portfolios, respectively, where Var (U) = σ_s^2 and Var (H) = $\sigma_s^2 + h^{*2}\sigma_f^2 - 2h^*\sigma_{s,f}$, respectively.

$$\text{Hedging effectiveness} = [\text{Var (U)} - \text{Var (H)}] / \text{Var (U)} \quad (2.10)$$

where, σ_s = standard deviation of the cash return
σ_f = standard deviation futures return
$\sigma_{s,f}$ = covariance between spot and futures return, and
h^* = optimal hedge ratio.

Results and Analysis

As the present study employs time series data, it becomes important to discuss the time series properties of the data series understudy. Results in Table 2 suggest that log returns of futures and cash markets are not normal.

Furthermore, optimal hedge ratio(s) have been estimated using eight econometric models namely: Naive, Ederington's OLS Model, ARMA (p, q), VAR, VECM, GARCH (p, q), EGARCH (p, q), and TARCH (p, q) for near month futures' contracts of 18 stocks understudy (Table 3). There are two important observations. Firstly, it is observed that in case of eight stocks, OLS gives the lowest coefficient of hedge ratio. Further, VECM gives lowest coefficient for four stocks, while VAR in case of two stocks. In case of all the stocks, the highest coefficient of optimal hedge ratio is given by time-varying models (i.e., GARCH, EGARCH, or TARCH). Secondly, it is observed that coefficient of optimal hedge ratio estimated through constant hedging models (OLS, ARMA-OLS, GARCH, EGARCH, and TARCH) is relatively smaller than the optimal hedge ratios obtained from time varying models (GARCH, EGARCH, and TARCH). From these findings, one conclusion can be drawn that hedging through constant hedging models is relatively economic than time-varying hedging models because smaller coefficient of optimal hedge ratio (which is obtained by constant hedging models) implies lower investment in futures contracts to hedge.

Further, the results of hedging effectiveness computed on the basis of variance reduction measure (suggested by Ederington (1979)) are shown in Table 4. These results reveal an important finding that highest hedging effectiveness is obtained using Ederington's OLS model[6] for all the stocks understudy (except BAJFINANCE, IBULHSGFIN, and INFRATEL where VAR model outperforms). On the other hand, naïve gives lowest hedging effectiveness in case of more than 50% of the stocks (11 out of 18 stocks understudy); whereas, in case of remaining 7 stocks, time-varying models gives lowest optimal hedge ratio.

Overall, a significant conclusion drawn from the above findings is that conventional hedge ratio performs better than time-varying hedge ratio. These findings conform the findings of Lien et al. (2002), Lien (2005), Maharaj et al. (2008), and Gupta and Singh (2009) which suggest

[6] These findings are consistent with the findings of Lien et al (2002), Moosa (2003), Lien (2005), Maharaj et al. (2008), Bhargava and Malhotra (2007), Rao and Thakur (2008) and Awang et al. (2014)

that use of sophisticated econometrical procedures does not provide for better hedging effectiveness; rather, complexity of the econometrical procedure may add cost to the portfolio.

Conclusion

The present study attempts to test the hedging efficiency of Indian Equity Futures Market by taking near month futures contracts of NIFTY50 index and 17 individual stock futures contracts. For testing hedging efficiency, the study applies eight hedge ratio estimation models namely: Naïve, Ederington's OLS Model, ARMA-OLS (p, q), VAR, VECM, GARCH (p, q), EGARCH (p, q), and TARCH (p, q). It is observed that the coefficient of optimal hedge ratio estimated through constant hedging models (OLS, ARMA-OLS, GARCH, EGARCH, and TARCH) is comparatively smaller than the optimal hedge ratios obtained from time-varying models (GARCH, EGARCH, and TARCH) implying that hedging through constant hedging models is relatively economical as compared to time-varying hedging models.

Furthermore, hedging effectiveness has been estimated using variance-reduction framework suggested by Ederington (1979) and the results have been reported in Table 4. It is found that OLS hedge ratio gives highest hedging effectiveness (except BAJFINANCE, IBULHSGFIN, and INFRATEL where VAR model gives highest hedging effectiveness); whereas, Naïve hedge ratio gives the lowest hedging effectiveness. These findings are consistent with the findings of Collins (2000), Lien et al. (2002), Moosa (2003), Lien (2005), Bhargava (2007), and Rao and Thakur (2008).

In the nutshell, it is observed that constant hedging models outperform the time-varying hedging models and these findings are consistent with the findings of Wang et al. (2015), who argues if sophistication and complexity of econometric models to estimate hedging effectiveness help to enhance the efficiency of hedging.

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Table 2: Descriptive Statistics

S. No.	Symbol	Return	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
1	Nifty50	Futures	4187	0.000441	0.015472	-0.469780	13.34624	18828.84 (0.000000)
		Cash	4187	0.000448	0.014737	-0.303116	12.17907	14749.04 (0.000000)
		Basis	4188	4.724946	15.80195	0.331313	5.053275	811.7172 (0.000000)
2	BAJFINANCE	Futures	456	-0.002823	0.109339	-19.95570	416.7896	3283481 (0.000000)
		Cash	456	-0.002809	0.109337	-19.92874	416.0601	3271937 (0.000000)
		Basis	457	9.581729	16.28920	0.284053	5.437581	119.2874 (0.000000)
3	BPCL	Futures	3830	0.000348	0.029407	-7.014955	176.1475	4815729 (0.000000)
		Cash	3830	0.000347	0.029441	-7.402308	185.1364	5328941. (0.000000)
		Basis	3830	0.588476	3.151144	-1.428785	23.88241	70911.94 (0.000000)
4	COALINDIA	Futures	1399	-0.000211	0.017346	0.166917	6.155177	586.7980 (0.000000)
		Cash	1399	-0.000211	0.018080	0.030914	6.092731	557.7818 (0.000000)
		Basis	1400	0.274250	3.247133	-4.746945	30.23756	48534.41 (0.000000)
5	EICHERMOT	Futures	629	0.001328	0.020394	-0.011058	5.218357	128.9869 (0.000000)
		Cash	629	0.001336	0.020576	0.072387	4.796008	85.08813 (0.000000)
		Basis	630	44.94825	53.58925	-1.177629	10.22929	1517.509 (0.000000)
6	GAIL	Futures	3360	0.000297	0.025425	-2.126738	49.62143	306831.0 (0.000000)
		Cash	3360	0.000299	0.025192	-2.298937	49.74515	308875.0 (0.000000)
7	HINDPETRO	Futures	3830	0.000362	0.031794	-10.70579	374.8319	22136988 (0.000000)
		Cash	3830	0.000361	0.031456	-11.24082	396.8924	24840202 (0.000000)
		Basis	3831	0.646672	2.837737	-2.673861	22.58106	65768.09 (0.000000)

S. No.	Symbol	Return	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
8	HINDUNILVR	Futures	3830	0.000376	0.017880	0.085941	8.592636	4996.095 (0.000000)
		Cash	3830	0.000376	0.018211	0.170767	8.139800	4234.414 (0.000000)
		Basis	3831	0.476481	2.095294	-0.943118	9.788379	7923.781 (0.000000)
9	IBULHSGFIN	Futures	579	0.001364	0.022171	-0.000171	4.747119	73.63973 (0.000000)
		Cash	579	0.001372	0.022225	-0.016588	4.808114	78.89788 (0.000000)
		Basis	580	1.130345	2.916575	-1.494980	5.450975	361.2224 (0.000000)
10	INFRATEL	Futures	372	-0.000401	0.022784	-0.087563	6.224958	161.6809 (0.000000)
		Cash	372	-0.000392	0.023157	-0.028899	5.960027	135.8591 (0.000000)
		Basis	373	0.960858	0.930485	-0.626881	5.599497	129.4512 (0.000000)
11	IOC	Futures	3360	1.49E-05	0.029009	-8.459908	205.7503	5795153 (0.000000)
		Cash	3360	1.97E-05	0.028730	-8.720166	217.6573	6493470 (0.000000)
		Basis	3361	0.640777	2.741698	-2.600712	17.47955	33149.58 (0.000000)
12	MARUTI	Futures	3416	0.001053	0.021997	-0.033435	6.243008	1497.570 (0.000000)
		Cash	3416	0.001054	0.022052	0.013933	5.807149	1121.710 (0.000000)
		Basis	3417	2.853000	7.895328	0.706197	5.711584	1330.857 (0.000000)
13	NTPC	Futures	3077	0.000254	0.019688	-0.112025	8.590044	4012.765 (0.000000)
		Cash	3077	0.000256	0.019429	-0.117414	7.949894	3148.360 (0.000000)
		Basis	3078	0.242690	0.985696	-3.707730	31.93954	114461.3 (0.000000)
14	RELIANCE	Futures	3830	0.000420	0.024427	-7.340180	213.3423	7094976 (0.000000)
		Cash	3830	0.000420	0.024424	-7.318183	213.2978	7091784 (0.000000)
		Basis	3831	2.905234	4.484507	2.481211	18.32038	41397.08 (0.000000)

S. No.	Symbol	Return	Count	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
15	TATASTEEL	Futures	3830	0.000461	0.028957	-1.229599	21.29025	54351.06 (0.000000)
		Cash	3830	0.000462	0.028607	-1.241230	21.90959	58046.08 (0.000000)
		Basis	3831	0.587914	2.801175	-2.813329	25.88557	88657.11 (0.000000)
16	TCS	Futures	3128	0.000288	0.026738	-11.78042	315.7499	12820576 (0.000000)
		Cash	3128	0.000288	0.026904	-11.42290	304.0776	11882447 (0.000000)
		Basis	3129	2.137200	6.345093	-0.837063	8.694432	4593.014 (0.000000)
17	ULTRACEMCO	Futures	2539	0.000505	0.020439	0.078001	5.754622	805.3159 (0.000000)
		Cash	2539	0.000507	0.020740	0.114797	5.991619	952.3891 (0.000000)
		Basis	2540	3.130197	7.437791	-0.692689	11.77550	8353.279 (0.000000)
18	ZEEL	Futures	2611	0.000196	0.029092	-5.793806	130.1609	1773757 (0.000000)
		Cash	2611	0.000198	0.029440	-5.760154	128.4595	1726830 (0.000000)
		Basis	2612	0.569736	1.205852	-1.376148	12.71139	11088.62 (0.000000)

Table 3: Estimation of Optimal Hedge Ratios

S. No	Symbol	Naive	OLS	ARMA OLS	VAR	VECM	GARCH	EGARCH	TARCH
1	NIFTY50	1	0.935901	0.952828	0.939036	0.9402854	0.956706	0.96703	0.962802
2	BAJFINANCE	1	0.999653	0.999331	0.997583	0.997876	0.999333	0.99963	0.999734
3	BPCL	1	0.976534	0.984169	0.981165	0.981404	0.998079	0.995229	0.994335
4	COALINDIA	1	0.988323	0.988792	0.990445	0.993639	0.980013	0.995693	0.992754
5	EICHERMOT	1	0.999024	1.00043	1.000058	1.002258	0.995955	1.004543	0.994432
6	GAIL	1	0.969722	0.976742	0.973302	0.97368	0.982184	0.99425	0.988726
7	HINDPETRO	1	0.97283	0.975617	0.974317	0.974771	1.002327	1.003622	1.002063
8	HINDUNILVR	1	0.988349	0.991899	0.991726	0.993982	1.000784	0.997474	1.003102
9	IBULHSGFIN	1	0.992401	0.997959	0.990588	0.989543	1.001441	1.003322	0.994208
10	INFRATEL	1	1.009893	1.009444	1.005303	1.001731	1.009321	1.010606	1.009821
11	IOC	1	0.974751	0.980081	0.974019	0.974417	0.972546	0.97671	0.990314
12	MARUTI	1	0.98279	0.990187	0.987937	0.987805	0.995405	1.001165	0.999582
13	NTPC	1	0.965666	0.967984	0.967432	0.968773	0.977355	0.99118	0.983779
14	RELIANCE	1	0.993205	0.995733	0.992889	0.992402	0.995948	0.996571	0.996487
15	TATASTEEL	1	0.976848	0.983592	0.976946	0.976809	0.987318	0.997117	0.988875
16	TCS	1	0.997971	1.000231	0.999794	0.998656	1.003007	1.000498	0.998895
17	ULTRACEMCO	1	0.974227	0.992293	0.985736	0.986549	0.999265	0.995578	1.003512
18	ZEEL	1	1.002231	0.99996	1.002631	1.002615	1.00567	1.004455	1.00268

Table 4: Variance Reduction

S. No	Symbol	Naive	OLS	ARMA OLS	VAR	VECM	GARCH	EGARCH	TARCH
1	NIFTY50	0.960829	**0.965391**	0.965067	0.965379	0.965368	0.964904	0.964307	0.964580
2	BAJFINANCE	0.994957	0.994959	0.994960	**0.994964**	0.994964	0.994960	0.994959	0.994959
3	BPCL	0.950350	**0.950912**	0.950850	0.950888	0.950886	0.950438	0.950554	0.950587
4	COALINDIA	0.897737	**0.897878**	0.897877	0.897871	0.897845	0.897825	0.897819	0.897854
5	EICHERMOT	0.977306	**0.977310**	0.977304	0.977306	0.977289	0.977310	0.977263	0.977303
6	GAIL	0.956282	**0.957234**	0.957179	0.957218	0.957215	0.957068	0.956606	0.956855
7	HINDPETRO	0.965566	**0.966334**	0.966325	0.966331	0.966330	0.966012	0.965350	0.965455
8	HINDUNILVR	0.941086	**0.941223**	0.941209	0.941210	0.941190	0.941068	0.941138	0.941006
9	IBULHSGFIN	0.976603	0.976686	0.976636	**0.976689**	0.976688	0.976574	0.976530	0.976677
10	INFRATEL	0.981906	0.981949	0.981951	**0.981953**	0.981927	0.981952	0.981945	0.981949
11	IOC	0.967474	**0.968139**	0.968107	0.968139	0.968139	0.968139	0.968134	0.967926
12	MARUTI	0.960262	**0.960566**	0.960507	0.960537	0.960538	0.960401	0.960220	0.960276
13	NTPC	0.955690	**0.956922**	0.956915	0.956918	0.956910	0.956774	0.956237	0.956574
14	RELIANCE	0.986125	**0.986175**	0.986167	0.986175	0.986174	0.986166	0.986162	0.986162
15	TATASTEEL	0.976682	**0.977243**	0.977193	0.977243	0.977243	0.977126	0.976812	0.977089
16	TCS	0.983029	**0.983034**	0.983028	0.983030	0.983033	0.983006	0.983026	0.983033
17	ULTRACEMCO	0.920405	**0.921070**	0.920739	0.920932	0.920913	0.920442	0.920611	0.920215
18	ZEEL	0.980096	**0.980099**	0.980096	0.980099	0.980099	0.980085	0.980093	0.980099

Appendix A: Sample Size and Sample Period of the Study

S. No.	Symbol	Period of study	Observations
1	NIFTY50	June 12, 2000 – March 31, 2017	4188
2	BAJFINANCE	May 29, 2015 – March 31, 2017	1185
3	BPCL	November 9, 2001 - March 31, 2017	11307
4	COALINDIA	August 5, 2011 - March 31, 2017	4014
5	EICHERMOT	September 10, 2014 - March 31, 2017	1704
6	GAIL	September 26, 2003 - March 31, 2017	9897
7	HINDPETRO	November 9, 2001 - March 31, 2017	11307
8	HINDUNILVR	November 9, 2001 - March 31, 2017	11307
9	IBULHSGFIN	November 28, 2014 - March 31, 2017	1554
10	INFRATEL	September 28, 2015 - March 31, 2017	933
11	IOC	September 26, 2003 - March 31, 2017	9897
12	MARUTI	July 09, 2003 - March 31, 2017	10065
13	NTPC	November 5, 2004 - March 31, 2017	9048
14	RELIANCE	November 9, 2001 - March 31, 2017	11307
15	TATASTEEL	November 9, 2001 - March 31, 2017	11307
16	TCS	August 25, 2004 - March 31, 2017	9201
17	ULTRACEMCO	December 29, 2006 - March 31, 2017	7434
18	ZEEL	September 15, 2006 - March 31, 2017	7645