Hedge Ratio Estimation & Hedging Effectiveness of stock and index futures in India

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Abstract

This paper investigates the hedging effectiveness of 21 stock and nifty futures contracts traded at NSE for the period Jan 2000 (Nov 2001 for stocks) to Nov 2006. Hedge ratios have been estimated using a host of measures ranging from naïve and OLS approaches to sophisticated methods like Multivariate GARCH. To make the comparison meaningful, hedge ratios were estimated on out of sample data in each of these cases. Besides strategies requiring higher frequency of rebalancing the portfolio were saddled with a penalty term which approximates the transaction cost. The hedge giving the least variance (out of 11 possible combinations) has been selected as the optimum one. Contrary to the general perception, I find that use of MGARCH does not yield superior performance (evidenced by lower portfolio volatilities) than either time-invariant or rolling OLS hedges. However in case of in-sample hedge ratios, MGARCH was found to be the clear winner.

Key words: Hedging Effectiveness, Multivariate GARCH, Stock Futures, Index Futures

JEL Classification: G13 G15

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1.0 Introduction & Overview of Literature

A hedge is effective if the price movements of the hedged item and the hedging derivative roughly offset each other. In case of financial assets like stocks and index, futures have been a preferred hedge (as against options) due to its higher liquidity and lower cost. The academicians and practitioners, however, have no consensus as to which method of estimating the hedge ratios gives the optimum hedge. Off late, sophisticated time-varying models such as Multivariate GARCH have been seen making rounds in the academic literature (for ex. Brooks, Henry and Persand (2002)).

Looking at the literature available, there has been much empirical work into the calculation of optimal hedge ratios. Studies which investigate measures of hedging effectiveness, using the simple Ordinary Least Squares Regression (OLS) for estimating hedge ratios are technically inadequate since it suffers from the problem of serial correlation in the OLS residuals and the heteroskedasticity often encountered in cash and futures price series. To counter the problem of changing variances of index futures and stock index prices, a number of papers measure optimal hedge ratios via autoregressive conditional heteroskedastic processes which allow for the conditional variances of spot and futures prices to vary over time. Myers and Thompson (1989) and Baillie and Myers (1991), for example, argue that asset prices are characterized by time-varying covariance matrices. As news about spot and futures prices arrives to the market in discrete bunches, the conditional covariance matrix, and hence the optimal hedging ratio becomes time-varying. (Park and Switzer, 1995 and Butterworth and Holmes, 2001)

Similarly, Brooks, Henry and Persand (2002) compare the effectiveness of hedging on the basis of hedge ratios derived from multivariate GARCH specification and other simpler techniques. Comparing on the basis of both variance and Minimum Capital Risk Requirement (MCRR), they find MGARCH based specifications outperform unhedged and naively hedged positions.

2.0 Methodology

The starting point for comparison is a position of no hedge (zero hedge).

$$h = 0 \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Various methods are considered in the order of increasing complexities for estimating hedge ratios. The easiest and most intuitively appealing strategy, involves the hedger taking up a futures position that is equal in magnitude, but opposite in sign to the spot market position, i.e. h = -1. If proportionate price changes in the spot market match exactly those in the futures market the price risk will be eliminated. However, in practice, it is unlikely for a perfect correlation between spot and future returns to exist, and hence the optimal hedge ratio will definitely differ from –1.

$$h = -1 \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Next approach considered is the OLS method. In this case, the hedge ratio is a constant number.

$$\Delta S_t = \alpha + \beta \Delta F_t + \varepsilon_t \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

However, this method works only if the conditional variance-covariance matrix is time-invariant and if spot and futures prices are not cointegrated. Since both these conditions can seldom be satisfied, plain OLS based hedge is not efficient.

If one still wants to persist with OLS, the efficiency of hedge ratio can be improved by performing rolling regressions. This allows the hedge ratio to vary over time. The critical issue is of deciding the window period and the period for forecast. In this period of forecast, the beta estimated for the time-sliding window would be kept constant. Essentially, it is the out of sample forecast which is meaningful rather than in sample estimation. Accordingly, in this paper, I have taken eight different combinations.

Table 1: Various combinations for Rolling OLS hedge

Combination	Window period	Period of forecast
(100,100)	Past 100 days of data	Constant beta for next 100 days
(100,88)	Past 100 days of data	Constant beta for next 88 days
(100,66)	Past 100 days of data	Constant beta for next 66 days
(100,44)	Past 100 days of data	Constant beta for next 44 days
(100,22)	Past 100 days of data	Constant beta for next 22 days
(100,10)	Past 100 days of data	Constant beta for next 10 days
(100,5)	Past 100 days of data	Constant beta for next 5 days
(100,1)	Past 100 days of data	Time-varying beta

Since period for a typical near month futures contract is 22 days on average, multiples of 22 has been considered as period of forecast. At the same time, higher frequency of 10 days and 5 days (approximating 2 weeks and 1 week respectively) have also been considered.

The next method considered is the Multivariate GARCH. Several MGARCH formulations have been proposed in the literature, including the VECH, the diagonal VECH and the BEKK models[1]. In this paper, I have followed the BEKK model proposed by Engle and Kroner (1995) as it successfully addresses the difficulty with VECH of ensuring the variance-covariance matrix as always positive definite. BEKK is represented as

$$H_t = W'W + A'H_{t-1}A + B'\Xi_{t-1}\Xi'_{t-1}B \qquad \ldots \quad \ldots \quad \ldots \quad (4)$$

where W, A and B are 3x3 matrices of parameters. These matrices being diagonal, give a total of 9 estimates. Data for 100 days has been used as window period on which a 22 day forecast is obtained. Though the forecast period is 22 days, the strategy requires changing the position on daily basis depending upon the predicted time-varying hedge ratio.

For evaluating the out sample hedge ratios, variances have been used. The best method is the one which offers the least variance. In order to penalize for the cost involved in

[1] Kroner and Ng (1998) for a detailed discussion

frequent rolling, an additional term has been added to the portfolio returns where the frequency of rebalancing has been lower than 22 days.

$$\lambda_t = 0.01 * \left| F_t h_t - F_{t-1} h_{t-1} \right| \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

where F represents stock/index futures closing price and h, the hedge ratio. Transaction cost has been assumed to be 1%.

3.0 Data and results

Analysis has been done for both stock and index returns. The starting period for index futures has been 12 January 2000, while for individual stock futures it varies from 9 November 2001 to 14 November 2001. The ending period has been uniformly set as 28 November 2006. Only those stocks which had data for all these period has been considered for this analysis, which left me with nifty and 21 stocks. Given the non-stationary nature of data, log returns have been used for all regressions. Table 2 and 3 give the descriptive statistics for spot and futures prices.

Table 4 and 5 give the mean returns for the portfolio (along with t statistic) under various strategies. Very few cases have mean returns different from zero. Table 6 and 7 indicate comparative hedging effectives with and without transaction cost. When a penalty term of 1% is included, only six cases had MGARCH giving the best (i.e. lowest) variance. Comparing this with in-sample data, (refer Table 8), about 11 cases (out of 22) favour MGARCH indicating that MGARCH performs better in in-sample analysis. If we were to club both (100, 1) (i.e. using past 100 days of data for OLS to predict the next day) and MGARCH together; the favourable cases are 9 and 15 out of 22 for out-sample and in-sample cases respectively.

When the choices were restricted to naïve hedge (h = -1), (100,1) and MGARCH (all out-sample), the results were 9, 6 and 7 respectively. If viewed as time-invariant versus time-varying hedge strategies the split is 9:13. Thus in case of out-sample analysis, one cannot

generalize that time-varying hedge ratio performs better than the time-invariant ones. Interestingly, for Nifty, among all combinations, rolling hedge of (100,1) was the clear winner in all cases.

4.0 Conclusion

In this paper, I have estimated hedge ratios using various strategies ranging from naïve hedge (h = -1), OLS, rolling OLS to Multivariate GARCH. Using six years of data for nifty and five years for 21 stocks, 11 different combinations of out-sample (and in-sample) analysis was conducted. For in-sample analysis, MGARCH clearly outperformed others in terms of least variance. However, for out-sample analysis, the verdict was split between time-invariant hedge (naïve hedge) and time-varying varieties (Rolling OLS (100,1) and MGARCH). Thus an important outcome of this paper has been that sophisticated methods like MGARCH cannot be pushed through as a panacea for all hedging exercises involving futures.

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Table 2: Descriptive Statistics – Spot Prices

	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	JB Stat	Prob	Obs
ACC	352.252	259.100	1109.000	129.450	250.472	1.387	3.827	468.721	0.000	1343
BAJAJ	1176.128	927.750	3269.250	358.400	795.550	1.094	2.920	266.276	0.000	1334
BHEL	781.503	562.750	2527.800	132.400	694.892	1.170	3.135	307.213	0.000	1342
BPCL	341.319	350.625	522.900	171.900	82.670	-0.200	2.184	45.832	0.000	1330
CIPLA	650.009	641.550	1398.650	191.200	369.789	0.250	1.519	136.997	0.000	1345
REDDY	959.336	905.550	1683.750	633.750	223.612	0.932	3.059	194.905	0.000	1345
GRASIM	1015.109	1082.050	2806.900	257.550	645.182	0.737	2.960	121.638	0.000	1343
GUJAMB	213.390	199.000	462.250	59.050	108.571	0.568	2.393	92.945	0.000	1345
HINDAL	762.713	727.050	1472.600	114.650	441.626	-0.088	1.612	103.682	0.000	1271
HLL	181.264	176.650	293.750	106.150	39.631	0.505	2.689	62.672	0.000	1345
HDFC	769.404	661.200	1659.600	313.850	316.300	0.818	2.718	144.493	0.000	1258
ITC	766.297	703.800	1940.100	115.450	437.260	0.285	2.506	31.863	0.000	1345
INFOSY	3248.461	3114.750	5886.700	1352.250	1138.150	0.323	2.052	73.840	0.000	1345
MTNL	131.712	131.400	219.800	82.250	22.110	0.730	4.886	318.214	0.000	1343
M&M	362.923	426.275	840.550	79.600	210.400	-0.003	1.699	94.776	0.000	1344
RANBAX	766.294	830.700	1269.350	320.250	258.406	-0.198	1.665	108.563	0.000	1345
RIL	543.329	503.450	1304.500	219.800	264.469	0.959	3.126	206.906	0.000	1345
SATYAM	396.427	331.550	880.300	144.100	192.138	0.948	2.721	205.952	0.000	1345
SBI	545.700	487.800	1293.050	170.400	262.632	0.394	2.092	80.965	0.000	1345
TPOWER	295.652	309.700	594.700	94.400	154.562	0.161	1.677	103.951	0.000	1345
TTEA	436.811	370.850	1008.150	147.650	259.474	0.574	1.906	141.085	0.000	1345
NIFTY	1750.827	1481.350	4015.950	854.200	806.156	1.113	3.190	348.713	0.000	1677

Table 3: Descriptive Statistics – Futures Prices

	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	JB Stat	Prob	Obs
ACC	361.377	261.050	1185.300	129.850	262.161	1.391	3.831	476.907	0.000	1358
BAJAJ	1192.161	931.400	3288.550	357.850	807.298	1.052	2.792	251.324	0.000	1349
BHEL	800.775	566.350	2654.750	133.750	715.205	1.151	3.057	299.606	0.000	1357
BPCL	341.041	349.600	527.900	172.000	81.808	-0.180	2.219	41.478	0.000	1345
CIPLA	647.634	636.775	1406.950	189.600	371.870	0.266	1.520	140.152	0.000	1360
REDDY	959.115	904.725	1694.450	635.100	224.315	0.941	3.065	200.953	0.000	1360
GRASIM	1035.868	1084.850	2819.550	258.450	667.584	0.775	2.998	135.814	0.000	1358
GUJAMB	212.994	196.975	464.350	58.950	108.244	0.585	2.421	96.580	0.000	1360
HINDAL	756.635	719.650	1491.800	115.300	443.919	-0.065	1.597	106.300	0.000	1286
HLL	181.874	177.525	291.500	106.400	39.909	0.468	2.608	58.321	0.000	1360
HDFC	778.370	663.450	1660.800	314.300	326.900	0.840	2.747	153.059	0.000	1273
ITC	759.971	705.250	1947.900	115.650	438.138	0.288	2.481	34.027	0.000	1360
INFOSY	3239.422	3094.625	5926.000	1351.500	1138.126	0.343	2.063	76.368	0.000	1360
MTNL	132.159	132.000	222.250	82.900	22.217	0.771	5.023	365.955	0.000	1358
M&M	368.011	429.500	853.500	79.750	214.569	0.038	1.789	83.409	0.000	1359
RANBAX	763.515	832.675	1263.300	320.800	260.367	-0.178	1.649	110.600	0.000	1360
RIL	553.197	508.650	1307.150	220.350	274.725	0.966	3.102	212.054	0.000	1360
SATYAM	397.847	334.525	878.250	143.600	191.698	0.947	2.748	206.841	0.000	1360
SBI	556.078	493.750	1369.750	171.200	273.923	0.495	2.381	77.288	0.000	1360
TPOWER	298.733	313.075	614.250	95.050	155.928	0.156	1.685	103.499	0.000	1360
TTEA	441.256	376.975	1018.450	148.100	260.763	0.552	1.882	139.890	0.000	1360
NIFTY	1748.076	1480.550	4018.650	855.400	804.481	1.119	3.216	353.004	0.000	1677

Table 4: Hedging Effectiveness – Mean of portfolio returns

	h = 0	h = -1	(100,100)	(100,88)	(100,66)	(100,44)	(100,22)	(100,10)	(100,5)	(100,1)	MGARCH
ACC	0.7098	-0.0091	0.0219	0.0490	0.0420	0.0222	0.0203	-0.0425	-0.0407	-0.0424	-0.0691
	2.73	-0.17	0.36	0.74	0.67	0.36	0.33	-0.71	-0.68	-0.71	-1.19
BAJAJ	1.7104	-0.0169	0.0406	0.0805	0.0551	0.0488	0.0377	-0.1356	-0.1400	-0.1395	-0.3303
	2.05	-0.08	0.16	0.32	0.22	0.20	0.15	-0.56	-0.58	-0.58	-1.43
BHEL	1.7468	-0.0001	0.0799	0.0828	0.0801	0.0871	0.0840	-0.0524	-0.0546	-0.0526	-0.2838
	2.81	0.00	0.44	0.47	0.45	0.49	0.47	-0.29	-0.30	-0.30	-1.56
BPCL	0.1393	-0.0035	0.0242	0.0203	0.0245	0.0100	0.0033	-0.0666	-0.0629	-0.0631	-0.1949
	0.59	-0.04	0.29	0.23	0.30	0.12	0.04	-0.82	-0.77	-0.77	-2.46
CIPLA	-0.5963	-0.0006	0.0494	0.0007	0.0055	0.0111	-0.0183	-0.1192	-0.1168	-0.1073	-0.2475
	-0.67	-0.01	0.43	0.01	0.05	0.11	-0.17	-1.12	-1.09	-1.01	-2.01
REDDY	-0.2617	-0.0026	0.0203	-0.0737	-0.0285	-0.0643	-0.0481	-0.2145	-0.2152	-0.2190	-0.1496
	-0.32	-0.02	0.11	-0.37	-0.14	-0.32	-0.24	-1.10	-1.11	-1.14	-0.86
GRASIM	1.8129	-0.0137	0.0583	0.0577	0.1023	0.0634	0.0572	-0.1131	-0.1138	-0.1140	-0.2947
	2.52	-0.09	0.35	0.35	0.61	0.38	0.35	-0.69	-0.69	-0.69	-1.74
GUJAMB	-0.0143	-0.0001	0.0173	0.0146	0.0155	0.0129	0.0113	-0.0221	-0.0207	-0.0347	-0.0329
	-0.04	0.00	0.44	0.38	0.40	0.34	0.29	-0.58	-0.54	-0.87	-0.85
HINDAL	-0.3658	-0.0020	-0.1110	-0.0894	-0.0712	-0.1141	-0.1045	-0.2286	-0.2323	-0.2346	-0.1204
	-0.33	-0.01	-0.68	-0.58	-0.46	-0.68	-0.62	-1.30	-1.32	-1.33	-0.90
HLL	0.0157	-0.0009	0.0067	0.0079	0.0081	0.0105	0.0149	-0.0147	-0.0142	-0.0130	-0.0350
	0.16	-0.03	0.21	0.24	0.24	0.33	0.46	-0.45	-0.44	-0.41	-1.12
HDFC	0.7439	-0.0091	-0.0095	0.0061	-0.0102	0.0283	0.0460	-0.0938	-0.0849	-0.0894	-0.3468
	1.31	-0.06	-0.06	0.04	-0.06	0.18	0.30	-0.60	-0.54	-0.57	-0.75
ITC	-0.3584	0.0009	-0.1868	-0.1571	-0.2031	-0.1685	-0.1657	-0.2812	-0.2650	-0.2464	-0.1047
	-0.26	0.01	-0.71	-0.65	-0.76	-0.64	-0.63	-1.00	-0.98	-0.96	-0.80
INFOSY	-0.5959	-0.0133	-0.1101	-0.0168	-0.2067	-0.2023	-0.1796	-0.7752	-0.7731	-0.7750	-0.7641
	-0.15	-0.03	-0.21	-0.04	-0.39	-0.39	-0.34	-1.45	-1.45	-1.46	-1.75
MTNL	0.0003	-0.0001	-0.0036	-0.0010	-0.0001	-0.0018	-0.0001	-0.0254	-0.0261	-0.0249	-0.0426
	0.00	-0.01	-0.16	-0.04	0.00	-0.08	0.00	-1.16	-1.19	-1.14	-1.86
M&M	0.5457	-0.0061	0.0266	0.0158	0.0369	0.0187	0.0352	-0.0306	-0.0273	-0.0308	-0.0328
	1.50	-0.09	0.37	0.22	0.51	0.26	0.49	-0.43	-0.38	-0.43	-0.46
RANBAX	-0.2234	-0.0003	0.0420	0.0104	0.0740	0.0201	0.0292	-0.0851	-0.0804	-0.0812	-0.1066
	-0.37	0.00	0.39	0.10	0.64	0.19	0.27	-0.80	-0.76	-0.77	-0.99
RIL	0.7331	-0.0096	0.0180	0.0083	0.0172	0.0126	0.0113	-0.0733	-0.0713	-0.0691	-0.1834
	2.01	-0.15	0.26	0.12	0.25	0.19	0.17	-1.07	-1.05	-1.02	-2.72
SATYAM	0.2197	-0.0021	-0.0096	0.0034	0.0106	-0.0027	-0.0012	-0.0776	-0.0784	-0.0741	-0.0701
	0.53	-0.04	-0.16	0.06	0.18	-0.04	-0.02	-1.29	-1.31	-1.25	-1.21
SBI	0.8140	-0.0089	0.0440	0.0666	0.0610	0.0416	0.0393	-0.0454	-0.0453	-0.0448	-0.1688
	2.51	-0.11	0.54	0.82	0.75	0.51	0.49	-0.56	-0.56	-0.55	-2.08
TPOWER	0.3373	0.0016	0.0260	0.0339	0.0283	0.0367	0.0468	-0.0179	-0.0198	-0.0247	-0.1315
	1.67	0.02	0.36	0.47	0.40	0.50	0.65	-0.25	-0.28	-0.35	-1.87
TTEA	0.4236	-0.0009	0.0149	0.0169	0.0259	0.0162	0.0163	-0.0430	-0.0443	-0.0433	-0.1593
	1.56	-0.01	0.19	0.23	0.34	0.21	0.21	-0.57	-0.59	-0.57	-2.09
NIFTY	1.3933	0.0073	0.1979	0.1764	0.2220	0.2133	0.2142	0.0293	0.0162	0.0192	-0.5843
	2.04	0.04	1.19	1.02	1.30	1.27	1.27	0.18	0.10	0.12	-3.35

Notes: 1.The figures against the stock / index name indicates the mean; while the figure below is the t-statistic

2. The last strategies (100,10) (100,5) (100,1) and MGARCH include 1% transaction cost

3. All combinations included above are out of sample estimations

Table 5: Hedging Effectiveness – Mean of portfolio returns

	(100,10) No Cost	(100,5) No Cost	(100,1) No Cost	MGARCH No Cost	MGARCH(In Sample) No Cost	MGARCH(In Sample Full cost)
ACC	0.0128	0.0141	0.0127	0.0310	0.0299	-0.0698
	0.21	0.24	0.21	0.54	0.54	-1.29
BAJAJ	0.0503	0.0441	0.0459	0.1170	0.0232	-0.3107
	0.21	0.18	0.19	0.48	0.11	-1.44
BHEL	0.0739	0.0724	0.0754	0.0347	0.0085	-0.2647
	0.41	0.40	0.42	0.19	0.05	-1.57
BPCL	-0.0072	-0.0039	-0.0042	-0.0156	-0.0421	-0.1910
	-0.09	-0.05	-0.05	-0.18	-0.50	-2.27
CIPLA	-0.0282	-0.0257	-0.0172	0.0894	0.1552	-0.3207
	-0.27	-0.24	-0.16	0.70	1.24	-2.58
REDDY	-0.0666	-0.0676	-0.0735	0.1160	-0.0167	-0.1501
	-0.34	-0.35	-0.39	0.64	-0.10	-0.91
GRASIM	0.0507	0.0494	0.0479	0.0277	0.0440	-0.2797
	0.31	0.30	0.29	0.16	0.28	-1.78
GUJAMB	0.0113	0.0130	-0.0009	-0.0507	-0.0011	-0.0340
	0.29	0.34	-0.02	-0.89	-0.03	-0.91
HINDAL	-0.1104	-0.1123	-0.1144	-0.8199	-0.0125	-0.1259
	-0.65	-0.66	-0.67	-0.76	-0.09	-0.88
HLL	0.0115	0.0120	0.0127	-0.0125	0.0070	-0.0355
	0.35	0.37	0.40	-0.28	0.23	-1.19
HDFC	0.0271	0.0368	0.0306	-0.0594	0.5546	-0.4385
	0.17	0.23	0.20	-0.36	1.28	-1.01
ITC	-0.1762	-0.1606	-0.1442	-1.1929	-0.0031	-0.1030
	-0.65	-0.62	-0.59	-0.83	-0.03	-0.84
INFOSY	-0.2205	-0.2218	-0.2202	-1.3320	-0.0341	-0.8187
	-0.42	-0.43	-0.43	-1.03	-0.08	-1.92
MTNL	-0.0009	-0.0017	-0.0005	-0.0039	-0.0009	-0.0463
	-0.04	-0.08	-0.02	-0.14	-0.04	-1.98
M&M	0.0332	0.0364	0.0327	0.0608	0.0219	-0.0328
	0.47	0.51	0.46	0.80	0.33	-0.49
RANBAX	0.0219	0.0255	0.0239	-0.0306	-0.0061	-0.1067
	0.20	0.24	0.23	-0.26	-0.06	-1.04
RIL	0.0067	0.0086	0.0105	0.0264	0.0301	-0.1768
	0.10	0.13	0.16	0.37	0.47	-2.80
SATYAM	-0.0044	-0.0053	-0.0010	0.0414	-0.0024	-0.0744
	-0.07	-0.09	-0.02	0.70	-0.04	-1.36
SBI	0.0372	0.0378	0.0366	0.1039	0.0367	-0.1663
	0.46	0.46	0.45	1.16	0.49	-2.20
TPOWER	0.0326	0.0302	0.0251	0.0271	-0.0095	-0.1260
	0.45	0.42	0.35	0.40	-0.15	-1.91
TTEA	0.0210	0.0199	0.0203	0.0194	0.0125	-0.1540
	0.28	0.26	0.27	0.25	0.18	-2.16
NIFTY	0.2188	0.2083	0.2063	0.1733	0.1519	-0.5821
	1.31	1.25	1.24	1.00	0.89	-3.42

Table 6: Out-sample evaluation of strategies (including transaction costs)

	h = 0	h = -1	(100,100)	(100,88)	(100,66)	(100,44)	(100,22)	(100,10)	(100,5)	(100,1)	MGARCH
ACC	90.396	4.035	4.707	5.510	4.799	4.721	4.579	4.482	4.414	4.375	4.202
BAJAJ	928.896	65.450	75.000	78.798	75.980	75.065	73.066	71.781	70.919	70.271	65.831
BHEL	518.335	37.978	40.011	38.839	38.445	39.164	39.113	39.643	39.753	39.055	40.887
BPCL	74.513	10.069	8.575	8.758	8.220	8.310	8.201	8.189	8.221	8.153	7.719
CIPLA	1054.369	15.429	16.380	13.462	14.095	13.722	13.861	14.163	14.154	14.148	18.777
REDDY	907.784	37.654	40.394	50.185	47.540	48.722	48.056	47.156	46.529	45.775	37.293
GRASIM	693.121	32.511	33.954	34.060	33.859	33.801	33.469	33.655	33.669	33.507	35.493
GUJAMB	135.932	1.902	1.890	1.860	1.849	1.831	1.828	1.819	1.822	1.988	1.871
HINDAL	1517.671	25.024	31.512	27.794	27.523	33.005	32.854	36.242	36.243	36.206	21.020
HLL	12.967	1.288	1.327	1.316	1.395	1.294	1.306	1.311	1.304	1.280	1.201
HDFC	402.543	26.922	29.356	28.073	29.051	28.537	27.895	28.662	28.522	28.025	249.595
ITC	2585.085	20.168	86.879	72.561	86.787	85.434	85.884	98.396	90.412	81.160	21.060
INFOSY	22192.08	246.95	353.64	245.69	341.69	333.26	338.19	354.93	352.97	348.66	237.420
MTNL	13.119	0.687	0.628	0.608	0.624	0.608	0.605	0.597	0.598	0.592	0.648
M&M	178.597	5.883	6.389	6.521	6.283	6.654	6.360	6.332	6.322	6.269	6.324
RANBAX	501.351	14.376	14.765	14.550	16.165	14.175	14.296	14.194	14.000	13.887	14.387
RIL	178.398	5.385	5.742	5.755	5.732	5.687	5.734	5.804	5.747	5.693	5.673
SATYAM	227.082	4.040	4.465	4.390	4.406	4.565	4.548	4.497	4.479	4.351	4.137
SBI	140.753	8.292	8.190	8.224	8.031	8.107	8.051	8.081	8.201	8.142	8.165
TPOWER	54.683	6.718	6.614	6.487	6.194	6.798	6.439	6.441	6.273	6.316	6.177
TTEA	98.535	7.084	7.337	6.967	7.056	7.230	7.199	7.106	7.109	7.066	7.245
NIFTY	779.549	52.551	43.779	45.325	45.165	44.118	44.678	43.836	43.994	43.405	47.993

Table 7: Out-sample evaluation of strategies with no transaction costs

	h = 0	h = -1	(100,100)	(100,88)	(100,66)	(100,44)	(100,22)	(100,10)	(100,5)	(100,1)	MGARCH
ACC	90.396	4.035	4.707	5.510	4.799	4.721	4.579	4.496	4.429	4.395	4.095
BAJAJ	928.896	65.450	75.000	78.798	75.980	75.065	73.066	71.849	71.105	70.495	73.819
BHEL	518.335	37.978	40.011	38.839	38.445	39.164	39.113	39.885	40.005	39.285	41.061
BPCL	74.513	10.069	8.575	8.758	8.220	8.310	8.201	8.217	8.237	8.175	9.000
CIPLA	1054.369	15.429	16.380	13.462	14.095	13.722	13.861	13.880	13.831	13.848	20.242
REDDY	907.784	37.654	40.394	50.185	47.540	48.722	48.056	46.475	45.793	45.063	41.448
GRASIM	693.121	32.511	33.954	34.060	33.859	33.801	33.469	33.762	33.799	33.629	38.009
GUJAMB	135.932	1.902	1.890	1.860	1.849	1.831	1.828	1.851	1.854	1.912	4.050
HINDAL	1517.671	25.024	31.512	27.794	27.523	33.005	32.854	33.758	33.788	33.774	1355.473
HLL	12.967	1.288	1.327	1.316	1.395	1.294	1.306	1.315	1.307	1.288	2.490
HDFC	402.543	26.922	29.356	28.073	29.051	28.537	27.895	28.480	28.378	27.942	30.930
ITC	2585.085	20.168	86.879	72.561	86.787	85.434	85.884	91.328	83.656	74.844	2594.754
INFOSY	22192.08	246.95	353.64	245.69	341.69	333.26	338.19	335.15	332.94	329.04	2082.05
MTNL	13.119	0.687	0.628	0.608	0.624	0.608	0.605	0.599	0.600	0.595	0.979
M&M	178.597	5.883	6.389	6.521	6.283	6.654	6.360	6.348	6.381	6.317	7.165
RANBAX	501.351	14.376	14.765	14.550	16.165	14.175	14.296	14.167	14.039	13.929	17.441
RIL	178.398	5.385	5.742	5.755	5.732	5.687	5.734	5.776	5.726	5.686	6.288
SATYAM	227.082	4.040	4.465	4.390	4.406	4.565	4.548	4.428	4.407	4.308	4.392
SBI	140.753	8.292	8.190	8.224	8.031	8.107	8.051	8.106	8.238	8.180	9.886
TPOWER	54.683	6.718	6.614	6.487	6.194	6.798	6.439	6.479	6.300	6.314	5.645
TTEA	98.535	7.084	7.337	6.967	7.056	7.230	7.199	7.125	7.126	7.091	7.206
NIFTY	779.549	52.551	43.779	45.325	45.165	44.118	44.678	43.775	43.925	43.385	47.739

Table 8: Comparative Results

	With Cost	No Cost	With Cost (In-Sample)	With Cost (Restricted Models)
h = 0	0	0	0	0
h = -1	9	11	5	9
(100,100)	0	0	0	0
(100,88)	2	3	1	0
(100,66)	1	1	0	0
(100,44)	0	0	0	0
(100,22)	0	1	0	0
(100,10)	1	0	1	0
(100,5)	0	0	0	0
(100,1)	3	5	4	6
MGARCH	6	1	11	7
	22	22	22	22

Notes: 1. In Table 6 and 7, the shaded box indicates the least variance portfolio.
2. The first two columns of Table 8 correspond to Table 6 and 7 respectively.
3. The third column gives the comparison with in-sample results
4. In case of fourth column, the comparison was between h=-1; (100,1) and MGARCH.
5. In all four cases, best hedge for Nifty was given by (100,1) rolling OLS