WORKING PAPER 53

VOLATILITY AND ITS PERSISTENCE IN INDIAN STOCK MARKET : A CASE STUDY OF 30 SCRIPS

Prabir Kumar Mohanty
B. Kamaiah

INSTITUTE FOR SOCIAL AND ECONOMIC CHANGE
2000

Institute for Social and Economic Change (ISEC) is engaged in interdisciplinary research in analytical and applied areas of the social sciences, encompassing diverse aspects of development. ISEC works with central, state and local governments as well as international agencies by undertaking systematic studies of resource potential, identifying factors influencing growth and examining measures for reducing poverty. The thrust areas of research include state and local economic policies, issues relating to sociological and demographic transition, environmental issues and fiscal, administrative and political decentralization and governance. It pursues fruitful contacts with other institutions and scholars devoted to social science research through collaborative research programmes, seminars, etc.

The Working Paper Series provides an opportunity for ISEC faculty, visiting fellows and PhD scholars to discuss their ideas and research work before publication and to get feedback from their peer group. Papers selected for publication in the series present empirical analyses and generally deal with wider issues of public policy at a sectoral, regional or national level. These working papérs undergo review but typically do not present final research results, and constitute works in progress.

VOLATILITY AND ITS PERSISTENCE IN INDIAN STOCK MARKET: A CASE STUDY OF 30 SCRIPS

Prabir Kumar Mohanty *
B Kamaiah**

ABSTRACT

This paper applies Autoregressive Conditional Heteroskedasticity (ARCH) methodology to model volatility and its persistence based on daily returns (1992-96) of 30 blue-chip securities traded in Bombay Stock Exchange. The results of the study show that the variance of returns varies over time and that the ARCH and GARCH models capture the volatility persistence.

---

* UGC Research Fellow, Department of Economics, University of Hyderabad, Hyderabad-500 046

** Professor, Institute for Social and Economic Change (ISEC), Bangalore-560 072. A major part of this work was carried out when the first author was at ISEC as doctoral fellow. The authors thank Allen Roy, V N Venkatesha and Krishna Chandran for their help in the preparation of this paper. The authors also thank an anonymous referee for helpful comments and Professor V V N Somayajulu, Dr. M Nageswara Rao and Dr. K V Raju (Coordinator, Working Paper Series at ISEC) for encouragement and support.

I. Introduction:

Beginning with the mean variance analysis of portfolio and asset returns, volatility has become central to much of modern finance theory. In recent times, empirical work involving high-frequency financial time series data has focussed on volatility of asset returns, which calls for careful attention. It has been observed that the asset returns exhibit changes, which are not independent over time. Rather large changes tend to be followed by large changes of either sign - and small changes tend to be followed by small changes [Mandelbrot (1965)]. The same regularity has been observed by Fama (1965), and several others [for instance, French et al. (1987)]. Several factors have been held responsible for this behaviour of financial prices. These include trading and non-trading days in asset returns [Fama (1965)], leverage effects [Black (1976)], financial and economic crisis [Schwert (1989)]. Also, when prices of securities move together across the markets, a common set of factors influencing the markets have also been found to produce temporal variation in the variance of return distribution. Further, the presence of unconditional excess kurtosis in financial time series has also been identified in the literature to produce temporal variation in returns distribution.

Statistically speaking, the basic motivation for modelling temporal variation in variance of returns distribution has been drawn from the time varying second order moments. The basis for this has been the fact that a series may be stationary when unconditional variance is constant, but when the variance conditional upon the information set changes over time the series becomes non-stationary. For example, if security price follows an AR(1) process, the long-run variance is constant but the variance at time t depends on the variance at time t-1. Exploiting the idea of time varying variance, a class of models characterizing such conditional variance has emerged. These models, due to Engel (1982), are known as the Autoregressive Conditional Heteroskedasticity (ARCH) models. A typical ARCH model allows the conditional variance to depend upon the past squared residuals in that variance in period t is modelled as a constant plus a distributed lag on the squared residual terms from previous periods. An ARCH(q) specification involves q lagged residual terms and the order q of the formulation shows up to what period the shock persists. The ARCH formulations have several extensions. The most prominent of them has been the Generalized ARCH or GARCH model [Bollerslev (1986)], which explains variance by two distributed lags, one on past squared residuals to capture high-frequency effects and the second on lagged values of variance itself to capture long-term influences. Another logical development that follows ARCH modelling is the ARCH in Mean (ARCH-M) class of models [Engle et al.(1987)], which allows the mean of a return sequence to depend upon its own conditional variance. This can be interpreted as including risk into return generation process and is an implication of mean variance analysis underlying many asset pricing models.

The introduction of the ARCH model has inspired many researchers in financial economics to model volatility and examine its persistence over time. However, in India, with the exception of the study by Amanulla (1997), there have not been attempts to model volatility in the ARCH/ GARCH framework. Amanulla's study contrasted the traditional CAPM with the conditional CAPM when the security returns follow either ARCH or GARCH process. The present study attempts to model volatility applying the ARCH methodology to daily stock returns of 30 blue-chip securities traded in BSE during the period 1992-96. The plan of the paper is as follows. Section-II presents a brief overview of select works which applied the ARCH methodology to stock return; section-III covers the empirical analysis. Concluding remarks follow in section-IV.

II. A Brief Overview of Select Works:

Since Engle's (1982) influential contribution, ARCH methodology has been extensively used in characterizing stock returns variance and covariance. ARCH effects have generally been found to be highly significant in the securities market. The literature in this regard has been truly abundant. It may be pointless to review all the studies. Hence, we review here only select studies of major importance and relevance. Studies by Bodurtha and Mark (1991) and Attanasio (1991) employed higher order ARCH models in analyzing the portfolios of monthly NYSE stock returns and monthly excess return or S&P index respectively. These two studies show that variance of stock returns is systematically evoked by different announcements leading to a seasonal pattern in the conditional variance. Similarly, the well-known weekend effect could also make the variance (volatility) a time dependent stochastic process, which can be captured by higher order ARCH models. It has been contended that a lower order specification of ARCH models may fail to take into account such deterministic influence (as week-end effect) and might lead to spurious results [French et al. (1987), Nelson (1990), and Connolly (1989)]. There has, however, been no unanimity in respect of the exact length of lag (order) to be used in an ARCH specification. Another important issue relating to ARCH models is the issue of adjusting for ARCH effects in residuals. This has been highlighted in the literature [Morgan and Morgan (1987), Bera et al. (1988), Connolly (1989)]. For example, Morgan and Morgan (1987), in a study of the small firm effect, find that correcting for the conditional variance in returns from portfolios long in small firms and short in large firms reduces the estimates of market risk and increases the estimates of market risk respectively.

Apart from the applicability of ARCH methodology to model stock return data, it has been quite important to capture the persistence of time varying volatility parameter. Poterba and Summers (1986) hypothesise that for multi-period assets like stocks, shocks persist for a longer period. In such cases, a time varying risk premium is expected to explain the large fluctuations observed in the stock market. If volatility changes are only transitory, no significant adjustments to the risk premium would be made by the market. Using a two-step procedure, Poterba and Summers however found that shocks to the US stock market were only short-lived, with a half life of less than six months. Using a GARCH (1,1)-M model, Chou (1988) reported a different result on the persistence of volatility, with average half life for volatility shocks being about one year.

Formal tests for a unit root in variance have been performed by several authors and a null hypothesis of a unit root is not rejected. The presence of unit roots has been found in different studies such as French et al. (1987), who found unit root in the variance of the S & P daily index, Chou (1988), in the variance of NYSE value weighted index, Pagan and Schwert (1990) in the variance of US stocks. Apart from this, the degree of persistence in volatility shocks is also investigated in Engle and Mustafa (1992), who combined the Black-Scholes option pricing formula with a stochastic variance process modeled by an ARCH process. The GARCH (1,1) model for the volatility of the underlying security, inferred from the observed option prices, indicates very strong persistence in conditional variance. However, a lower persistence is reported after the October 1987 crash. Along this line Friedman and Laibson (1989) modified the ARCH model such that outliers or extremely large shocks, are allowed to have their dynamic effects. Interestingly, the results, based on Australian data, showed that ordinary shocks tend to persist longer than outliers. So GARCH models which do not distinguish outliers from ordinary shocks, tend to underestimate the persistence of ordinary shocks. Lamoureux and Lastrapes (1990) argued that the high degree of persistence in GARCH models might be due to a misspecification of variance equation by introducing dummy variables for deterministic shifts in the unconditional variance. They discovered that the duration of volatility shocks is substantially reduced. A similar point has been raised by Diebold (1986), who contended that the apparent existence of a unit root as in the IGARCH models may be the results of the shifts in regimes, which affect the level of unconditional variance.

Thus so far as the persistence of volatility is concerned, mixed empirical results have been found, which may shed light on the linkages between different modelling dichotomies and hence renders the examination of persistence of volatility as a scope for further research.

In India, there have been very few attempts to explain the volatility in the Indian stock market. A study conducted by Amanulla (1997), which used stocks traded in BSE and NSE, detected the presence of ARCH effect in security price movements and concluded that the capital asset pricing model (CAPM) with time varying conditional variance was better explaining than the traditional CAPM. But till date no serious attempt has been made to explain volatility in the ARCH framework. Thus, in light of very few studies undertaken for Indian stock market, we have made an attempt to apply

ARCH methodology to stock return data to carry out a detailed analysis of volatility in the market.

III. Empirical Analysis:

The present study formulates and estimates ARCH and GARCH models to model the volatility of 30 blue-chip scrips traded in the Bombay Stock Exchange. The data set contains daily returns (log price differentials) on securities for the period 1992 to 1996 (see the Appendix). Here it is assumed that the daily security return follows a first order autoregressive (AR(1)) process. Before estimating the ARCH / GARCH models to capture volatility, relevant diagnostic statistics are computed and presented in table 1. The coefficient of skewness, in no case equals to zero, and hence indicates that return distribution is skewed. The kurtosis for all the return distributions are greater than 3, thereby indicating leptokurtic distribution. The Bera-Jarqua(BJ) statistic, which exceeds critical chi-square value with 2 degrees of freedom in all cases, rejects the normality of the underlying distribution. To further analyze the behaviour of stock returns, Ljung-Box(LB) statistic are obtained to trace the presence of autocorrelation among residuals of the returns as well as squared residuals. As evident from the table, in most of the cases the presence of autocorrelation is significant, both for residuals as well as squared residuals. The Augmented Dicky-Fuller (ADF) test statistics indicate that the return series are stationary in nature. To sum up, stock returns are not identically and independently distributed. This may lead us to conclude that return variance process is time varying and heteroskedastic in nature and hence ARCH formulation would be appropriate.

After estimating the AR model and obtaining the residuals, the LM test is employed to test for the presence of

5th order ARCH disturbances in the squared residuals. We have consistently considered the order of the ARCH process to be 5. This however, may involve some arbitrariness. According to the test procedures, the TR^2 statistic (where T is the sample size and R^2 is the coefficient of determination) follows asymptotically a chi-squared distribution with degrees of freedom 5. These statistics are reported in table 1. It is observed from the table that in 24 out of 30 cases, the statistic is significantly higher, leading to rejection of the null hypothesis of 'no 5th order ARCH effects' at 5% and 1% levels except in the case of scrip no 15 where the null hypothesis is rejected at 10% level only. These results confirm the presence of ARCH effect in the log price differentials of the 30 securities investigated, implying that investment in these securities will result in increased estimated variance and therefore increased risk during the periods of unexpected shocks and diminishing risk during periods of relative stability.

The results obtained from the AR(1) model with disturbance term following ARCH (5) structure are reported in table 2. The constant term a_0 is found to be significant in most of the cases indicating that the returns process has a drift element. Further, most of the a_1 coefficients are found to be significant and less than one, thereby indicating stability in security return. Further, the a_1 coefficients exhibit daily serial autocorrelations and in this regard the result indicates that positive daily autocorrelations are more common than negative ones, as evidenced from the table.

The ARCH(5) models have been estimated by maximising the log likelihood function using an iterative procedure based on the method of BHHH. For given values of past realized investment returns, α_0 and α_i (i = 1 ..... 5) are estimated for total return on each of these securities.

These results are reported in table 2. The constant term α_0 for each scrip is found to be positive and significant in most of the cases, which indicates that the volatility of asset returns could also increase even in the absence of any influence during the period considered. The summation of α_i s is always less than one, indicating that the estimated variance is finite. Moreover, the lagged disturbance terms are understood here as measures of individual's intuition of working of the market based on information of previous periods. The coefficients of lagged disturbance terms contain information enough for an individual to make his own decision for investment based on the changes in the return of previous period. These coefficients represent the relative contribution of the previous period's shocks to the conditional variance in the current period. The coefficients reported show that in most of the cases (approximately 21 to 23 cases) these are significant at lags 1,2,3 and 4. The coefficients, from the market point of view may be interpreted as follows: the volatility of previous trading day is carried over to the current period and persisting over a period of three days in most of the cases as most of the coefficients are significant up to lag 4. For example, in the case of first scrip α_3 coefficient is 0.0553, which implies that about 5.53% of today's volatility is carried over to a period of next three days. It may be noted that if ARCH(i) is found to hold for a particular security while ARCH(j) is present in another security where j>i, then trading in the former security is relatively more myopic than the same in later. However, at lag=5 only 15 out of 30 cases report the coefficients to be significant, which shows a declining trend in the persistence of volatility. In other words, distant shocks to volatility are not significant in most of the cases.

Another essential point that may be noted here is that ARCH error structure and autoregressive parameter of the

$\{y_t\}$ process interact with each other so that volatility of $\{y_t\}$ is increasing in α_i and a_1. The explanation is intuitive. Any large shock in e_t will be associated with a persistently large variance; the larger is α_i the larger is the persistence. Moreover, the greater the autoregressive parameter a1, the more persistent is the volatility for any given change in y_t. Therefore, stronger the tendency for y_t to remain away from its mean the greater is the variance.

In addition to the ARCH (5) models, GARCH models at various lags have been estimated. The results of GARCH (1,1) model are reported in table 3. The GARCH (1,1) model incorporates another term - the one containing σ_{t-12}. It is considered to have information about the market structure in general as well as that information which plays an active part in influencing the price of the scrip considered. The results in our case exhibited that in 24 out of 30 scrips the GARCH(1,1) coefficients are found to be significant and positive, thus implying that the volatility is captured by GARCH(1,1) model. The GARCH model also conveys the important implications for persistence of variance, as represented by the sum of the coefficients of lagged squared disturbance (α) and that of past variance (β). The sum ($\alpha+\beta$) approaches to unity ($\alpha+\beta>0.8$) in 23 cases, which thus shows that volatility is persisting in most of the cases and the sum quantifies the degree of persistence. At the same time, it may be pointed out that in no case is the sum equal to unity, which implies that there is no random walk behaviour exhibited by conditional variance. This has a very important implication for the security return determination. In most of the cases, though the sum is near unity, with α small and β large, the conditional volatility will change slowly over time, in which case volatility may not generate a large bias. Therefore, it may be assumed to be constant and thus does not allow any large bias in security return. This is better explained by the estimation of GARCH(1,1)-M model where the square root of conditional variance is allowed to enter in the original AR(1) model. Thus, the coefficient δ represents the relation between stock return and volatility. However, the result reported in table 4 shows that only 6 out of 30 cases show significant δ coefficients and hence, the relationship between stock return and volatility is not strongly established.

IV. Concluding Remarks:

In this paper, ARCH and GARCH models have been employed to capture the time varying nature of variance of returns of 30 blue-chip securities traded in Bombay Stock Exchange. Using the daily data for the period 1992-96, it is shown that variances of total returns on most of the securities changed significantly over time. The results of ARCH(5) model reveal the time varying volatility as well as its persistence over time in most of the cases. However, the coefficients of GARCH(1,1) model show that volatility is changing only slowly over time. The implication of this finding is that the returns on securities may not be significantly affected by volatility changes.

APPENDIX

1. Data:

The data set consists of daily closing prices of 30 blue-chip scrips traded in Bombay Stock Exchange for the period 1992-96. The data have been collected from different issues of Stock Exchange Review, BSE. The scrips selected for the study are given below. For carrying out empirical analysis the price series are converted to return series in the following way:

$$y_{it} = \log(cp_{it}) - \log(cp_{it-1})$$

where y_{it} is the return on security i in period t, and cp_{it} is the closing price of security i at period t.

2. List of Scrips:

No.	Name of the Scrip	No.	Name of the Scrip
1	Arvind Mills	16	Indian Hotels Co.
2	Associated Cements	17	IPCL
3	Bajaj Auto	18	ITC
4	BHEL	19	Larsen & Toubro
5	BSES Ltd.	20	Mahindra & Mahindra
6	Colgate Palmolive	21	MTNL
7	Great Eastern Shipping	22	Nestle Ltd.
8	Glaxo India	23	Ranbaxy Laboratories
9	Gujurat Ambuja Cement	24	Reliance Industries
10	Grasim Industries	25	SBI
11	Hindustan Lever	26	SAIL
12	Hindalco Industries	27	Tata Chemicals
13	HPCL	28	TELCO
14	ICICI	29	TISCO
15	IDBI	30	Tata Petrochemicals

Table-1: Summary Statistics

Company	Skewness	Kurtosis	BJ[a]	LB(12)[b]	$LB^2(12)$[c]	ADF	LM[d]
1	-0.55	11.06	2897.96	25.31	326.68	-12.84	93.08
2	-2.33	35.80	49278.53	23.24	16.39	-11.62	27.23
3	0.19	25.01	21754.85	18.23	78.92	-13.06	47.23
4	-0.04	8.55	1012.96	36.89	108.74	-10.93	51.91
5	0.58	10.87	2839.97	32.77	424.01	-12.47	69.43
6	-1.39	23.53	19303.21	27.55	324.02	-14.38	59.82
7	0.47	26.50	24487.43	19.53	218.01	-13.52	56.34
8	-5.32	111.40	531988.51	38.60	0.99	-14.49	0.37
9	-7.77	170.70	1271700	22.54	317.01	-12.88	18.27
10	1.28	16.37	8326.41	35.69	365.34	-12.85	59.43
11	3.84	56.99	133489.21	89.03	201.58	-15.21	74.01
12	-2.25	83.14	288344.33	12.32	3.39	-12.42	1.88
13	-13.25	299.89	3205700	7.03	0.28	-11.18	0.01
14	-6.21	125.02	677631.31	4.56	0.01	-13.13	0.06
15	-0.20	9.72	562.26	8.76	10.47	-6.16	9.24
16	-3.00	53.41	115797.90	17.80	19.68	-12.37	15.44
17	-1.98	261.11	21036.71	16.01	46.79	-13.36	46.50

Company	Skewness	Kurtosis	BJ[a]	LB(12)[b]	LB²(12)[c]	ADF	LM[d]
18	-6.63	149.44	971163.35	19.66	52.20	-12.95	74.37
19	1.02	14.80	6464.63	47.16	503.0	-13.32	98.82
20	-2.37	43.41	74297.22	21.42	223.01	-13.27	43.23
21	- 0.38	7.20	604.16	31.06	367.81	-10.26	56.33
22	-2.35	60.75	150277.50	17.91	1.34	-14.16	0.87
23	-4.29	59.69	146302.43	25.66	1.71	-13.30	1.16
24	2.30	23.03	10780.73	38.58	72.06	-9.99	41.69
25	-4.63	96.01	386900.94	15.68	39.23	-13.42	64.69
26	0.08	15.54	2247.50	26.44	141.48	-10.83	69.71
27	-0.69	25.45	22754.37	46.47	54.96	-13.15	17.16
28	-2.85	50.32	102049.43	10.48	23.92	-12.79	18.70
29	0.35	12.23	3864.17	17.32	189.62	-13.22	36.26
30	-7.78	141.70	863634.03	19.23	131.23	-13.31	49.28

a Bera Jarqua Statistic, approximately distributed as central Chi-square(2) under the null hypothesis of normality in the underlying distribution of returns.

b Ljung - Box Statistic to test autocorrelation among residuals of returns.

c Ljung - Box Statistic to test autocorrelation among squared residuals of returns

d Lagrange Multiplier Test Statistic to test null hypothesis of no ARCH effect against alternative of ARCH effect. Critical values of Chi-square at 1%, 5% and 10% are 15.08, 11.07 and 9.23 respectively.

Table-2: Estimation of ARCH(5) Model

$$y_t = a_0 + a_1 y_{t-1} + e_t$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \ldots\ldots + \alpha_5 e_{t-5}^2$$

Company	a_0	a_1	α_0	α_1	α_2	α_3	α_4	α_5
1	-0.001	0.130*	0.003*	0.381*	0.124*	0.055	0.191*	0.187*
	(-1.77)	(3.62)	(14.03)	(7.25)	(3.76)	(1.93)	(6.88)	(8.57)
2	-0.002*	0.080*	0.006*	0.019	0.001	0.126*	0.107*	0.870*
	(-3.31)	(3.13)	(12.26)	(0.99)	(0.06)	(7.36)	(4.50)	(10.42)
3	-0.014*	-0.592*	0.007*	0.210*	0.098	0.223*	0.086*	0.050*
	(-15.59)	(-13.05)	(10.75)	(12.13)	(1.94)	(7.14)	(8.53)	(2.25)
4	0.003	-0.057	0.005*	0.370*	0.167*	0.177*	0.148*	0.150*
	(0.16)	(-1.44)	(10.41)	(6.99)	(5.45)	(5.18)	(3.81)	(4.38)
5	0.007	0.140*	0.002*	0.298*	0.222*	0.258*	0.003	0.007
	(0.08)	(4.04)	(17.32)	(8.57)	(7.56)	(6.87)	(0.225)	(0.58)
6	-0.003*	0.077*	0.001*	0.213*	0.018*	0.511*	0.054*	0.002*
	(-8.96)	(3.81)	(13.55)	(20.38)	(6.32)	(6.68)	(2.02)	(14.78)
7	0.001	-0.131*	0.009*	0.106*	0.012*	0.134*	0.424*	0.002*
	(1.90)	(-2.70)	(10.13)	(2.21)	(8.74)	(8.92)	(3.13)	(14.78)
8	-0.005	0.097	0.001*	0.119*	0.004	0.002	0.003	0.004
	(-0.30)	(1.97)	(89.66)	(4.60)	(0.65)	(0.23)	(0.19)	(1.57)
9	-0.020*	0.102*	0.009*	0.020*	0.023*	0.002	0.019*	0.491
	(-2.02)	(2.19)	(11.10)	(2.78)	(15.61)	(0.06)	(2.54)	(1.35)

Contd...

Company	a_0	a_1	α_0	α_1	α_2	α_3	α_4	α_5
10	-0.002	0.185*	0.001*	0.195*	0.038	0.283*	0.103*	0.001
	(-0.45)	(5.31)	(16.09)	(4.51)	(1.85)	(15.84)	(5.32)	(0.05)
11	0.001	0.142*	0.001*	0.262*	0.157*	0.184*	0.057*	0.218*
	(0.069)	(5.24)	(15.33)	(7.45)	(4.85)	(8.69)	(2.17)	(7.55)
12	-0.001	0.019	0.001*	0.001	0.017	0.492*	0.002	0.106*
	(-0.37)	(0.79)	(20.62)	(1.15)	(0.78)	(14.56)	(0.24)	(23.72)
13	-0.017	-0.524	0.020*	0.011	0.013	0.013	0.009	0.013
	(-1.02)	(-1.43)	(22.47)	(1.35)	(0.02)	(0.09)	(0.26)	(1.44)
14	-0.174	-0.311*	0.165	0.101	0.015	0.054	0.003	0.017
	(-1.78)	(2.97)	(1.63)	(0.77)	(0.02)	(1.49)	(0.03)	(0.19)
15	-0.082	-0.002*	0.002*	0.386*	0.173*	0.009	0.023	0.005
	(-1.16)	(-2.07)	(14.08)	(5.64)	(2.71)	(0.02)	(1.08)	(0.23)
16	-0.006*	-0.125*	0.002*	0.661*	0.116*	0.007	0.013*	0.169*
	(-9.64)	(-7.07)	(9.38)	(9.47)	(2.92)	(0.36)	(14.43)	(12.11)
17	-0.004	0.100*	0.005*	0.076*	0.081*	0.009*	0.159*	0.245*
	(-0.46)	(2.68)	(13.05)	(2.13)	(2.33)	(2.34)	(8.94)	(11.40)
18	-0.004	0.026*	0.004*	-0.010	0.082*	0.011*	0.011*	0.011*
	(-0.85)	(3.38)	(37.01)	(-1.28)	(2.17)	(20.05)	(44.09)	(40.46)
19	-0.010	0.093*	0.002*	0.343*	0.075*	0.119*	0.308*	0.003
	(-1.63)	(2.48)	(15.38)	(6.29)	(2.41)	(4.77)	(8.97)	(0.01)
20	-0.002	-0.003*	0.003*	0.131*	0.069*	0.141*	0.002	0.173*
	(-0.07)	(-3.32)	(12.40)	(18.60)	(3.52)	(6.39)	(0.16)	(5.17)

Contd...

Company	a_0	a_1	α_0	α_1	α_2	α_3	α_4	α_5
21	-0.003	0.012*	0.003*	0.428*	0.119*	0.010	0.214*	0.092*
	(-0.42)	(3.31)	(10.02)	(8.66)	(2.75)	(0.43)	(8.01)	(2.77)
22	0.001	0.098*	0.004*	0.725*	0.008	0.133*	0.004	0.002
	(1.95)	(2.27)	(16.67)	(7.03)	(0.81)	(6.41)	(1.17)	(0.36)
23	-0.010*	-0.144*	0.001*	0.074*	0.542*	0.100*	0.138*	0.015
	(-6.77)	(-4.71)	(10.73)	(2.17)	(10.04)	(2.92)	(12.40)	(1.60)
24	-0.005	0.154*	0.002*	0.001	0.511*	0.097*	0.217*	0.481*
	(-0.07)	(5.33)	(5.18)	(0.01)	(21.26)	(2.73)	(5.21)	(9.31)
25	-0.096*	0.106*	0.188*	0.453	0.305*	0.402*	0.514*	0.670*
	(-2.56)	(7.57)	(11.28)	(1.79)	(2.72)	(3.06)	(2.77)	(2.04)
26	-0.002	-0.073*	0.003*	0.376*	0.295*	0.100*	0.058*	0.005
	(-1.94)	(-3.22)	(12.19)	(7.33)	(9.08)	(3.13)	(2.05)	(0.40)
27	-0.002*	0.270*	0.002*	0.408*	0.099*	0.054*	0.002	0.012
	(-5.40)	(12.16)	(19.51)	(23.68)	(5.19)	(2.21)	(0.02)	(1.12)
28	-0.004	0.038*	0.002*	0.497*	0.003*	0.111*	0.004	0.079*
	(-1.40)	(8.03)	(10.28)	(8.80)	(2.61)	(3.58)	(0.60)	(13.57)
29	-0.003	0.078*	0.006*	0.088*	0.303*	0.024*	0.019*	0.128*
	(-0.47)	(3.63)	(23.90)	(3.74)	(8.37)	(2.87)	(32.61)	(3.94)
30	-0.017*	-0.430*	0.003*	0.690*	0.365*	0.069*	0.014*	0.003
	(-12.86)	(-8.96)	(18.93)	(12.58)	(4.96)	(2.91)	(2.97)	(0.88)

*Figures in parentheses represent respective t-ratios. * significant at 5% level of significance.*

Table-3:
Estimation of AR(1) Model With GARCH(1,1) Process

$$y_t = a_0 + a_1 y_{t-1} + e_t$$

$$\sigma_t^2 = \omega + \alpha e_{t-1}^2 + \beta \sigma_{t-1}^2$$

Company	a_0	a_1	ω	α	β
1	-0.005	0.082*	0.004*	0.130*	0.837*
	(-0.63)	(2.53)	(9.79)	(11.39)	(94.14)
2	-0.030*	-0.104*	0.006	0.514*	0.333*
	(-5.09)	(-2.32)	(0.52)	(17.86)	(2.15)
3	-0.006	-0.050	0.009*	0.003*	0.943*
	(-0.39)	(-1.54)	(6.73)	(94.83)	(104.16)
4	-0.002	0.078*	0.004*	0.520*	0.408*
	(0.19)	(3.24)	(11.53)	(10.46)	(13.31)
5	0.004	0.136*	0.001*	0.275*	0.678*
	(0.49)	(3.75)	(10.42)	(12.67)	(37.64)
6	-0.001	-0.015*	0.102*	0.231*	0.652*
	(-0.49)	(-3.23)	(9.35)	(24.55)	(133.21)
7	-0.008	-0.023	0.002*	0.004*	0.976*
	(-0.67)	(-0.93)	(82.77)	(6.27)	(133.21)
8	-0.003	0.108*	0.001*	0.147*	0.277
	(-0.19)	(2.36)	(39.63)	(5.64)	(1.27)
9	-0.002	-0.043	0.105*	0.146*	0.773*
	(-1.28)	(-0.96)	(13.04)	(58.90)	(175.33)
10	-0.003	0.189*	0.002*	0.114*	0.825*
	(-0.07)	(5.95)	(7.42)	(6.61)	(42.29)
11	-0.001	0.151*	0.043*	0.284*	0.067*
	(-1.96)	(6.51)	(8.21)	(8.05)	(7.46)
12	-0.002	0.008*	0.007*	0.229*	0.724*
	(-0.17)	(3.20)	(7.33)	(7.98)	(23.48)
13	-0.001	-0.207*	0.007*	0.229*	0.724*
	(-0.27)	(-3.20)	(7.33)	(7.98)	(23.48)
14	-0.019	0.010	0.040	0.013*	0.151
	(-0.55)	(0.02)	(0.69)	(3.66)	(0.90)
15	-0.002	0.088	0.002*	0.386*	0.156
	(-1.92)	(0.92)	(7.91)	(6.03)	(1.83)

Contd...

Company	a_0	a_1	ω	α	β
16	-0.004* (-9.19)	-0.199* (-6.05)	0.003* (17.33)	0.190* (25.01)	0.671* (23.82)
17	-0.001 (-0.15)	0.016 (0.79)	0.002* (63.73)	0.001* (2.67)	0.976* (58.17)
18	-0.001 (-0.60)	0.004 (0.12)	0.003* (3.82)	0.006* (36.37)	0.887* (29.45)
19	-0.002 (-0.36)	0.073* (2.36)	0.002* (7.61)	0.142* (8.50)	0.833* (59.74)
20	-0.008 (-1.28)	-0.222* (-2.13)	0.001 (1.23)	0.127* (23.09)	0.735* (3.39)
21	-0.001* (-5.55)	-0.074* (-2.10)	0.001* (10.73)	0.276* (23.24)	0.657* (31.80)
22	-0.001 (0.12)	0.061 (1.92)	0.001 (1.01)	0.002 (1.02)	0.898* (9.13)
23	-0.001* (-5.55)	-0.324* (-15.32)	0.006* (11.86)	0.214* (21.75)	0.218* (24.59)
24	-0.001 (-1.03)	0.099* (3.52)	0.004* (7.04)	0.223* (7.24)	0.667* (39.89)
25	-0.001 (-0.29)	-0.005 (-0.30)	0.001* (17.73)	0.216* (27.40)	0.607* (33.55)
26	-0.002* (-2.75)	0.008 (0.25)	0.002* (9.58)	0.422* (11.24)	0.446* (12.89)
27	-0.004 (-0.41)	0.718* (4.76)	0.002* (9.58)	0.422* (11.24)	0.446* (12.89)
28	-0.011 (-1.96)	-0.204 (-1.73)	0.001 (1.15)	0.032* (20.65)	0.689* (2.51)
29	-0.042 (-0.48)	0.087* (2.47)	0.791* (14.06)	0.123* (10.25)	0.813* (18.43)
30	-0.004* (-18.12)	-0.355* (-28.45)	0.003* (11.36)	0.117* (3.25)	0.688* (67.16)

Figures in parentheses represent respective t-ratios.

** significant at 5% level of significance.*

Table-4: Estimation of GARCH(1,1) - M Model

$$y_t = a_0 + a_1 y_{t-1} + \delta \sigma_t^2 + e_t$$

Where, $\sigma_t^2 = \omega + \alpha e_{t-1}^2 + \beta \sigma_{t-1}^2$

Company	a_0	a_1	δ
1	0.031 (1.30)	0.040 (1.68)	-0.931 (-1.31)
2	-0.069* (-13.71)	0.376* (16.77)	0.455* (11.90)
3	0.215 (0.04)	0.406 (0.49)	-0.858 (-0.03)
4	-0.005 (-1.23)	-0.195* (-5.21)	0.182 (1.53)
5	-0.747 (-0.01)	0.289 (1.61)	0.513 (0.01)
6	0.020 (0.01)	0.263 (0.48)	-0.128 (-0.01)
7	0.037 (0.02)	0.235 (0.68)	-0.345 (-0.04)
8	-0.104* (-5.06)	0.356* (2.10)	0.795* (3.61)
9	0.143 (0.06)	0.051 (1.53)	-0.504 (-0.06)
10	-0.592 (-0.02)	0.031 (0.33)	0.534 (0.02)
11	-0.592 (-0.02)	0.205 (0.53)	-0.150 (-0.06)
12	0.489 (0.35)	0.471 (0.89)	-0.248 (-0.36)
13	0.566 (0.08)	0.149 (0.40)	-0.264 (-0.08)
14	0.973 (0.13)	0.069 (1.33)	-0.423 (-0.13)

Contd...

Company	a_0	a_1	δ
15	0.003*	-0.083*	0.014
	(2.45)	(-2.67)	(0.25)
16	-0.288	0.463	0.147
	(-0.07)	(1.20)	(0.01)
17	0.105*	-0.054*	-0.276*
	(14.83)	(-3.09)	(-14.93)
18	0.271	0.074*	-0.107
	(1.42)	(2.38)	(-1.21)
19	-0.011	0.213	-0.010
	(-0.07)	(0.49)	(-0.01)
20	-0.009*	-0.018	0.315*
	(-2.81)	(-0.44)	(2.61)
21	0.063	0.352	-0.416
	(0.14)	(1.25)	(-0.11)
22	-0.190	0.256	0.956
	(-1.44)	(0.92)	(1.11)
23	-0.452*	0.084*	0.114*
	(-2.73)	(2.77)	(2.71)
24	0.170	0.624*	-0.796
	(0.05)	(5.44)	(-0.05)
25	0.701	0.201	-0.206
	(0.27)	(0.81)	(-0.28)
26	-0.008*	0.256*	0.216*
	(-7.41)	(12.23)	(6.42)
27	0.132	0.385	-0.554
	(0.90)	(0.75)	(-0.06)
28	0.293	0.091*	-0.113
	(0.99)	(2.49)	(-1.11)
29	0.206	-0.466	-0.102
	(0.02)	(-1.04)	(-0.02)
30	-0.190	0.258	0.956
	(-1.44)	(0.92)	(1.11)

Figures in parentheses represent respective t-ratios.

** significant at 5% level of significance.*

References:

Amanulla, S (1997), "Indian Stock Market: Asset Price Behaviour and Stock Market Efficiency", Ph.D Dissertation, University of Hyderabad, Hyderabad.

Attanasio, O P (1991), "Risk, Time Varying Second Moments and Market Efficiency", Review of Economic Studies, 58, 479(494.

Bera, A K (1988), E Bubnys, and H Park (1988), "Conditional Heteroskedasticity in Market Model and Efficient Estimates of Betas", Financial Reviews, 23, 201(14.

Black, F (1976), "Studies in Stock Price Volatility Changes", Proceedings of American Statistical Association 171(81.

Bollerslev, T (1986), "Generalized Autoregressive Conditional Heteroskedasticity", Journal of Econometrics, 31, 307(327.

Bodurtha, J N, and N C Mark (1991), "Testing the CAPM with Time Varying Risks and Returns", Journal of Finance, 46, 1485(1505.

Chou, R Y (1988), "Volatility Persistence and Stock Valuations: Some Empirical Evidence Using GARCH", Journal of Applied Econometrics, 3, 279(94.

Connolly, R A (1989), "An Examination of the Robustness of the Weekend Effect", Journal of Financial and Quantitative Analysis, 24, 133(69.

Diebold, F X (1986), "Modeling the Persistence of Conditional Variance: A Comment", Econometric Reviews, 5, 51(56.

Engle, R F (1982), "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U.K. Inflation", Econometrica, 50, 987(1008.

Engle, R F, D M Lilien and R P Robins (1987), "Estimating Time Varying Risk Premia and the Term Structure: The ARCH-M Model", Econometrica, 55, 391(407.

Engle, R F and C Mustafa (1992), "Implied ARCH Models from Option Prices", Journal of Econometrics, 52.

Fama, E F (1965), "The Behaviour of Stock Market Prices", Journal of Business, 38, 34(105.

French, K.R, G W Schwert, and R F Stambaugh (1987), "Expected Stock Returns and Volatility", Journal of Financial Economics, 19, 3(30.

Friedman, B M and D I Laibson (1989), "Economic Implications of Extraordinary Movements in Stock Prices", Brookings Papers on Economic Activity, 2, 137(89.

Lamorureux, C G and W.D Lastrapes (1990), "Heteroskedasticity in Stock Return Data: Volume versus GARCH Effects," Journal of Finance, 45, 221(29.

Mańdelbrot, B (1963), "The Variation of Certain Speculative Prices", Journal of Business, 36, 394(419.

Morgan, A and I Morgan (1987), "Measurement of Abnormal Returns from Small Firms", Journal of Business and Economic Statistics, 15, 121(29.

Nelson, D B (1990), "ARCH Models as Diffusion Approximations", Journal of Econometrics, 45, 7(38.

Pagan, A R and G W Schwert (1990), "Alternative Models for Conditional Stock Volatility", Journal of Econometrics, 45, 267(90.

Poterba, J and L Summers (1986), "The Persistence of Volatility and Stock Market Fluctuations", American Economic Review, 76, 1142(51.

Schwert, G W (1989), "Why Does Stock Market Volatility Change over Time?" Journal of Finance, 44, 1115(53.

Schwert, G W and P J Seguin (1990), "Stock Volatility and the Crash of 87", Review of Financial Studies, 3, 77(102.

Recent Working Papers

H G HANUMAPPA
Social Amenities Spread in Rural Karnataka

H G HANUMAPPA &
K N ANANTHARAMAN
Economics of Silk Industry: Micro and Macro Issues

H G HANUMAPPA
Agro-Climatic Regional Planning
Adequacy of the Strategy

HEMLATA RAO
The Economic Reforms and Industrial Development
(The Karnataka Experience)

HEMLATA RAO
Equalisation payments in Canada

M JOHNSON SAMUEL AND
M LINGARAJU
Migrants to Bangalore

M MAHADEVA
Development and Change Under Integrated Tribal Development Project

R MUTHARAYAPPA
Indigenous Health Care System in Karnataka: An Exploratory Study

M V NADKARNI AND GOVINDARU V
Nobody's Child: The Economic and Institutional Aspects of Soil Conservation in India

M V NADKARNI
Economics and Ecological Concern

M V NADKARNI
Use and Management of Common Lands: Towards an Environmentally Sound Strategy

K N NINAN AND
S LAKSHMIKANTHAMMA
Sustainable Development:
The Case of Watershed Development in India

K N NINAN
Poverty and Income Distribution in India

K N NINAN
Economics of Shifting Cultivation

M PRAHLADACHAR AND
K GAYITHRI
Industrial Potential in Karnataka

M PRAHLADACHAR AND K GAYITHRI
Electronics Industry: Status and Prospects

M PRAHLADACHAR
Some Aspects of Ground Water Resource Development and Management in Karnataka

PRAKASA RAO V L S THIMMAIAH G MAJUMDAR H K AND SESHAIAH S
District Planning Officers Training Programme

RAMESHWAR TANDON
Asian Debt Scenario for the Late 1980s

V M RAO, H G HANUMAPPA AND S ERAPPA
Karnataka Dry Land Agriculture: Some Policy Issues

P H RAYAPPA AND M LINGARAJU
Demographic Transition in the South: A Regional Perspective

P H RAYAPPA
Right to Work

S N SANGITA AND VAIDYA VIBHAVATHI
Ethics in Superior Civil Services in India: With Special Reference to Recruitment and Training

T R SATISH CHANDRAN
Fiscal Discipline and Fiscal Consolidation at the Central and State Levels: Problems and Prospects

T R SATISH CHANDRAN
Economics of Power Generation: Issues and Choices

N SIVANNA
The Public Distribution System in Karnataka: A Study of Its Organisation and Management Aspects

SUKHPAL SINGH AND VINOD VYASULU
Fundamental Theoretical Contributions

G THIMMAIAH
The Political Economy of Populist Programmes

G THIMMAIAH
Economic Liberalisation in Agricultural Sector

B P VANI AND VINOD VYASULU
Growth, Variability, Instability and Production Behaviour of Rice Crop in Karnataka: A District Level Analysis

VINOD VYASULU
Tariffs and All That: On Some Conundrums in Railway Economics

VINOD VYASULU
Management of Poverty Alleviation Programmes in Karnataka: An Overview

VINOD VYASULU AND D RAJASEKHAR
The Rural Credit System in the 1990s

VINOD VYASULU
On Choosing Environmentally Sound and Self-Reliant Technologies: Reflections on Indian Experiences

SYED AJMAL PASHA
Uncultivated Lands: Institutional Aspects of their Use and Management in Karnataka

S N SANGITA
Effective and Responsive Government in Karnataka: An Action Plan

M GOVINDA RAO
Intergovernmental Transfers in Selected Countries

K MATHIYAZHAGAN
People's Choice of Health Care Provider Policy Options For Rural India

SUPRIYA ROYCHOWDHURY
The State in Comparative Politics : A Critique

M GOVINDA RAO
Principles of Intergovernmental Transfers Have the Finance Commissions Followed Them?

M GOVINDA RAO
InterGovernmental Fiscal Arrangements In A Transitional Economy : A Look At Vietnam

SYED AJMAL PASHA
Forest use and Management A Comparative Perspective from India and Canada

S AMANULLA AND B KAMAIAH
Indian Stock Market : Price Integration and Market Efficiency

ALLEN ROY, S AMANULLA AND B KAMAIAH
Indian Stock Market : A Test of A Semi-Strong form of Efficiency

K V RAJU AND TUSHAAR SHAH
Revitalisation of Irrigation Tanks in Rajasthan: An Approach

PRICE : Rs.30-00

INSTITUTE FOR SOCIAL AND ECONOMIC CHANGE
Prof. V. K. R. V. Rao Road, Nagarbhavi, Bangalore - 560 072, India
Phone : 0091-80 - 3215468, 3215519, 3215592 ; Fax: 0091-80 - 3217008
Grams: ECOSOCI, Bangalore - 560 040
E-mail:kvraju@ isec.kar.nic.in