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THE PRICING OF RISKS IN INDIA'S FINANCIAL MARKETS: A GARCH ANALYSIS

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THE PRICING OF RISKS IN INDIA'S FINANCIAL MARKETS: A GARCH ANALYSIS

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According to the finance literature, risks associated with various financial instruments and their corresponding market segments could be stochastic and evolve continuously over time, reflecting the developments in the macroeconomy and the financial system. This study undertakes an empirical analysis of risk pricing for India's financial markets using Generalised Autoregressive Conditional Heteroskedasticity (GARCH) model. Empirical results provide various insights about the nature of risk pricing underlying money, credit, bonds, equity and foreign exchange market segments. Broadly, all market segments, excepting the corporate bond market, showed the ability to price risks over the sample period. International integration was found to accentuate risk pricing in the domestic stock market. From policy perspective, these findings may contribute to financial stability analysis and serve useful for monitoring financial markets and devising strategies for their further developments in the Indian context.

1. INTRODUCTION

Economists have learned lessons from various crises across the emerging market economies, which occurred during the late 1990s and the early part of the current decade, and the global crisis originating from an advanced economy such as the US in the more recent period. First, sustained economic progress cannot be achieved without efficient and stable financial systems. Second, a stable financial system is reflected in the ability of constituent financial market segments to price risks associated with various financial instruments (Mohan,

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2007[1], Trichet, 2009). Third, the crisis to a financial system could occur through various risks pertaining to liquidity, credit, interest rate, exchange rate and asset prices, apart from macroeconomic risks. Fourth, it is useful to have continuous assessment and monitoring of the risk-pricing mechanism underlying the financial markets for policy purposes.

In the Indian context, a key objective of financial sector reform beginning from the early 1990s has been to promote price discovery process in financial markets and thereby, improve allocation and operating efficiencies of intermediaries and market participants. The reform process has completed two decades. It is now generally agreed that Indian financial markets have shown considerable maturity in terms of price discovery process. There is evidence of integration among various market segments, reflecting on the operating efficiency of financial markets (Bhoi and Dhal, 1999, RCF 2005-06). However, there is dearth of empirical analysis on risk pricing in Indian financial markets. From the latter perspective, several pertinent questions arise in the Indian context. Whether the various financial market segments are capable of pricing risks dynamically? Whether various financial market segments behave differently in this regard? Which risks are important for the Indian financial system? These questions motivate the authors for undertaking the present study. Taking leads from the finance literature, the study engages in analysis of risk-pricing as reflected in the movement of various interest rates, exchange rate and equity prices using the generalised autoregressive conditional heteroskedasticity (GARCH) model. The idea here is that each financial variable represents a market segment identified with its underlying risk characteristics. Illustratively, the interbank call money segment reflects on liquidity effect. Commercial paper and corporate bond yields could reflect on credit market and the associated risks. Yields on treasury instruments could reflect on interest

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[1] Statement made by Dr. Rakesh Mohan, Deputy Governor of the Reserve Bank of India and Leader of the Indian Delegation to the International Monetary and Financial Committee, Washington DC on April 14, 2007.

rate risk or the market risk. The stock market could be attributable to asset price risks while the spot and forward exchange rates could be related to risks associated with the external sector in terms of exchange rate and capital flows. Rest of the paper is structured into four sections. Pertaining to review of literature, methodology and data used in the study, empirical findings and conclusion in order.

2. THE REVIEW OF LITERATURE

According to the theoretical finance literature, the concept of risk pricing owes to the modern portfolio theory (MPT) or popularly, the mean-variance optimization theorem (MVT) of Markowitz (1952), and subsequently, the capital asset pricing model (Treynor, 1962, Sharpe,1964, Lintner,1965 and Mossin,1966), the arbitrage pricing theory (Ross, 1976), several interest rate models (Vasicek, 1977, Brennan and Schwartz, 1980 and Cox, Ingersoll and Ross,1985, and Chan *et.al.* (1992) and derivatives pricing models (Black and Scholes, 1973, Merton, 1973). According to the MVT, investors are rational and averse to risks. Given two assets that offer the same expected return, investors will prefer the less risky one. A rational investor will not invest in a portfolio if a second portfolio exists with a more favorable risk-return profile. Thus, an investor wanting higher returns must accept more risk, and the exact trade-off will depend upon individual risk aversion characteristics. Inspired by Markowitz's seminal contribution, the capital asset pricing model (CAPM) postulated a theoretically appropriate required rate of return of an asset, if that asset is to be added to an already well-diversified portfolio, given that asset's non-diversifiable risk. The CAPM took into account the asset's sensitivity to non-diversifiable risk (also known as systemic risk or market risk), often represented by the quantity beta (β) in the financial industry, as well as the expected return of the market and the expected return of a risk-free asset. The arbitrage pricing theory (APT) holds that the expected return of a financial asset can be modeled as a linear function of various macro-economic factors or theoretical market indices, where sensitivity to changes in each factor is represented by a factor-specific beta coefficient. The model-derived rate of return will then be used to price the asset correctly - the asset price should equal the expected end of period price discounted at the rate implied by model. If the price diverges, arbitrage should bring it back into equilibrium.

Theoretical models of asset prices were based on certain key assumptions. First, in the CAPM model, the risk free interest rate was assumed to follow a deterministic process with a linear drift and Gaussian white noise process. Also, deviations from the security market line (SML) were assumed to be normally distributed with zero drift and a constant variance to ensure the absence of abnormal returns under efficient market conditions. As opposed to the deterministic risk free interest rate, Vasicek (1977), Brennan and Schwartz (1980) and Cox, Ingersoll and Ross (1985) suggested affine class term structure of interest rates such that the latter could be characterised as stochastic process with a jump diffusion process. Chan *et.al.*,(1992) suggested a generalised diffusion model[2] , popularly known as CKLS model. Das (2002), Johannes (2004), and Piazzesi (2005) also identified a jump component in the interest-rate movement. The jump component generates interest-rate innovations that are not normally distributed. Despite this improvement, popular models of the short rate produced untenable results when fitted to the data (Gray, 1996, Ball and Torous, 1999, Duffee, 1993, Duan and Jacobs, 2001). Second, it was assumed that an asset's risk is time invariant and it could be characterised as a constant unconditional measure such as sample standard deviation or variance. Several studies found that this assumption was always violated in the real world. Mandelbrot (1963) and Fama (1965)

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[2] Chan, et.al. (1992) suggested the generalised model as

$$dr = (\alpha + \beta r)\, dt + \sigma r^{\gamma}\, dw$$

where dW is increment from a standard Brownian motion. For estimation purpose, the equation in discrete time framework is

$$\Delta r_r = r_t - r_{t\text{-}1} = \alpha + \beta r_{t\text{-}1} + \varepsilon_t$$

recognised volatility clustering, i.e., large changes in the price of an asset are often followed by other large changes and small changes are often followed by small changes. A formal model was developed by Engle (1982). He postulated the concept of conditional volatility, since risks to economic and financial variables could follow a dynamic stochastic process and evolve with time. Thus, he developed the autoregressive conditional heteroskedasticity (ARCH) model for measuring stochastic volatility. Subsequently, the model was extended to the generalized ARCH (GARCH) by Bollerslev (1986). Furthermore, Engle, Lilien, and Robins (1987) suggested the ARCH-in-Mean (ARCH-M) model, which allows the mean of a sequence to depend on its own conditional variance on the basis of the ARCH framework. Nelson (1991) developed the exponential GARCH (EGARCH) model, based on the conditional variance defined over logarithm scale. Glosten, Jagannathan, and Runkle (1993), and Zakoian (1994) introduced the threshold ARCH (TARCH) model to account for the leverage effect on the ARCH models, thus, allowing for asymmetric or differential impact of positive and negative shocks on volatility. Hamilton and Susmel (1994) developed regime switching ARCH (SWARCH) model. Baillie, Bollerslev and Mikkelsen (1996) developed fractionally integrated GARCH, i.e., FIGARCH(p; d; q) model of conditional volatility to analyse long-memory in financial variables.

The works of Engle (1982), Bollerslev (1986), Engle, Lilien, and Robins (1987), Nelson (1991) and Glosten, Jagannathan, and Runkle (1993) have inspired a large empirical literature focused on measuring risk-pricing in financial markets. Initially, the ARCH model was used for measuring the inflation risk, recognising that the uncertainty of inflation tends to change over time (Engle, 1982, and Engle and Kraft, 1983). Following their work, several authors including Longstaf and Schwartz (1992), Brenner *et. al.* (1996), Koedijk *et.al.*, (1997), Andersen and Lund (1997), Ball and Torous (1999), Bali (2000), Christiansen (2005), and Honget *et.al.*,

(2004) exploited the GARCH model in order to improve upon the short rate models and found that an additional stochastic volatility factor or a GARCH-type process is useful to accommodate the strong conditional heteroskedasticity in short-term interest rates. Deriving from these studies, GARCH models have witnessed applications to the entire spectrum of financial markets including money, credit, bond, common stocks and foreign exchange markets across several countries. Providing a review of the bourgeoning literature is beyond the scope of this paper. For illustrative purpose, a list of studies using GARCH models is shown in Box 1.

2.2 Key Aspects of Risk Pricing

What is striking about the numerous studies using GARCH analysis of financial markets is that they provide a generalised perspectives on risk pricing and bring to the fore various crucial features of modern financial markets, as succinctly demonstrated by Engle and Patton (2001). These aspects of risk pricing are discussed below.

First, volatility clustering and persistence are key features of financial markets. In other words, past volatility explains current volatility. Financial markets are characterised with time varying conditional mean and variance of return on various instruments.

Second, due to risk aversion and dynamic portfolio adjustment, which is made possible by the advanced technology infrastructure, investors are able to quickly process information. This implies that investors' expected return also depends upon the conditional variance of the financial instruments consistent with continuous time mean-variance optimization or risk-return trade-off hypothesis.

Third, financial markets exhibit asymmetric response to good and bad news, implying differential impact of positive and negative innovations or shocks on volatility and the expected rerun of an asset.

Box 1: Studies on GARCH Models applied to Financial Markets

Studies	Details
1. Interest Rates	
Bali and Wu (2005)	Used three interest rates: fed funds rate, 7-day euro dollar rate, 3-m T-bill rate, GARCH, Non-standard distribution – Generalised Error Distribution (GED)
Brailsford and Maheswaran (1998)	Short-term interest rate in Australia, 30-day BAB rate preferred to 90 and 180 day. T-GARCH analysis
Christiansen (2008)	Regime switching level Univariate and Bivariate GARCH short rates; US (1-m euro dollar rate), UK (1-m LIBOR) and Germany (1-m euromark)
Duan and Jacobs (2001, 2007)	FIGARCH for short term interest rates (1-week euro dollar rate, daily and weekly data), test of long-memory
Edwards, S (1998)	30-day deposit rates in Argentina, Chile, and Mexico, GARCH analysis
Edwards and Susmel (2003)	Univariate and multivariate SWARCH model, interest rates in EMES, i.e., Argentina, Brazil, Chile, Hong Kong and Mexico; 30-day deposit and interbank rates
Galac, *et.al.* (2007)	Croatia money markey (overnight, 91-day,180-day and 364-day treausry bills), explanatory variables (repo, liquidity, etc), ARIMA-GARCH analysis
Gray (1996)	GARCH with regime switch, Weekly data 1-m US T-bill rate
Kleibergen (1993)	Bayesian approach to GARCH, US treasury bill rate, addressed the non-stationary problem
Koedijk, *et.al.* (1997)	GARCH and CKLS models for one-month US treasury bill rate, used weekly and monthly data.
Murta (2007)	Portuguese money market (overnight interest rate) intra-day data, GARCH analysis
Nowman and yahia (2008)	Level-GARCH for EURIBOR (1-m & 6-m maturities) and FIBOR (1-m) interest rates
Raunig and Scharten (2006)	GARCH, linkage between money market uncertainty and retail interest rates (deposit and lending rates), 10 OECD countries compared.
Rosenblum and Strongin (1983)	Federal funds rate, commercial paper, not GARCH model, moving standard deviation.
Shahiduzzaman and Naser (2007)	GARCH model for the Overnight call money rate in Bangladesh
Smith (2002)	CKLS and GARCH model for US 30-day T-bill rate, used monthly data
Suardi 2008	CKLS, GARCH(1,1) for US 3-m treasury bill, Australia 90-day bank bills rate

Box 1: Studies on GARCH Models applied to Financial Markets

Studies	**Details**
Syklos and Skoczylas (2002)	ARIMA-GARCH-in-Mean for Real interest rates, interest rates are borrowing and lending rates, studied 10 industrialised countries
2. Equity Market	
Durand and Scott (2003)	Ishares Australia, EGARCH-m, found negative impact of risk on return
French *et.al.* (1985)	Expected market risk premium (Stock return less Treasury bill rate); Garch-in-Mean model; positive relationship between risk and return
Kiani (2006)	Excess stock return in Pakistan (stock return over Treasury bill rate) GARCH with state space representation
Kim and Sheen (1998)	Bivariate GARCH, International linkage of interest rate volatility-Australia and the US (3-month treasury bill rate and 10-year government bond yield)
Lamoureux (1990)	GARCH Daily stock returns in the US
Nam *et.al.* (2002)	Asymmetric non-linear smooth transition GARCH, the US excess stock return; month equity return for three stock exchanges NYSE, AMEX and NASDAQ (stock return over 1-month treasury bill rate)
Ozun (2007)	GARCH for 14 stock markets (emerging and developed) return and US 10-yr treasury rate explanatory variable
3. Exchange rate/Forward Premium	
Bidarkota (2004)	Forward premium (us dollar/pound)
Corte, *et.al.* (2007)	
Bhar, *et.al.* (2007)	Currency forward premium 1-m, 2-m, and 3-m maturities, daily data Franc/US dollar and Yen/Dollar, interest rate spread, data 3-m treasury bill rate (France, Japan, and the US)
McCurdy and Morgan (1991)	BVGARCH model Uncovered interest rate parity, US interest rate and Euro currency US dollar exchange rate US
4. Multivariate GARCH	
Bauwens *et.al.* (1997)	Cointegrated VAR-GARCH model for short and long rates, for five developed countries (US, UK, France, Germany and Belgium)
Berument (1999)	Interest rate with expected inflation, GARCH, test of fisher hypothesis
Ferreira and Lopez (2004)	MVGARCH model Interest rate (3-m libor rate for dollar, deutch mark, and yen) and exchange rate, used for analysing Value at Risk,
Hansen and Lunde (2001)	Exchange rate and stock prices, intra-day data, GARCH
LI and Zou (2007)	MVGARCH(DCC) for China Treasury bond and stock market
Yang *et.al.* (2009)	MVGARCH (monthly stock and bond yield data) US and UK, 150 years (1855-2001)

Fourth, the price discovery process in efficient markets is characterised with inter-linkage among various market segments and their comovement led by a common benchmark risk free instrument.

Fifth, exogenous variables relating to macroeconomic developments could also play an important role in influencing the conditional return and variance of financial markets.

Sixth, financial markets, generally, follow non-standard statistical distribution function, implying that investors can exploit arbitrage opportunities in the short run.

Seventh, volatility characteristics of financial markets could be distinguished across the frequencies such as daily, weekly, monthly and quarterly dimensions, reflecting upon synchronous or non-synchronous nature of trading and information efficiency of markets.

3. METHODOLOGY AND DATA

As discussed in the earlier section, various aspects of risk pricing in financial markets could be analysed through the threshold-GARCH-in-mean model (TGARCHM) of Engle, Lilien and Robins (1987) and the exponential GARCH-in-Mean (EGARCHM) model of Nelson (1988), consistent with the standard risk-return trade-off hypothesis and the asymmetric news and leverage effects. Basically, a GARCH model for a financial asset variable comprises two equations; one for the mean (or expected return) and the other for variance of a financial time series variable. It could be formulated in terms of a univariate model or multivariate model with or without explanatory variables in the mean and variance equations. In our case, we adopt the univariate TGARCHM or EGARCHM model suitable to specific market segment. The TGARCHM specified in terms of mean and the conditional variance of a stationary financial variable (y) is as follows:

The mean equation for a stationary financial variable ‘y’ follows an ARMA(p,q) process as[3]

$$\Phi(L)y_t = \alpha + \Theta(L)\varepsilon_t + \lambda\sigma_t^2 \qquad (1)$$

Or with exogenous variables (X) as

$$\Phi(L)y_t = \alpha + \Sigma_1^s \beta_j X_{j,t} + \Theta(L)\varepsilon_t + \lambda\sigma_t^2 \qquad (2)$$

where $\Phi(L)$ and $\Theta(L)$ are the autoregressive (AR) and moving average (MA) lag polynomials

$$\Phi(L) = \quad \prod_{\iota=1}^{p} (1 - \Phi_\iota L) \qquad (3)$$

$$\Theta(L) = 1 + \Sigma_{\iota=1}^{q} \theta_\iota L^\iota \qquad (4)$$

respectively. The variance equation follows a threshold GARCH-in-mean (TGARCHM) process as

$$\sigma_t^2 = c + \Sigma_i \theta_i \varepsilon_{t-i}^2 + \Sigma_i \omega_j \sigma_{t-j}^2 + + \Sigma_k \psi_k \Gamma_{t-k} \varepsilon_{t-k}^2 \qquad (5)$$

Or with exogenous variables (Z) as

$$\sigma_t^2 = c + \Sigma_i \theta_i \varepsilon_{t-i}^2 + \Sigma_i \omega_j \sigma_{t-j}^2 + \Sigma_m \mu_m Z_m + \Sigma_k \psi_k \Gamma_{t-k} \varepsilon_{t-k}^2 \qquad (6)$$

In the above model, the parameter (λ) measures the trade-off between risk and return, and thereby, reflects on how the risk is priced in the financial market. The parameter ψ captures the threshold effect with the term $\Gamma_t = 1$ when $\varepsilon_{t-k} < 0$, and 0 otherwise. With the asymmetric effect, good news will have the impact on the conditional variance to the extent of sum of θ_q and ψ_k coefficients while the bad news will have the impact equal to the sum of θ_q coefficients only. The above model could also be modified to exponential GARCH-in mean model (EGARCHM) with asymmetry (leverage) effect, which

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[3] Here, in the mean equation, the variance (σ^2) term account for the risk-return trade-off. Alternatively, the mean equation may be specified with standard deviation (σ) or logarithm of variance i.e. $\ln(\sigma^2)$.

may be suitable to some financial variables. For EGARCHM, the variance equation is expressed as follows.

$$\text{In}\ \sigma_t^2 = c + \Sigma_i \theta_i \frac{\varepsilon_{t-i}}{\sigma_{t-i}} + \Sigma_i \omega_j\ \text{In}\ (\sigma_{t-j}^2) + \Sigma_m \mu_m Z_m + \Sigma_k \psi_k \left|\frac{\varepsilon_{t-k}}{\sigma_{t-k}}\right| \qquad (7)$$

A GARCH model provides a generalized perspective on risk pricing mechanism and can be applied to various interest rates and asset return variables. For a meaningful analysis of whether risk-pricing in financial markets is efficient, the GARCH model could be enriched with various key theoretical and applied finance perspectives.

First, the standard benchmark principle used by various studies and official agencies may be considered. Illustratively, the Congressional Budget Office in the US analyses risks associated with various financial markets in terms of spread variables, defined as the spread of interest rates on market instruments over the risk free rate such as the 3-month Treasury bill rate. The underlying principle here is that the return on a market instrument (R_j) should equal the sum of return on à risk-free instrument, typically, the Treasury bill rate (R_g) and the risk premium (ρ). The risk premium could again be broken into some deterministic identifiable component driven by the X variables (including a drift or intercept term) and the idiosyncratic component or innovation (ε). Therefore, we define the spread variable as

$$S_{j,t} = (R_{j,t} - R_{g,t}) \qquad (8)$$

which could follow a GARCH model with appropriate mean and variance equations from equation (1) through equation (6). In our case, such specification could be adopted for interest rates pertaining to certificates of deposits, commercial papers, and the long-term bond yield.

Second, the finance literature also suggests some market specific principles. For the inter-bank borrowing and lending segment, the benchmark interest rate could be the policy short-term interest rate such as the repo rate in the Indian context, since the latter provides a corridor to the former (Singh and

Dhal, 1999). Thus, the mean equation for this segment could be modeled in terms of the spread of the call money rate over the repo rate:

$$S_{call,t} = (R_{call,t} - R_{repo,t}) \tag{9}$$

and its mean equation as an ARMA process:

$$\Phi(L)S_{call,t} = \alpha + \Theta(L)\varepsilon_t + \lambda\sigma_t^2 \tag{10}$$

Similarly, for the foreign exchange market, the covered interest rate parity (CIP) hypothesis suggests that the forward exchange premium (f_e) should equal to the spread of domestic interest rate (R_d) over the foreign interest rate (R_f) under no arbitrage condition. Therefore, the mean equation for this market segment can be specified as

$$S_{f,t} = f_{e,t} - (R_{d,t} - R_{f,t}) \tag{11}$$

with its ARMA mean equation as

$$\Phi(L)S_{f,t} = \alpha + \Theta(L)\varepsilon_t + \lambda\sigma_t^2 \tag{12}$$

Similarly, the analysis of spot exchange rate can be made in line with *uncovered interest rate parity*, which entails that changes in exchange rate should equal to interest rate differential between domestic and foreign countries (Pattnaik, *et.al.* 2003).

As regards the equity market, studies prefer ‘international capital asset pricing model (IACPM)’, recognising the role of foreign investors and international integration of domestic stock markets with global markets (Solinik,1974, Taylor,1989, Kasa,1992, Raj and Dhal 2008). Following Taylor (1989), the mean equation for the equity return in the domestic stock market (S_e^d) could be specified in line with the IACP model as follows:

$$\Phi(L)S_{e,t}^d = \alpha + \beta S_{e,t}^m + \Theta(L)\varepsilon_t + \lambda\sigma_t^2 \tag{13}$$

where the variables are defined as

$$S^{d}_{e,t} = R^{d}_{e,t} - R^{d}_{g,t} \tag{14}$$

$$S^{m}_{e,t} = R^{m}_{e,t} - R^{m}_{g,t} \tag{15}$$

$R^{d}{}_{e}$ and $R^{d}{}_{g}$ are the return on equity and risk free interest rate in the domestic market, and $R^{m}{}_{e}$ and $R^{m}{}_{g}$ are similar variables in the global market, respectively.

3.2 Data

In this study, we use monthly data on interest rates, exchange rate and stock prices culled out from the official source such as the RBI (Handbook of Statistics on the Indian Economy and Monthly Bulletin and Thomson's Datastream). The sample period is April 1993 to March 2009. The variables used in the study are weighted average call money rate (call), commercial paper rate(CPS), certificates of deposit rate (CDS), 91-day treasury bills rate (G91), 10-year Government of India bond yield (G10) and Rupee-US dollar forward exchange rate premium for maturities of 1-month (FR1) and 3-month (FR3). The stock return (BSER) is derived from the BSE sensitive index.

4. EMPIRICAL ANALYSIS

Table 1 provides summary statistics for various interest rate spread variables based on monthly data over the sample period March 1993 to March 2009. All spread variables, had significant non-zero mean. The spread variables also had significant positive skewness and kurtosis statistic. The Jarque-Bera (JB) statistic, defined in terms of skewness and kurtosis measures, is significantly large, suggesting that the financial variables cannot be normally distributed. Interest rate spreads relating to commercial paper, certificates of deposits and long-term government bond yield had more or less similar sample standard deviation. The forward exchange rate premium variables had sample standard deviation twice larger than the same for commercial paper, certificates of deposits and long-term bond yield. The equity return[4] spread has largest

Table 1: Summary Statistics of Financial Market Variables

	Financial Variables							
Statistics	Call	CDS	CPS	FR1	FR3	G91	G10	BSER
1	2	3	4	5	6	7	8	9
Mean	1.67	1.20	2.43	0.77	0.51	1.65	2.00	1.17
Median	0.64	1.10	2.11	-0.05	0.06	1.28	1.55	0.23
Maximum	28.08	5.89	7.73	27.00	19.05	6.22	6.46	60.49
Minimum	-5.27	-0.98	0.21	-6.61	-6.34	-1.67	-0.65	-78.92
Std. Dev.	3.71	1.29	1.51	3.98	3.42	1.73	1.57	31.08
Skewness	3.98	0.79	1.08	2.98	1.78	1.00	1.10	-0.25
Kurtosis	24.02	3.77	3.97	17.33	9.03	3.62	3.46	2.44
Jarque-Bera (JB)	4040.55	24.49	44.75	1665.15	392.23	35.09	32.48	4.47
Probability (JB)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11

Note : All variables are defined in terms of spread over their respective benchmark variables as defined below:
Call: call money rate *minus* Repo rate. CDS: Certificates of Deposit rate *minus* 91-day Treasury Bill rate. CPS: Commercial Paper rate *minus* 91-day Treasury Bill rate. G91: 91-day Treasury bill rate *minus* Repo rate. G10: 10-year Government bond yield *minus* 91-day Treasury Bill rate. FR1: 1-month forward exchange premium minus the interest rate differential between 91-day Treasury bill rate. FR3: 3month forward exchange premium minus the interest rate differential between 91-day Treasury bill rate and the US 3-month Treasury bill rate. BSER: BSE Sensex equity return minus the 91-day Treasury Bill rate.

mean and standard deviation but low skewness and kurtosis. Nevertheless, the JB statistic showed that the equity return departed from the normal distribution like all other financial variables.

Table 2 presents the results of unit root test based on the Augmented Dickey-Fuller (ADF) and Philips-Perron methodologies. In terms of Philips-Perron test, the computed test statistic in absolute terms was greater than the 5 per cent critical value, implying that the spread variables were stationary in nature. For the ADF test, all variables excepting the equity return turned out to be stationary at 5 per cent level of significance. The equity return could be stationery at 10 percent level of significance.

For identifying the suitable ARMA model for the mean of the interest rate spread variables, it is necessary to examine the autocorrelation (ACF) and partial autocorrelation functions (PACF) of the spread variables (Table 3). There are certain common features. First, for all spread variables, the PACF declined

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[4] If P is the stock price index, the annualised return from daily data is derived as $R=(P_t/P_{t-252}-1)*100$ as there are about 252 business days in a year. On the basis of natural logarithm transformed stock price index (p), the annualised return is derived as $R = (p_t-p_{t-252})*100$. It may be noted here that our analysis is not based on total equity return and therefore, we do not take into account the dividend yield.

Table 2: Unit Root Test

Interest Rate Spreads	Philips-Perron Test	ADF Test
1	2	3
Call	-8.38	-3.38
CDS	-3.79	-3.96
CPS	-3.94	-4.00
FR1	-5.12	-5.12
FR3	-7.44	-4.33
G10	-2.75	-2.89
BSER	-2.78	-2.77

5% critical value is -2.88

sharply after the first lag. On the other hand, the ACF decayed slowly for CDS, CPS, FR3, G10 and BSER and rapidly for the call money rate. Such ACF and PACF imply that the conditional mean of the spread variables could be characterized with first order autoregressive AR(1) model.

The ACF and PACF for the square of spread variables after being adjusted to their sample mean could be used to examine whether their variance could be characterized with ARCH/GARCH models (Table 4). It was evident that the ACF and PACF for most variables declined rapidly after the first lag, implying that the first order GARCH(1,1) model could be appropriate for the conditional variance of the spread variables. For a more formal test, we estimated two types of mean model for each variable, AR(1) and ARMA(1,1) and then the ARCH effect was tested using LM test as shown in Table 5. For most of the spread variables, the coefficient of MA(1) term was not statistically significant at 5 per cent level of significance. Thus, the AR(1) model was found as the appropriate mean model for the spread variables. For this model, the ARCH effect could not be rejected for all spread variables excepting the 10-year yield spread.

With the above statistical results, we now turn to the GARCH analysis for each market segment. The empirical analysis for each financial variable was carried out in a structured manner. First, the standard mean equation using ARMA(1,0) or the AR(1) model was estimated. Subsequently, we extended the AR(1) model to GARCH variance equation, under alternative specifications

Table 3: Autocorrelation Structure of Financial Variables

Lags	ACF Call	PACF	Q-statistics	ACF CDS	PACF	Q-statistics
1	2	3	4	5	6	7
1	0.53	0.53	54.77	0.85	0.85	140.65
2	0.38	0.13	82.54	0.73	0.03	244.71
3	0.36	0.16	107.58	0.62	-0.02	320.02
4	0.42	0.22	141.92	0.55	0.09	379.85
5	0.31	-0.03	160.79	0.49	0.03	428.45
6	0.21	-0.05	169.47	0.45	0.03	469.18
Lags	CPS			FR1		
1	0.82	0.82	131.36	0.73	0.73	90.55
2	0.70	0.09	228.10	0.49	-0.10	131.33
3	0.57	-0.09	292.29	0.41	0.19	159.56
4	0.45	-0.04	333.21	0.39	0.09	185.58
5	0.39	0.11	364.13	0.28	-0.15	198.85
6	0.34	0.03	387.71	0.18	0.01	204.23
Lags	FR3			G91		
1	0.86	0.86	144.06	0.92	0.92	164.53
2	0.70	-0.16	239.26	0.84	-0.02	302.91
3	0.63	0.27	316.46	0.78	0.04	421.26
4	0.58	-0.03	382.18	0.74	0.14	528.70
5	0.50	-0.04	432.01	0.71	0.05	628.26
6	0.43	0.03	469.37	0.69	0.07	722.70
Lags	G10			BSER		
1	0.95	0.95	141.05	0.93	0.93	169.68
2	0.90	0.06	270.34	0.85	-0.18	310.28
3	0.86	0.00	388.67	0.75	-0.14	420.34
4	0.83	0.09	499.38	0.64	-0.12	500.93
5	0.79	-0.08	600.58	0.52	-0.10	555.25
6	0.75	-0.05	692.18	0.40	-0.09	587.76

Note: ACF and PACF are auto-correlation and partial auto-correlation of finnacial spread variables.

with distributional assumption changing from normal to generalised distribution, GARCH-in-mean effect and the threshold/asymmetric effects. For choosing a final model, we looked at the log-likely hood function and various information criteria. The results of our empirical exercises in respect of various market segments are as follows.

4.1 Call Money Rate

The call money rate spread over the repo rate could be characterised through an AR(1)-TGARCHM(LV) model with log variance in the mean equation (Table 6). The GARCH model suggests that the mean spread of the

Table 4: Test of ARCH Effect

Lags	ACF	PACF	Q-statistics	ACF	PACF	Q-statistics
	Call			CDS		
1	2	3	4	5	6	7
1	0.53	0.53	54.77	0.87	0.87	149.47
2	0.38	0.13	82.54	0.76	0.01	263.66
3	0.36	0.16	107.58	0.65	-0.05	347.58
4	0.42	0.22	141.92	0.56	0.04	411.33
5	0.31	-0.03	160.79	0.50	0.06	462.52
6	0.21	-0.05	169.47	0.46	0.05	505.89
	CPS			FR1		
1	0.83	0.83	134.30	0.73	0.73	90.55
2	0.71	0.08	234.05	0.49	-0.10	131.33
3	0.57	-0.11	299.29	0.41	0.19	159.56
4	0.45	-0.06	339.63	0.39	0.09	185.58
5	0.39	0.12	369.54	0.28	-0.15	198.85
6	0.33	0.03	391.74	0.18	0.01	204.23
	FR3			G91		
1	0.86	0.86	144.06	0.92	0.92	164.53
2	0.70	-0.16	239.26	0.84	-0.02	302.91
3	0.63	0.27	316.46	0.78	0.04	421.26
4	0.58	-0.03	382.18	0.74	0.14	528.70
5	0.50	-0.04	432.01	0.71	0.05	628.26
6	0.43	0.03	469.37	0.69	0.07	722.70
	G10			BSER		
1	0.95	0.95	141.05	0.94	0.94	192.04
2	0.90	0.06	270.34	0.84	-0.30	347.09
3	0.86	0.00	388.67	0.73	-0.12	463.97
4	0.83	0.09	499.38	0.61	-0.11	545.28
5	0.79	-0.08	600.58	0.49	0.04	599.35
6	0.75	-0.05	692.18	0.39	-0.03	633.25

Note : ACF and PACF are auto-correlation and partial auto-correlation of the square of financial spread variables adjusted to their sample mean. ‘Q’ statistic reported in the table are significant at 5 per cent level of significance.

call money rate over the repo rate as reflected in intercept term in the mean equation could be 28 basis points, which is significantly lower than the estimate (164 basis points) in the ARMA(1,0) model without GARCH effect. The threshold term had negative impact on variance, implying for the favourable impact of good news in terms of moderating risk in this market segment. However, the variance of call money spread over the repo rate showed high (low) persistence with bad (good) news affect the market, as reflected in the sum of ARCH and GARCH coefficients higher than unity under bad news but lower than unity (including the threshold coefficient) under good news. The

Table 5: Test of First order ARCH(1) Effect in Interest Rate Spreads

	AR(1) Coefficient	t stat	ARMA(1,1) Coefficient	t stat	AR(1) Coefficient	t stat	ARMA(1,1) Coefficient	t stat
1	2	3	4	5	6	7	8	9
Regressors	CDs				CPS			
Intercept	1.1208	3.32	1.1172	3.26	2.4357	6.49	2.4274	5.89
AR (1)	0.8682	26.10	0.8715	23.56	0.8426	21.42	0.8721	20.78
MA (1)			-0.0162	-0.20			-0.1064	-1.25
$\bar{R}^2$	0.78		0.78		0.71		0.71	
LL	-179.42		-179.41		-232.92		-232.00	
DW	2.02		1.99		2.15		1.99	
AIC	1.880		1.890		2.447		2.448	
BIC	1.914		1.941		2.481		2.499	
ARCH (1)	26.51		26.97		4.89		3.48	
	FR1				FR3			
Intercept	0.8139	1.164	0.8039	1.15	0.4187	0.46	0.4631	0.621
AR (1)	0.7320	13.360	0.6376	7.85	0.8599	23.19	0.7712	21.097
MA (1)			0.2033	1.97			0.3417	2.874
$\bar{R}^2$	0.53		0.54		0.74		0.75	
LL	-398.22		-396.92		-377.14		-371.85	
DW	1.86		2.02		1.72		2.08	
AIC	4.851		4.847		3.970		3.925	
BIC	4.889		4.904		4.004		3.976	
ARCH (1)	60.07		63.29		65.66		54.72	
	G10				BSER			
Intercept	0.1023	1.56	0.0813	4.191	-0.2544	-0.34	-0.2508	-0.27
AR (1)	0.9490	36.97	0.9589	26.183	0.9519	38.76	0.9242	29.78
MA (1)			-0.0979	0.801			0.2498	3.39
$\bar{R}^2$	0.90		0.90		0.89		0.89	
LL	-109.47		-108.86		-726.77		-721.14	
DW	2.10		1.94		1.45		1.92	
AIC	1.457		1.462		7.552		7.504	
BIC	1.497		1.522		7.586		7.555	
ARCH(1)	2.15		1.56		16.06		4.70	
	Call				G91			
Intercept	1.6423	3.34	1.6095	2.08	0.1338	1.78	0.0721	1.21
AR (1)	0.5296	8.55	0.8561	14.05	0.9152	31.04	0.9515	38.50
MA (1)			-0.5056	-4.99			-0.2331	-3.03
$\bar{R}^2$	0.28		0.31		0.84		0.84	
LL	-485.63		-485.36		-226.61		-223.40	
DW	2.14		1.89		2.26		1.91	
AIC	5.160		5.114		2.394		2.371	
BIC	5.194		5.165		2.428		2.422	
ARCH(1)	16.25		6.54		21.23		13.84	

Notes: LL: Log Likelihood. DW: Durbin-Watson Statistics

AIC and BIC are Araike and Schwartz-Bayes information Criterion, respectively, and t stat is ‘t’ statistics.

The ARCH(1) statistic refers to ‘F’ statistic. The 5 per cent critical value of F(1,191) is about 3.8. The large sample critical values of ‘t’ stat and ‘z’ stat at 5 per cent level of significance are +/- 1.95 and +/- 1.65, respectively.

Table 6: Call Money Rate

	AR(1)		AR(1) GARCH		AR(1) GARCH		AR(1) GARCHM (*)		AR(1) GARCHM ($)	
	Coefficient	t-stat	Coefficient	z-stat	Coefficient	z-stat	Coefficient	z-stat	Coefficient	z-stat
1	2	3	4	5	6	7	8	9	10	11
Mean Equation										
Intercept (α_1)	1.6423	3.34	1.4506	1.3	0.0115	0.51	-1.4977	-7.32	0.2833	4.03
AR(1): (β_1)	0.5296	8.55	0.7155	5.95	0.7605	83.85	0.4327	72.94	0.5651	36.38
ARCH-M (β_1)							0.9254	9.9	0.0464	3.12
Veriance Equation										
Intercept (α_2)			3.0537	6.91	0.022	1.12	0.7928	14.79	0.0431	2.11
ARCH (1) (β_2)			0.3603	3.36	1.0233	2.1	0.1973	10.56	0.9475	2.49
GARCH (1) (β_3)			0.3481	3.93	0.6301	8.18	0.8588	85.65	0.6407	9.54
Threshold (β_4)							-0.4775	-9.72	-0.8951	-2.19
Distribution (β_5)					0.5023	10.72	0.3737	13.35	0.5616	13.57
$\bar{R}^2$	0.28		0.25		0.22		0.24		0.26	
LL	-485.63		-447.81		-298.86		-308.67		-295.14	
DW	2.14		2.48		2.51		2.33		2.16	
AIC	5.1601		4.8774		3.7366		3.3509		3.2079	
SIC	5.1944		4.973		3.329		3.4882		3.3451	

Notes: * and $ refer to ARCH-M term in the form of GARCH standard deviation and GARCH variance in logarithm form, respectively, This applies to all other tables in the paper.

ARCH-M term implying for the volatility in the call money market had statistically significant positive impact on the call money rate, thus, reflecting on the pricing of liquidity risk. However, its size was low, implying that as large as 25 per cent volatility could be associated with a percentage point increase in call rate's spread over the repo rate. Moreover, the market was found to be characterised with non-standard distribution, reflecting the impact of extreme movement in this market.

4.2 Commercial Paper

For the commercial paper, the threshold ARMA(1,0)-GARCH-in-mean model (with standard deviation in the mean equation) turned out to be the appropriate model as compared with the ARMA(1,0) model (Table 7). In this model, the intercept coefficient estimated at 2.56 in the mean equation was statistically significant, which implied the extent to which the commercial paper rate could deviate from the 91-day Treasury bill rate on average in the medium term. The coefficient of the ARCH-M term was positive and statistically significant, suggesting that the market segment

Table 7: Commercial Paper Rate

	AR(1)		AR(1)-GARCH		AR(1)-GARCH		AR(1)-GARCH*		AR(1)-GARCH*	
Variables	Coefficient	t stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9	10	11
Mean Equation										
Intercept	2.4357	6.49	1.6797	5.38	1.6434	5.21	2.5298	7.55	2.5584	8.03
AR (1)	0.8426	21.42	0.8664	23.31	0.8819	26.57	0.8113	18.44	0.7993	14.06
ARCH-M							0.3485	2.64	0.3246	1.98
Variance Equation										
Intercept			0.0155	1.76*	0.0235	1.31**	0.0161	1.39*	0.0233	2.34
ARCH (1)			0.1857	3.44	0.22280	2.27	0.1755	2.27	0.3441	2.34
GARCH (1)			0.8141	20.06	0.7652	10.42	0.8220	13.78	0.7945	13.97
Threshold									-0.3264	-1.99
Distribution (GD)					1.1899	6.50	1.1433	6.74	1.1636	7.07
$\bar{R}^2$	0.71		0.69		0.69		0.70		0.70	
LL	-232.92		-210.02		-202.3975		-199.08		-197.17	
DW	2.15		2.17		2.1708		2.18		2.22	
AIC	2.4471		2.2398		2.2726		2.1467		2.1372	
SIC	2.4810		2.3246		2.2108		2.2654		2.2729	

was capable of pricing risks on a continuous basis. In terms of the coefficient size of ARCH-M term, an increase in standard deviation by 3 percentage points could lead to one percentage point increase in the commercial paper rate over the 91-day Treasury bill rate. The threshold term was negative and statistically significant, implying that good (bad) news led to lower (higher) volatility in this market segment. However, the market segment exhibited volatility persistence under bad news since the sum of ARCH and GARCH effects exceeded unity. The market was associated with non-standard distribution.

4.3 Certificates of Deposits

For the certificates of deposits (CDS), the ARMA(1,0)-GARCH-in-mean without threshold effect was found to be the appropriate model (Table 8). The statistically significant intercept term in the mean equation showed that on average, the CDS rate could be higher than the Treasury bill rate by 1.5 percentage points, somewhat higher than the AR(1) model. The CD spread also exhibited volatility persistence. The threshold term had

Table 8: Certificates of Deposit Rate

	AR(1)		AR(1)-GARCH		AR(1)-GARCH		AR(1)-GARCH*		AR(1)-GARCH*	
Variables	Coefficient	t stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9	10	11
Mean Equation										
Intercept	1.1208	3.32	0.2339	0.93**	-0.1562	-0.50**	1.4699	3.37	1.5255	3.15
AR(1)	0.8682	26.10	0.9237	44.57	0.9324	44.16	0.8795	26.14	0.862	23.80
ARCH-M							0.2136	2.35	0.2110	2.10
Variance Equation										
Intercept			0.0044	1.45**	0.0040	1.15**	0.0027	1.06**	0.0040	1.55**
ARCH(1)			0.3658	4.68	0.3448	2.95	0.2657	2.85	0.3386	2.52
GARCH(1)			0.6898	12.62	0.7111	8.91	0.7778	11.59	0.7695	10.81
Threshold									-0.1939	-1.05**
Distribution					1.2411	6.20	1.1296	6.89	1.1603	6.90
$\bar{R}^2$	0.78		0.77		0.77		0.78		0.78	
LL	-179.42		-124.15		-119.97		-117.12		-116.76	
DW	2.02		2.08		2.08		2.12		2.14	
AIC	1.8801		1.33383		1.3054		1.2862		1.2928	
SIC	1.9139		1.4229		1.4068		1.4046		1.4281	

significant impact on the variance of CDS spread attributable to good and bad news. The coefficient of the ARCH-M term was significant, implying for the risk pricing in the market segment.

4.4 Government Bond Yield

For the yield spread, i.e., the spread of 10-year government bond over the 91-day treasury bill rate, the ARMA(1,0)-TGARCH model was found appropriate for the analysis (Table 9a). In this model, the intercept term was significant and the size of coefficient suggested that the long rate could be higher than the short rate by 144 basis points. The coefficient of ARCH effect in the mean equation, which is indicative of risk pricing, was also found statistically significant. For every percentage point increase in the standard deviation, the mean spread could be higher by 0.65 percentage points. The threshold term was positive and significant, but its size was quite low. In the variance equation, the persistence was more or less due to the GARCH effect. The statistically significant coefficient for the generalised distribution was indicative of the non-standard distribution of the yield spread.

Table 9a: Government (10-Year) Bond Yield

	AR(1)		AR(1)-GARCH		AR(1)-GARCH*		AR(1)-GARCH*	
Variables	Coefficient	t stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9
Mean Equation								
Intercept	0.1023	1.56	0.1173	1.71	0.0363	0.90	1.4426	5.28
AR(1)	0.9490	36.97	0.9223	25.36	0.9453	48.74	0.8105	26.64
ARCH-M							0.6584	5.90
Variance Equation								
Intercept			0.0112	4.03	0.0108	1.77	0.0061	4.07
ARCH(1)			0.0179	1.62	0.0090	0.47	-0.0078	-3.01
GARCH(1)			0.9153	48.97	0.9209	23.62	0.9480	127.25
Threshold							0.0475	2.39
Distribution					0.9814	8.03	0.8560	8.28
$\bar{R}^2$	0.90		0.90		0.89		0.91	
LL	-109.47		-98.37		-81.60		--68.97	
DW	2.10		2.03		2.06		2.12	
AIC	1.4571		1.3513		1.1451		1.0061	
SIC	1.4967		1.4503		1.2639		1.1646	

For the short-end of the Government securities market, the spread of 91-day Treasury bill rate over the repo rate[5] was consistent with AR(1)-GARCH with logarithm of conditional variance in the mean equation (Table 9b). The intercept term in the mean equation was statistically significant and positive but small at 22 basis points. Thus, the 91-day Treasury bill could exceed repo rate on average by a quarter percentage point. The conditional variance had

Table 9b: Government 91-day Treasury Bill

	ARMA		ARMA_GARCH*	
Variables	Coefficient	t stat	Coefficient	Z stat
1	2	3	4	5
Mean Equation				
Intercept	0.1338	1.78	0.2272	3.35
AR(1)	0.9152	31.04	0.9599	90.89
ARCH-M			0.1198	2.74
Variance Equation				
Intercept			0.1012	2.65
ARCH(1)			0.6149	1.81
GARCH(1)			0.3451	2.83
Threshold			-0.0720	-0.20
Distribution			0.7784	7.77
$\bar{R}^2$	0.84		0.83	
LL	-226.61		-151.88	
DW	2.26		2.34	
AIC	2.394		1.674	
SIC	2.428		1.810	

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[5] The repo rate used in the study is the middle of repo and reverse repo rate.

positive effect, reflecting on the risk to the market segment had a positive effect on the 91-day Treasury bill spread as the coefficient of conditional variance term was found statistically significant in the mean equation. The conditional variance associated with the market segment was found to be persistent, as the sum of ARCH and GARCH terms were closer to unity. However, the market segment was not affected by news as the threshold term was statistically insignificant.

4.5 Forward and Spot Exchange Rates

For the 1-month forward exchange rate premium, the intercept coefficient in the mean equation for the spread of the 1-month forward exchange rate premium over the interest rate differential turned out negative in the GARCH model, where-as it was 81 basis points in the simple AR(1) model (Table 10). The coefficient of the GARCH volatility was significant but negative. Interestingly, when the model was allowed to have a threshold term to capture the news impact, the latter did not turn out to be significant. Unlike the GARCH model, the EGARCH model could show a positive impact of GARCH variance in the mean equation, and a significant impact of news effect on the market volatility. An interesting finding was that the drift parameter in the mean

Table 10: One-month Forward Exchange Rate Premium

	AR(1)		AR(1)-GARCH		AR(1)-GARCH		AR(1)-GARCH*		AR(1)-GARCH*		AR(1)-EGARCH$	
Variables	Coefficient	t stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9	10	11	12	13
Mean Equation												
Intercept	0.8139	1.03	0.2159	0.59	-0.4918	-2.23	-1.2104	-1.608	-1.4075	-2.07	-0.9055	-1.31
AR(1)	0.7320	13.74	0.6956	14.31	0.7386	19.82	0.7254	17.98	0.7530	19.17	0.6016	46.75
ARCH-M							-0.1889	-1.96	-0.1730	-1.72	1.3786	6.82
Variance Equation												
Intercept			0.4248	4.52	0.3494	1.99	0.4370	2.12	0.44	2.25	2.27534	6.78
ARCH(1)			0.6956	5.14	0.5389	2.23	0.5875	2.12	0.6677	2.01	-0.1334	-3.26
Threshold									-0.1905	-0.39	0.0847	5.496
GARCH(1)			0.3852	5.86	0.4751	3.33	0.4263	3.00	0.4230	2.98	-0.6231	-11.13
Distribution					0.8954	7.64	0.8370	7.24	0.8395	7.35	0.5611	8.71
$\bar{R}^2$	0.53		0.52		0.51		0.50		0.50		0.47	
LL	-398.22		-315.98		-296.52		-295.35		-295.19		-321.77	
DW	1.86		1.77		1.84		1.68		1.73		1.50	
AIC	4.8512		3.8906		3.618		3.6649		3.6750		3.9973	
SIC	4.8889		3.9847		3.735		3.7967		3.8256		4.1479	

equation was negative but not significant. This could imply two features of the market: a stronger rupee and the absence of arbitrage opportunity in the exchange market. Another interesting aspect of the EGARCH model was that the sum of ARCH and GARCH coefficients were negative and less than unity, implying that volatility could not be persistent in foreign exchange market. This result was not surprising, when one takes into account the stable exchange market objective and intervention strategy of the authorities. These findings were also evident for the three-month forward exchange rate premium (Table 11).

For the spot exchange rate of Indian Rupee per US dollar, the spread of annual depreciation over the interest rate differential (call money rate less 3-month LIBOR rate) was found to be consistent with AR(1)-GARCH model with logarithm of variance in the mean (Table 12). In this model, the intercept term in the mean equation was positive but statistically insignificant, suggesting that the spot exchange rate did not show a tendency to be away from uncovered interest parity in the long-run. Similarly, in the variance equation, the threshold term was not statistically significant, implying that the market did not respond asymmetrically to good or bad news. However, the conditional variance term

Table 11: Three-month Forward Exchange Rate Premium

	AR (1)		AR (1)-GARCH		AR (1)-GARCH		AR (1)-GARCH*		AR-EGARCH*		AR-EGARCH$	
Variables	Coefficient	t stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9	10	11	12	13
Mean Equation												
Intercept	0.4187	0.46	0.2943	0.53	-0.6096	-1.23	-1.6422	-0.63	-0.3511	-0.59	0.1740	0.16
AR(1)	0.8599	23.19	0.9008	31.01	0.8993	30.49	0.9066	30.28	0.6963	41.25	0.7248	35.15
ARCH-M							-0.0544	-0.44	0.8630	7.81	1.4635	8.12
Variance Equation												
Intercept			0.0549	2.38	0.0816	1.62	0.0821	1.60	1.9032	4.91	2.0788	6.95
ARCH(1)			0.5180	5.34	0.6018	2.94	0.5949	2.98	-0.3493	-3.60	-0.6386	-4.89
Threshold									0.4810	6.50	0.3737	5.34
GARCH(1)			0.5904	13.02	0.5162	4.92	0.5193	4.92	-0.4353	-3.52	-0.3031	-6.71
Distribution					1.1857	7.79	1.1847	7.80	0.5944	8.07	0.5736	9.31
$\bar{R}^2$	0.74		0.73		0.73		0.73		0.67			
LL	-377.14		-290.89		-282.22		-282.19		-331.41			
DW	1.72		1.78		1.77		1.77		1.27			
AIC	3.9700		3.0983		3.018		3.0281		3.5540			
SIC	4.0041		3.1835		3.1202		3.1473		3.6902			

Table 12: Spot Exchange Rate

	AR(1)		AR(1)-GARCH		AR(1)-GARCH		AR(1)-GARCH (*)		AR(1)-GARCH ($)	
Variables	Coefficient	t stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9	10	11
Mean Equation										
Intercept	-0.4502	-0.26	-9.5766	-2.65	-10.77	-2.14	-2.3631	-1.20	1.7099	1.04
AR(1)	0.8321	19.32	0.9271	32.51	0.9739	67.48	0.9191	41.48	0.8938	38.06
ARCH-M							0.0931	2.22	0.4334	3.55
Variance Equation										
Intercept			1.2583	4.16	1.2348	2.05	0.9456	1.82	0.5876	2.14
ARCH(1)			0.8238	6.43	0.8745	2.90	1.1269	2.36	1.0701	2.68
GARCH(1)			0.3755	6.64	0.3645	3.17	0.4060	3.42	0.4904	6.08
Threshold							-0.4739	-0.79	-0.5375	-1.14
Distribution					0.8824	8.66	0.9157	7.94	0.8493	8.37
$\bar{R}^2$	0.66		0.64		0.63		0.65		0.66	
LL	-537.00		-483.56		-461.96		-460.72		-456.33	
DW	2.21		2.30		2.39		2.38		2.38	
AIC	5.64		5.11		4.90		4.91		4.86	
SIC	5.68		5.20		5.00		5.04		4.99	

had positive and significant effect in the mean equation, implying that risk to the market had a pass-through effect on expected variation in the spot exchange rate. The most notable aspect of spot exchange rate was the volatility persistence, which was evident from the ARCH and GARCH coefficients in the conditional variance equation. The sum of these two coefficients was significantly higher than unity. Also, the generalised error distribution term was statistically significant, as conditional volatility in the market was affected by skewness and kurtosis attributable to the episodes of some sharp variations in the exchange rate.

4.6 Equity Market Return

For the equity market, the ARMA(1,0)-TGARCH-M model was suitable for modeling the spread of domestic equity return over the 91-day Treasury bill rate (Table 13). Here, we estimated four GARCH models. Two models were estimated with the mean equation having risk-return trade-off alternatively in terms of conditional standard deviation and variance. Further, for analysing the impact of international integration, two other GARCH models were estimated by incorporating the equity return spread for a global market, i.e., the US market as an explanatory variable in the mean equation. The estimated GARCH models provide some crucial insights about the risk pricing in the Indian context as compared with other market segments. First, the mean of equity return spread, as reflected in the intercept term in the mean equation in the ARMA-GARCH model was significantly higher than the simple ARMA(1,0) model. Second, the coefficient of ARCH-M, reflecting on risk-return trade-off was found statistically significant. A notable point here is that the coefficient of ARCH-M in the mean equation, which measures the risk-return trade-off, was negative, unlike the positive impact estimated for interest rates and the associated financial market segments discussed earlier. The asymmetry effect was positive, unlike the other market segments. These finding are in line with the theoretical and empirical literature. Black (1972) suggested this phenomenon as the leverage effect as volatilities and asset returns are negatively correlated. Because, declining stock prices imply an increased leverage on firms, worsening the debt/equity ratio. Thus, agents presume

Table 13: BSE SENSEX Equity Return

			Without the impact Global Market				With the impact of Global market			
	AR(1)		AR(1)-GARCH(*)		AR(1)-GARCH($)		AR(1)-GARCH*		AR(1)-GARCH$	
Variables	Coefficient	t stat	Coefficient	Zstat	Coefficient	Zstat	Coefficient	Zstat	Coefficient	Zstat
1	2	3	4	5	6	7	8	9	10	11
Mean Equation										
Intercept	-0.2544	-0.34	27.9347	4.98	95.5609	3.15	50.6805	13.26	160.6576	9.06
AR(1)	0.9519	38.76	0.8935	15.97	0.9090	20.10	0.6084	8.14	0.5639	9.22
ARCH-M			-2.8402	-4.98	-21.1323	-3.21	-5.7171	-24.71	-37.3597	-9.98
Global stock							0.6860	8.14	0.7736	8.99
Variance Equation										
Intercept			17.4071	2.08	36.5300	2.46	4.8029	2.13	4.7917	2.09
ARCH(1)			-0.1461	-3.45	-0.0844	-2.58	-0.1209	-5.02	-0.1052	-5.23
GARCH(1)			0.8522	9.19	0.6079	3.79	0.9373	26.47	0.9453	27.39
Threshold			0.1743	3.40	0.1205	2.66	0.2208	5.97	0.1623	6.11
Distribution			1.3263	7.26	1.4205	7.28	1.6933	4.99	1.9053	5.22
$\bar{R}^2$	0.89		0.89		0.90		0.89		0.89	
LL	-726.77		-704.17		-705.46		-690.90		-690.16	
DW	1.45		1.84		1.96		1.77		1.57	
AIC	7.5520		7.3800		7.3933		7.2528		7.2452	
SIC	7.5858		7.5152		7.5286		7.4049		7.3974	

investing in the firm to be riskier, resulting in volatility. Rising volatility, on the other hand, also makes investments riskier, and prices should fall in order to reflect this. Third, when global market was introduced in the GARCH model, the mean return increased by two fold and also, the ARCH-M coefficient rose significantly, thereby, suggesting that international integration accentuate risk pricing in the domestic market. Fourth, the intercept term in the variance equation was significantly moderated in the GARCH model in the presence of global market, thus, reflective on the benefit of international integration in terms of risk pricing over longer horizon.

4.7 Corporate Bond Yield

For the corporate bond yield, we examined the behavior of the spread of AAA rated 10-year corporate bond yield over the risk free rate alternatively with respect to 91-day Treasury bill, 364-day Treasury bill and 10-year Government bond yield based on data available for the sample period April 2000 to March 2009. Initially, we estimated the ARMA(1,0) model and then tested whether the residuals arising from the model could be subject to first order ARCH effect through LM test, so that the GARCH modeling could be taken up for the market segment. Results from the AR(1) model showed that on average, corporate bond yield could be higher than the 91-day Treasury bill, 364-day treasury bill and the

Table 14: Corporate Bond Yield Spread

	Spread over 91-day Treasury bill		Spread over 364-day Treasury bill		Spread over 10-year Government bond yield	
	ARMA(1,0)		ARMA(1,0)		ARMA(1,0)	
Variables	Coefficient	T stat	Coefficient	T stat	Coefficient	T stat
1	2	3	4	5	6	7
Intercept	2.44	8.33	2.34	4.56	1.34	2.88
AR(1)	0.86	14.63	0.93	17.59		25.49
$\bar{R}^2$	0.67		0.74			0.86
LL	-57.2		-35.26			-5.42
DW	1.96		2.03			1.99
AIC	1.10		0.69			0.14
SIC	1.15		0.74			0.19
First Order ARCH LM test :						
Fstat (probability)	2.48 (0.12)		0.01(0.99)			0.56(.45)

10-year Government bond yield by 244, 234 and 134 basis points, respectively (Table 14). However, none of the three alternative corporate bond yield spread variables could pass through residual ARCH test and therefore, the GARCH exercise could not be taken up. This result suggests that risk pricing could be lacking for this market segment. It may be noted that the finding is line with the literature in the Indian context (RCF, 2005-06). The Committee on corporate debt market (Chairman: R. H. Patil) pointed out various problems including the risk pricing affecting this market segment and made various recommendations for developing the market segment in India.

4.8 Risk Pricing during Global Crisis

In the earlier section, our empirical analysis was based on the full sample period, i.e., April 1993 to March 2009, which included the period since January 2008 associated with the global crisis. A critical issue arises here. Did the risk pricing mechanism underlying the Indian financial markets change since January 2008? Thus, the sample period was restricted to December 2007 for the chosen GARCH models (Table 15). A comparision between models under the restricted sample and full sample provided some interesting insights into the risk pricing mechanism. First, for the call money market, there was a significant increase in the ARCH and GARCH coefficients in the variance equation. The coefficient of threshold variable almost doubled in the environment of global crisis, implying for the sensitivity to bad (good) news about liquidity risk. However, on a positive note, the ARCH-M coefficient declined rapidly in the mean equation in the more recent period than the earlier period. Second, for the commercial paper, its long run mean spread over the 91-day Treasury bill, i.e. (intercept term in the mean equation) declined, attributable to the monetary easing pursued in the more recent period. There was no significant change in the volatility persistence as reflected in the coefficients of ARCH and GARCH terms. The threshold terms in the variance equation, however, increased to reflect greater sensitivity to good/bad news.

Table 15 :Risk Pricing and Global Crisis

	Full Sample (1993-2009)		Restricted (1993-2007)		Full Sample (1993-2009)		Restricted (1993-2007)	
Variables	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5	6	7	8	9
	Call				CPS			
			Mean Equation					
Intercept	0.2833	4.03	-6.83	-17.29	2.5584	8.03	3.17	5.23
AR(1)	0.5651	36.38	0.32	23.54	0.7993	14.06	0.9	45.5
ARCH-M	0.0464	3.12	3.24	20.3	0.3246	1.98	0.22	3.4
			Variance Equation					
Intercept	0.0431	2.11	2.5	10.16	0.0233	2.34	0.007	2.7
ARCH(1)	0.9475	2.49	0.22	24.06	0.3441	2.34	0.08	20.2
GARCH(1)	0.6407	9.54	0.73	36.22	0.7945	13.97	1.02	60.9
Threshold	-0.8951	-2.19	-0.47	-34.76	-0.3264	-1.99	-0.27	-6.06
Distribution	0.5616	13.57	0.35	12.7	1.1636	7.07	1.37	7.58
Rsq	0.26		0.22		0.7		0.72	
LL	-295.14		-299.99		-197.17		-157.8	
DW	2.16		2.2		2.22		2.2	
	CDS				G10			
			Mean Equation					
Intercept	1.5255	3.15	1.48	3	1.4426	5.28	-0.25	-0.6
AR(1)	0.862	23.8	0.89	27.2	0.8105	26.64	0.97	55
ARCH-M	0.211	2.1	0.21	2.25	0.6584	5.9	-0.16	-0.6
			Variance Equation					
Intercept	0.004	1.55**	0.004	1.32	0.0061	4.07	0.25	2.6
ARCH(1)	0.3386	2.52	0.3	2.3	-0.0078	-3.01	0.01	0.39
GARCH(1)	0.7695	10.81	0.76	10.1	0.948	127.25	-0.25	-0.8
Threshold	-0.1939	-1.05**	-0.08	-0.42	0.0475	2.39	0.14	0.74
Distribution	1.1603	6.9	1.1	6.8	0.856	8.28	1	7.4
Rsq	0.78		0.8		0.91		0.89	
LL	-116.76		-96.2		-68.97		-76	
DW	2.14		2.2		2.12		2.2	
	FR1				FR3			
			Mean Equation					
Intercept	1.21	1.96	0.95	1.44	2.47	3.57	2.53	4.3
AR(1)	0.76	19.7	0.77	19.63	0.78	20.47	0.72	16.94
ARCH-M	0.36	2.6	0.3	2.03	0.51	3.83	0.71	4.9
			Variance Equation					
Intercept	-0.39	-3.4	-0.5	-3.09	-0.41	-3.34	-0.37	-4.35
ARCH(1)	0.73	3.98	0.88	3.51	0.83	4.4	0.72	6.2
GARCH(1)	0.89	18.2	0.84	12.8	0.85	16.2	0.88	23.4
Threshold	-0.23	-1.8	-0.25	-1.54	0.06	0.52	0.08	0.93
Distribution	0.91	6.1	1	5.6	0.9	10.1	0.87	10.1
Rsq	0.56		0.57		0.44		0.42	
LL	-291.1		-257.5		-353.3		-322.2	
DW	2.36		2.44		2.7		2.7	
	BSER (without global)				BSER (with global)			
			Mean Equation					
Intercept	27.9347	4.98	26.69	4.9	50.6805	13.26	27.1	6.5
AR(1)	0.8935	15.97	0.9	16.7	0.6084	8.14	0.82	17.1
ARCH-M	-2.8402	-4.98	-2.77	-4.64	-5.7171	-24.71	-3.2	-6.7
Global					0.686	8.14	0.43	4.28
Intercept	17.4071	2.08	19.67	2.19	4.8029	2.13	7.35	2.5
			Variance Equation					
ARCH(1)	-0.1461	-3.45	-0.14	-3.02	-0.1209	-5.02	-0.14	-4
GARCH(1)	0.8522	9.19	0.81	7.19	0.9373	26.47	0.93	20.7
Threshold	0.1743	3.4	0.17	2.8	0.2208	5.97	0.2	3.8
Distribution	1.3263	7.26	1.6		1.6933	4.99	1.75	4.93
Rsq	0.89		0.89		0.89		0.89	
LL	-704.17		-644		-690.9		-635	
DW	1.84		1.94		1.77		1.82	

The ARCH effect in the mean equation also increased, implying greater risk-return trade-off in this market. A similar finding also held for the certificates of deposits. Third, the 10-year government bond yield showed a significant increase in its average spread over the short-rate as implied by the intercept term in the mean equation. It also witnessed a significant accentuation of risk-return trade–off in the more recent period. Fourth, as regards the forward exchange premium, the mean spread increased for the 1-month maturity but remained more or less stable for the 3-month maturity. A similar pattern held for the ARCH-M term or the risk-return trade–off parameter. The market showed more or less stability in the threshold term relating to the news impact. Fifth, for the equity market, the expected return (the intercept term) showed stability in the absence of global market variable. In the presence of the latter, however, there was a sharp increase in the expected return. A similar pattern of results also held for the risk-return trade-off parameter. A notable point was that the underlying persistence characteristic of the market did not show any significant change. Moreover, the market's response to good (bad) news was not much affected. Finally, the spot exchange rate showed two interesting aspect of change in terms of underlying risk pricing for the alternative sample period (Table 16). On the one hand, the GARCH model without the threshold effect showed a shift from a statistically significant to insignificant intercept term in the mean

Table 16: Risk Pricing in Spot Exchange Rate and Global Crisis

	Full Sample (1993-2009)		Restricted (1993-2007)	
Variables	Coefficient	Z stat	Coefficient	Z stat
1	2	3	4	5
Mean Equation				
Intercept	1.5578	0.73	4.5587	1.94
AR(1)	0.9212	50.37	0.9100	51.18
ARCH-M	0.3698	3.59	0.5780	4.40
Variance Equation				
Intercept	0.7480	2.03	0.6764	2.40
ARCH(1)	0.8333	3.02	0.6592	3.10
GARCH(1)	0.4548	4.63	0.5111	6.16
Distribution	0.8370	8.68	0.8432	8.90
$\bar{R}^2$	0.66		0.59	
LL	-456.99		-416.66	
DW	2.39		2.51	

equation for the spread of annual variation in exchange rate over the interest rate differential. On the other hand, the coefficient size of conditional variance term in the mean equation declined when the sample included the recent crisis period. This result could be attributable to the effectiveness of exchange rate management in the more recent period.

5. CONCLUSION

In this study, we used the univariate GARCH model to evaluate the ability of various financial market segments to price risks in the Indian context. Empirical analyses brought to the fore several insights in this regard. First, the various segments of financial markets, excepting the corporate bond yield, exhibited their ability to price risks. A crucial finding here was that the underlying risk pricing mechanism for various interest rates was different from that of the equity returns. In particular, the conditional measure of risk arising from the GARCH model had positive impact on the conditional mean of various interest rate spreads, reflecting the trade-off between risk and return in the associated markets. On the other hand, the conditional risk showed inverse relationship with equity return, attributable to the leverage effect as postulated in the finance literature. Second, different market segments pertaining to liquidity, interest rate, credit, exchange rate and asset prices exhibited different volatility persistence. Third, money market interest rates, forward exchange rate premium and equity prices showed significant asymmetric response to good (bad) news. Fourth, the spot exchange rate did not show a tendency to depart from the interest rate parity over longer horizon, despite showing volatility persistence. Fourth, all financial variables were found to be consistent with non-standard generalised error distribution. This implied that markets also took into account skewness and kurtosis measures influenced by the extreme movements as part of pricing risks. Fifth, international integration accentuated risk pricing in the domestic stock market in terms of higher mean and risk-return trade off.

From policy perspective, an understanding of the risk pricing mechanism assumes importance in many ways. The ability of markets to price various risks could reflect on the risk management by financial intermediaries and participants to hedge against risks, devise optimal hedging strategies, establish trading strategies and make portfolio allocation decisions. Also, risk pricing could imply for operating efficiency on the part of financial intermediaries and other market participants. Such efficiency in turn contribute to efficiency in allocation of resources to productive sectors, thereby, leading to a more matured and developed financial system. In terms of our empirical analysis, two key findings need to be mentioned here. First, financial markets at short-end showed their ability to price risks. Second, at the long end of the market, the sensitiveness of the equity market to international integration and the absence of risk pricing in the long-term corporate bond market segment require some thoughts on developing these market segments further.

Going beyond the study, the risk pricing analysis could be extended in three ways for further research. First, a multivariate GARCH analysis involving interest rates, exchange rate and equity prices could serve useful in terms of identifying how different risks percolate across market segments. Second, the GARCH analysis could be carried out using macroeconomic factors so as to identify whether the various types of risks connect with fundamentals such as inflation, growth, liquidity and turnover. Third, the evidence from the risk pricing analysis arising from monthly data could be compared with daily and weekly data in order to derive insights on the risk pricing due to the speed of markets in processing information. Taken together, these aspects of risk pricing could enrich financial stability analysis in the Indian context.

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