Volatility Spillover in India, USA and Japan Investigation of Recession Effects

Sinha, Pankaj and Sinha, Gyanesh

Faculty of Management Studies, University of Delhi, Delhi

6 April 2010

Volatility Spillover in India, USA and Japan: Investigation of Recession Effects

Pankaj Sinha and Gyanesh Sinha

Faculty of Management Studies, University of Delhi

Abstract

In the past decades, there has been an unprecedented increase in cross border transactions between countries in terms of goods and financial flows. This integration has been fuelled by search of lower risk investments, risk diversification, search for cost effective and more efficient factors of production and dreams of global dominance in the world wide market place. An important result of these capital flows was its impact on linkages of global asset returns and spillover of volatility from one capital market to another. This study aims to understand the spillover effect between the US, the Japan capital markets and Indian equity index (Sensex). We analyze whether the volatility spillover is contemporaneous (directly in the very same day), or dynamic/lagged (with one day lag). A GARCH (1,1) model for modelling volatility spillover has been undertaken for this purpose. This paper concludes that contemporary volatility of the Japan capital markets influenced Sensex in the pre-recession period but in the post recession there was no significant contemporaneous spillover from USA and Japan capital markets to Sensex. However, US became a significant factor while considering dynamic spillover in the post-recession era. Also, there was no bidirectional volatility spillover from India to US. But, the study showed evidence of dynamic volatility spillover from Indian market to Japanese Capital market.

Introduction

In the past decades, there has been an unprecedented increase in cross border transactions between countries in terms of goods and financial flows. This integration has been fuelled by search of lower risk investments, risk diversification, search for cost effective and more efficient factors of production and dreams of global dominance in the world wide market place. This integration has been gaining momentum because of gradual lifting of restrictions on capital flows and relaxation of exchange control in many countries. Advances in computer technology, telecommunications and transportation have also expedited international financial flows.

An important result of these capital flows was its impact on linkages of global asset returns. With freer flows, market became more closely connected. These linkages were evident during stressful market events, such as the International Crash of October 1987, European Currency Crisis in 1992, the Asian flu in 1997, the Russian Government's default and the collapse of LTCM in 1998, and the recent subprime crisis of 2007, when stock markets around the world experienced abrupt downfalls.

These simultaneous downfalls in markets across the world generated academic and industry interest in understanding the correlations between the global equity markets and several researchers have examined the degree of interdependence among the world's major equity markets. Two main approaches to analyze interdependence can be recognized from the literature. The first approach is to examine various aspects of market interdependence using cointegration and causality. The second approach is to examine interdependence in terms of volatility spillover.

USA and Japan capital markets have been established as two of the most influential capital markets in the world through various researches. In 2008, crash in USA and Japan capital market was followed by crashes in other capital markets throughout the world. During that time, Sensex (Bombay stock Exchange Benchmark) recorded loss of 74%. On the other hand, in 2006 and 2007, Sensex gave return of respectively 38% and 37%. But with financial crisis caused by subprime mortgage in USA, Sensex fell continuously.

This paper contributes to the existing literature in two ways. First, this paper attempts to investigate the contemporaneous and dynamic volatility spillover effects between Indian capital market and two of the most influential capital markets in the world, USA and Japan. It is intuitive to assume only unidirectional impact to exist from USA and Japan, but this paper will show that this is not the case always. Second, this paper examines the impact if recession as a structural change in these capital markets in terms of volatility spillover. It is intuitive to assume that after recession, resilient emerging markets such as India would impact unstable USA and Japan capital markets in a different manner as there has been lot more capital inflow into India post recession. This paper will show how this structural change is evident in volatility spillover effects between these three capital markets.

The paper is divided into five sections. The second section provides the literature review in the area of volatility spillover research. The third section illustrates the data used and the econometric model used to compute volatility spillover effects. The fourth section provides insights into the relationship between the volatilities and extent of volatility spillover between each capital market pair. In the fifth section, the conclusion of the work is presented.

Literature Review

Bala and Premaratne (2003) study the direction of volatility of stock market of US, UK, Hong Kong and Japan. The models they use include GARCH, Vector Autoregression and MGARCH Model and Asymmetric GARCH with GJR extensions. They conclude that there exists a strong degree of relationship between stock market of Singapore and Hong Kong, followed by Singapore and US, Singapore and Japan, Singapore and UK. They also observe a flow of volatility from Singapore to Hong Kong, Japan and US markets.

Abraham and Seyyed (2006) analyse whether the stock markets of United States, Saudi Arabia and Bahrain are integrated, by employing cointegration techniques. They employ the US index, Saudi Index and Bahrain index for the study. To examine the flow of volatility from one market to the other, the authors use EGARCH model. From cointegration, they do not find a long term relationship between the stock indices of the stock markets of the three economies and attribute this to the difference in orientation and size of Bahrain (financial services dominate here) and Saudi Arabia (based on trade in crude oil). From results of EGARCH model, they observe a flow of information from Bahrain to Saudi Arabia.

Mulyadi (2009) using return data of stock market of Indonesia, USA and Japan and applies the GARCH(1,1) model to assess the volatility spillover of returns across the three markets. The analysis is for the period ranging from January 2004 to December 2008. The paper studies both types of volatility spillover – contemporaneous and dynamic. The author provides evidence that there is presence of both types of volatility spillover between the three stock markets i.e. Indonesia and USA and Indonesia and Japan.

Janakiramanan and Lamba (1998) use vector autoregression to study the linkage between the equity market of Australia, Hong Kong, Japan, New Zealand, Singapore, US, Indonesia, Malaysia and Thailand. Their results suggest that US markets influence stock markets of all the countries chosen for the study except that of Indonesia. They conclude that the reason for integration across markets is either geographical or economical or due to cross listing of stocks.

Baele (2003) find that for nearly all European equity markets countries, the probability of a high EU and US shock spillover intensity has increased significantly over the 1980s and 1990s, even though the increase is more pronounced for the sensitivity to EU shocks. In fact, in many countries, the sensitivity to EU shocks dropped considerably after 1999. Their study shows that, EU shocks explain about 15 percent of local variance, compared to 20 percent for US shocks and that while the US – as a proxy for the world market - continues to be the dominating influence in European equity markets, the importance of the regional European market is rising considerably.

By using the VAR method, Cheung and Cha (1998) empirically investigate the relationships between the four Asian emerging markets: Hong Kong, Korea, Singapore and Taiwan, and the two largest markets in the world: U.S. and Japan. They find that the four AEMs react differently to the price movements in the U.S. and the Japanese markets. They conclude that the U.S. plays an important role in leading other equity markets. Their research shows that while most of forecast error variance of the return rates in these markets is explained by domestic own innovations, U.S. and Japanese innovations have more explanatory power in Hong Kong and Singapore than in Korea and Taiwan. This foreign effect is pronounced after the Crash of the October 1987, especially in Singapore. The results show that the U.S. market affects the Hong Kong and the Singapore markets, but not the Korean and the Taiwanese markets while the Japanese market has little impact except on the Korean market.

Piero et al (1998) investigate the spillover of volatilities using daily returns in the New York (United States), Tokyo (Japan) and Frankfurt (Germany) stock markets during the period from January, 1990 to September, 1993. They find stock market of New York to be the most influential market. Their study finds Tokyo to be the most sensitive market, with a level of sensitivity that more than doubles that of New York, with Frankfurt between the two. Lin, Engle, and Ito (1994) provide evidence of transmission using intraday daily data of the stock markets of Tokyo and New York. They find that the day time returns of Tokyo are related to Overnight returns of New York stock market. They find bi-directional flow of impact of return and volatilities across New York and Tokyo.

Kupiec (1991) studies the stock market return volatility correlations among 15 OECD countries and concludes that the average pair wise correlation among these 15 countries' stock returns increased over 50 percent between the first and the second half of the 1980s. Their examination of the individual correlation estimates indicates that the correlations between G7 countries' indices became measurably stronger earlier, whereas the correlations among the non-G7 country indices increased for the most part during the late 1980s. They find that correlation changes for the 1980s indicate that, for the G7 markets, returns have become only slightly more positively correlated over the period whereas for the other markets, return correlations have increased more substantially. The estimates show that volatilities, particularly among the major markets, were much more strongly positively correlated in the second half of the 1980s as compared with the first half of the decade.

Hamao, Masulis, and Ng (1990) study the three major financial markets of the world including Tokyo, London and New York utilising ARCH models and their study concludes that there was absence of volatility spillover effect prior to October 1987.

A few studies have been performed using Indian stock market as one of the markets. Mukherjee and Mishra (2008) conclude that apart from different degrees of correlations, both in terms of returns and volatility of returns, among Indian equity index viz. SENSEX with that of twelve other Asian countries, there is a significantly positive and bi-directional contemporaneous intraday (open-to close) return spillover among India and almost all the foreign countries except only with Sri Lanka. But unlike contemporaneous spillover, transmission of information lagged by one day, alternatively dynamic intraday spillover among India and its major Asian counterparts are not found to be stronger, especially in one direction, i.e. from other Asian countries to India. These facts clearly suggest that the information generated in Indian market gets transferred into other Asian markets not only on the same day but also in the next day.

Using indices of NIFTY of India, STI of Singapore and TAIEX of Taiwan for the period Janaury 1994 to November 2002, Nath (2003) concludes that absence of integration exists in the long run between the stock markets. Using Granger causality they provide evidence that returns of one stock market mildly influence returns in another stock market. Kumar and Mukhopadhyay (2002) use Granger Causality and GARCH model and its variants to analyse the interdependence between NSE Nifty and NASDAQ composite index of US. They find that there is unidirectional causality from NASDAQ to NSE.

Data and Methodology

The closing price of indices of the three countries viz. India (Sensex), Japan (Nikkei 225), and USA (S&P 500) are utilised for this study and the data has been extracted from website of Yahoo Finance. The study ranges from January 1st 2005 to December 31st 2009. To the study the effect of recession, data is split into two periods, January 1st 2005 to December 31st 2007 (pre-recession), and January 1st 2008 to December 31st 2009 (post-recession).

To calculate volatility of returns data from October 25th 2004 to December 31st 2009 has been used. Log return (percentage) has been calculated. Daily closing price data of the indices has been used as daily return to capture all possible interactions. For volatility standard deviation of past 50 days of the returns on all the indices has been computed.

Model used

We used GARCH (1, 1) model in this research to analyze volatility spillover from time series data. GARCH model is the accurate model for volatility as the error terms in the return time series show heteroskedastic behaviour. This model has been sauggested by Mulyadi (2009), Mukherjee and Mishra (2008). This means that, the variance of the error terms is not constant for these time series.

$$var\,(\varepsilon_{i,t}) \neq constant$$

For each of the indices, the volatility is calculated from standard deviation of past 50 days returns which is further used in the GARCH model. The following two models are used to test contemporaneous spillover (equation 1 to 4), and dynamic spillover (equation 5 to 8):

Model for contemporaneous spillover

$$R_{i,t} = \gamma_0 + \gamma_1 R_{i,t-1} + \gamma_2 R_{j,t} + \gamma_3 h_{j,t} + \varepsilon_{i,t} \qquad (1)$$

$$h_{i,t} = \alpha_0 + \alpha_1 \varepsilon_{i,t-1}^2 + \alpha_2 h_{i,t-1} + \delta_1 h_{j,t} \qquad (2)$$

$$R_{j,t} = \theta_0 + \theta_1 R_{j,t-1} + \theta_2 R_{i,t} + \theta_3 h_{i,t} + \varepsilon_{j,t} \qquad (3)$$

$$h_{j,t} = \beta_0 + \beta_1 \varepsilon_{j,t-1}^2 + \beta_2 h_{j,t-1} + \Phi_1 h_{i,t} \qquad (4)$$

$R_{i,t}$: Return of domestic capital market at t period

$R_{i,t-1}$: Return of domestic capital market at t-1 period

$R_{j,t}$: Return of foreign capital market at t period

$R_{j,t-1}$: Return of domestic capital market at t-1 period

$h_{i,t}$: Volatility of domestic capital market at t period

$h_{i,t-1}$: Volatility of domestic capital market at t-1 period

$h_{j,t}$: Volatility of foreign capital market at t period

$h_{j,t-1}$: Volatility of foreign capital market at t-1 period

$\varepsilon_{i,t}$: Error of domestic capital market at t period

$\varepsilon_{j,t}$: Error of foreign capital market at t period

From above model we can see that $R_{j,t}$ and $h_{j,t}$ are contemporaneous spillover variable from foreign capital market (another country). Meanwhile, models used to test dynamic spillover are:

Model for dynamic spillover

$$R_{i,t} = \eta_0 + \eta_1 R_{i,t-1} + \eta_2 R_{j,t-1} + \eta_3 h_{j,t-1} + \varepsilon_{i,t} \qquad (5)$$

$$h_{i,t} = \chi_0 + \chi_1 \varepsilon_{i,t-1}^2 + \chi_2 h_{i,t-1} + \omega_1 h_{j,t-1} \qquad (6)$$

$$R_{j,t} = \psi_0 + \psi_1 R_{j,t-1} + \psi_2 R_{i,t-1} + \psi_3 h_{i,t-1} + \varepsilon_{j,t} \qquad (7)$$

$$h_{j,t} = \xi_0 + \xi_1 \varepsilon_{j,t-1}^2 + \xi_2 h_{i,t-1} + \rho_1 h_{j,t-1} \qquad (8)$$

$R_{i,t}$: Return of domestic capital market at t period

$R_{i,t-1}$: Return of domestic capital market at t-1 period

$R_{j,t-1}$: Return of foreign capital market at t-1 period

$R_{j,t-1}$: Return of domestic capital market at t-1 period

$h_{i,t}$: Volatility of domestic capital market at t period

$h_{i,t-1}$: Volatility of domestic capital market at t-1 period

$h_{j,t-1}$: Volatility of foreign capital market at t-1 period

$\varepsilon_{i,t}$: Error of domestic capital market at t period

$\varepsilon_{j,t}$: Error of foreign capital market at t period

This paper tries to test both the contemporaneous and dynamic volatility spillover. Dynamic volatility spillover needs to be studied as there is a trading time lag between the USA and both the India and Japan capital markets. In table 1, trading time of three capital markets has been shown.

Table 1: Table of trading time on the Indian, Japanese and US capital markets

	All in IST	
	Opening	Closing
Nikkei 225 (Japan)	5:30 AM	11:30 AM
Sensex (India)	9:30 AM	3:30 PM
S&P 500 (USA)	7:00 PM	1:30 AM

Graphical Analysis

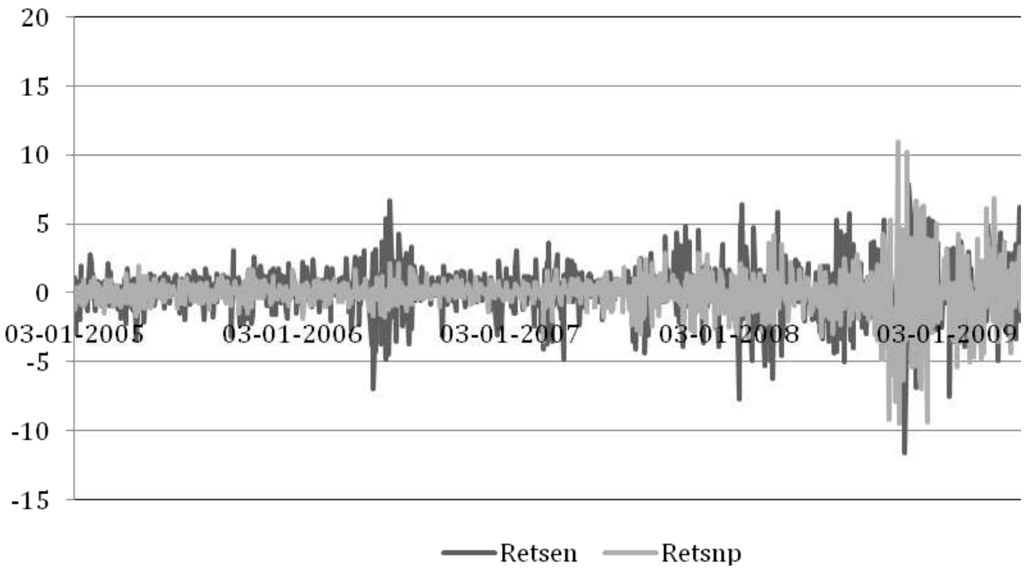

Figure 1: Graph of daily return on Sensex and S&P

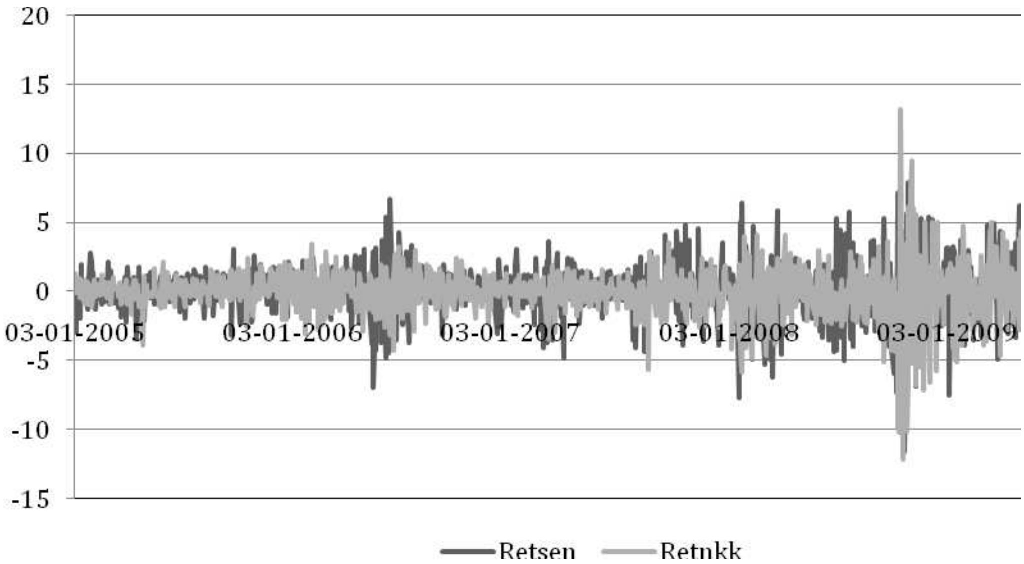

Figure 2: Graph of daily return on Sensex and Nikkei225

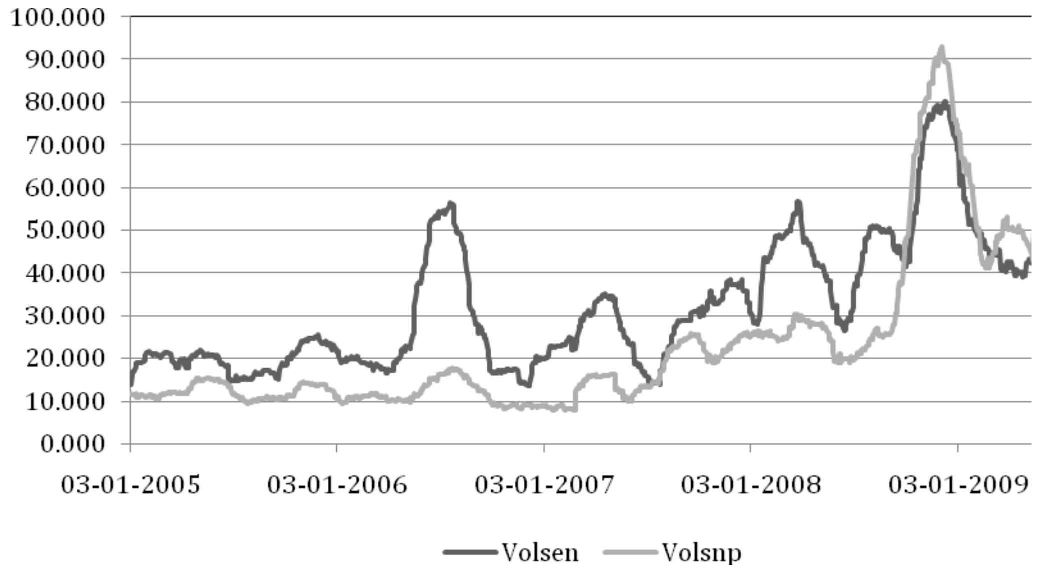

Figure 3: Graph of volatility of daily returns on Sensex and S&P

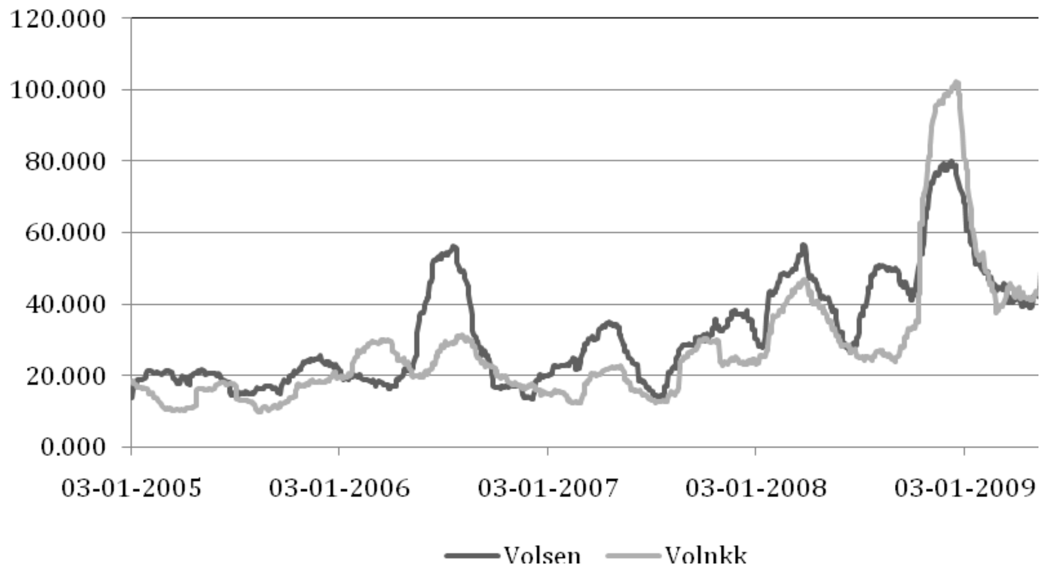

Figure 4: Graph of volatility of daily returns on Sensex and Nikkei225

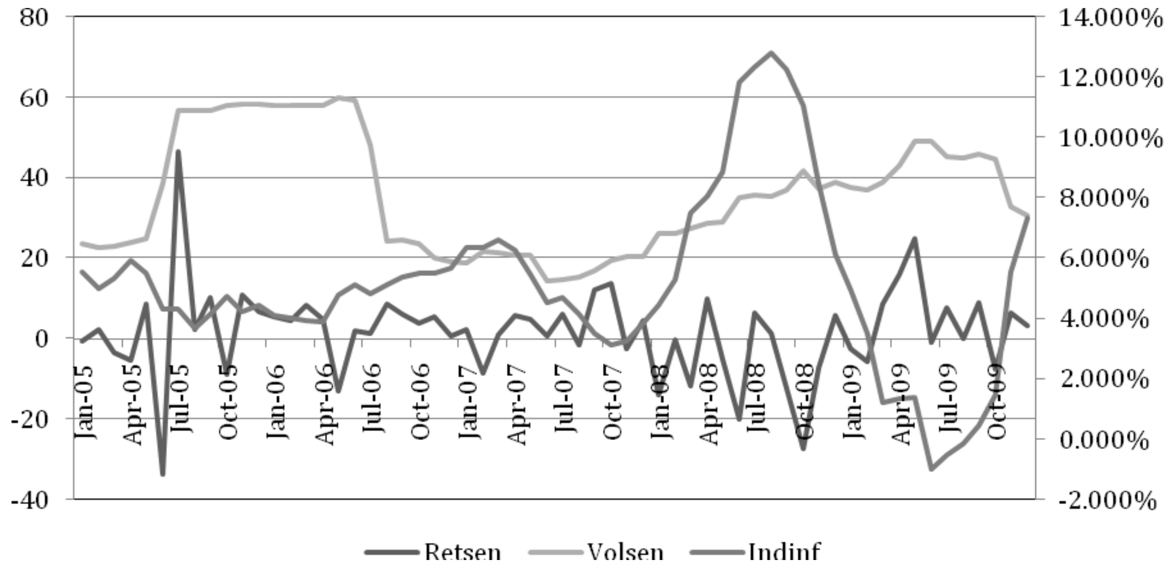

Figure 5: Graph of monthly returns, volatility and inflation for Sensex

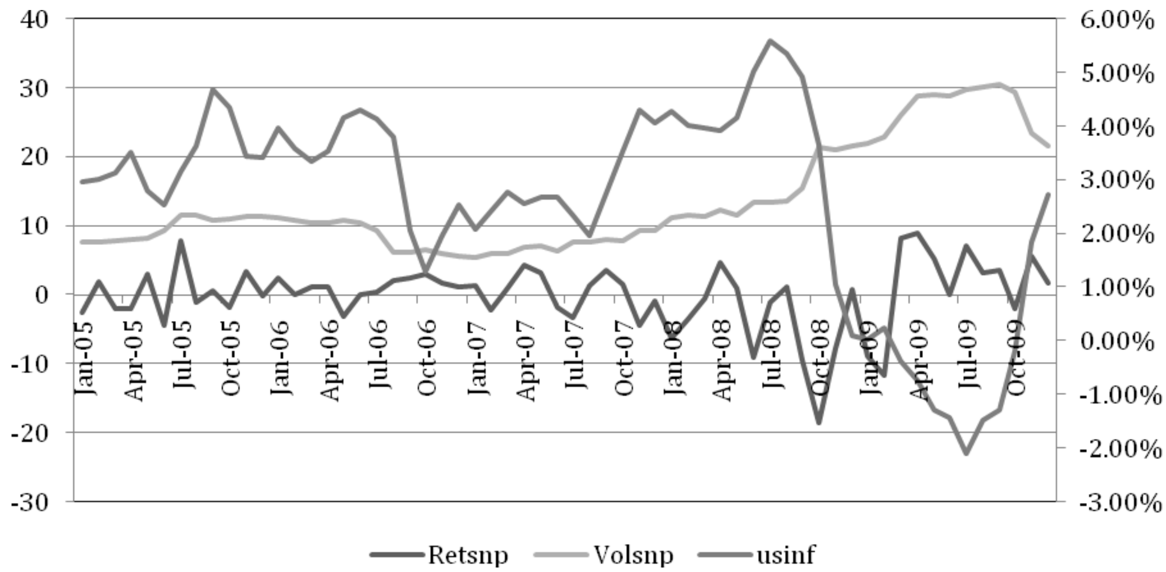

Figure 6: Graph of monthly returns, volatility and inflation for S&P

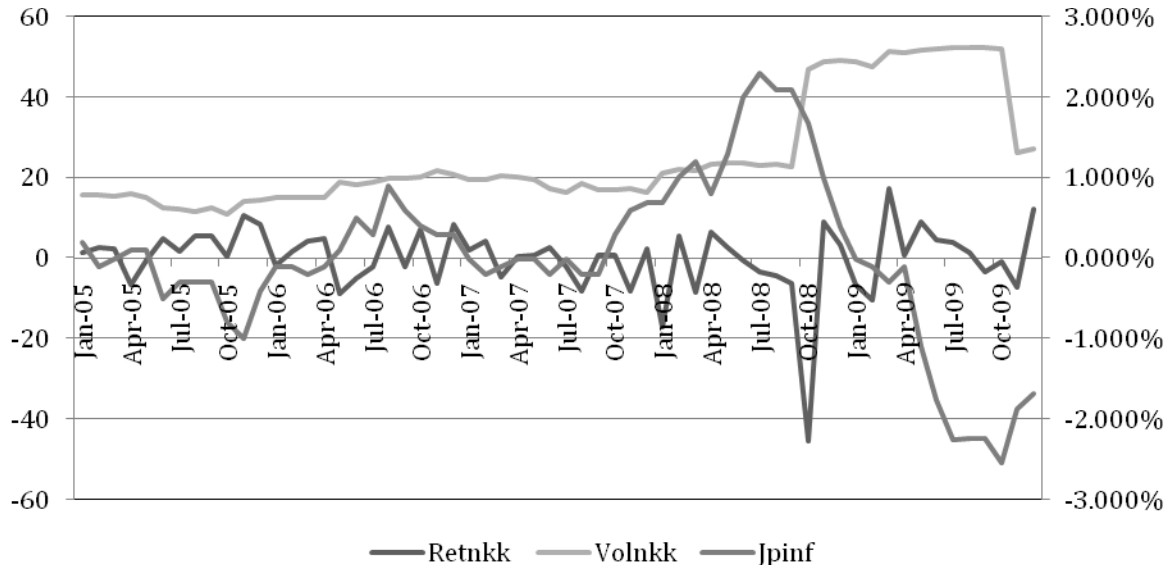

Figure 7: Graph of monthly returns, volatility and inflation for Nikkei

From the graphical analysis, we can see that there has been a significant shift in volatility levels after December 2007. The first news of financial institutions getting bust started coming out as early as January 2008 with AIG being the first. These incidents kept happening for the better part of 2008, with the major setback being, Lehman brothers going belly up. Thus, the period of 2005 to 2007 is taken to understand behaviour of capital markets before recession and the period of 2008 to 2009 is taken to understand the behaviour of markets post recession.

Results and Analysis

Test of contemporaneous volatility spillover between Sensex and S&P

In this section, we analyze contemporaneous volatility spillover between India and USA. From table 2 we can see that δ_1 coefficient shows that there is no significant volatility spillover from USA. However, as we have discussed earlier that there is a time lag between India and USA capital markets. So, the existence of volatility spillover from USA capital market which affected Indian capital market should be subject to advance research by employing dynamic model. The result will be discussed later on.

Meanwhile, from table 3 we can extract that volatility of USA capital market is not affected from volatility spillover of Sensex . From testing of first model, we can conclude that there is no volatility spillover between USA and Indian capital market both pre-recession period and post recession period.

However, it is interesting to note that in the post recession period, the previous day return become statistically insignificant (for level of significance = 5%) in determining present day return.

Table 2: Result of processed data from equation (1) and (2), Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
γ_0	-0.041544	-0.316885	-0.028388	-0.148728
γ_1	0.090798	2.174800	0.063755	1.311623
γ_2	0.160036	2.889944	0.391963	6.933713
γ_3	0.016684	1.706479	0.002061	0.348263
α_0	0.039067	1.302703	-0.088828	-0.901629
α_1	0.115752	5.510796	0.135067	4.587107
α_2	0.823674	25.515110	0.812787	21.562960
δ_1	0.005232	1.722136	0.012268	2.138149

Table 3: Result of processed data from equation (3) and (4) , Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-score	Value	Z-Score
θ_0	-0.036471	-0.529967	-0.049623	-0.239448
θ_1	-0.123143	-2.847798	-0.197384	-3.791932
θ_2	0.082884	4.409342	0.205026	6.276906
θ_3	0.002713	1.010074	0.001701	0.339276
β_0	0.015654	2.180277	-0.001838	-0.044276
β_1	0.056888	3.737308	0.091741	4.202666
β_2	0.910630	34.761610	0.897729	34.378450
Φ_1	0.000087	0.278828	0.000873	0.599420

Test of contemporaneous volatility spillover between Sensex and Nikkei

For the pre-recession period of 2005-2007, there was volatility spillover from Japanese capital markets to Sensex. However, this spillover was not significant in the post recession period of 2008-2009. For the Japanese capital market it is observed that previous day returns became significant only in the post recession period.

Table 4: Result of processed data from equation (1) and (2), Sensex and Nikkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
γ_0	-0.169407	-1.230426	0.104242	0.453526
γ_1	0.080071	1.907028	0.053331	1.092605
γ_2	-0.007382	-0.161961	0.055292	1.137688
γ_3	0.018673	2.712984	-0.001183	-0.178301
α_0	0.084454	2.739194	-0.095806	-0.666870
α_1	0.112846	5.651388	0.147464	4.777687
α_2	0.838648	31.763020	0.823236	20.586860
δ_1	0.000180	0.142080	0.009736	1.389624

Table 5: Result of processed data from equation (1) and (2), Sensex and Nikkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
θ_0	0.228946	2.128537	-0.179305	-0.644636
θ_1	0.002095	0.047006	-0.104283	-2.065412
θ_2	-0.005196	-0.226936	-0.001051	-0.037009
θ_3	-0.006659	-1.431707	0.003585	0.558723
β_0	-0.006428	-0.280609	0.071975	0.841636
β_1	0.094497	5.195824	0.137161	4.653833
β_2	0.862447	29.655440	0.818903	21.077180
Φ_1	0.002493	1.755695	0.002833	0.870515

Test of dynamic volatility spillover between Sensex and S&P

Previous day volatility was found to be significant in the post recession period, when considering spillover from USA to India, given that the previous day trading impacts trading Sensex today. It is interesting to note that where previous day return became significant only in post recession period for USA, previous day volatility was significant only in pre-recession period.

Table 6: Result of processed data from equation (5) and (6), Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
η_0	-0.002081	-0.015706	-0.039353	-0.189116
η_1	0.054678	1.433382	-0.005663	-0.117724
η_2	0.499621	9.869871	0.283437	5.127445
η_3	0.012216	1.232930	0.002819	0.411089
χ_0	0.050256	1.637629	-0.242964	-1.585071
χ_1	0.110654	5.091310	0.134927	3.854870
χ_2	0.828251	24.486350	0.790752	15.111090
ω_1	0.003611	1.251171	0.021756	2.187564

Table 7: Result of processed data from equation (7) and (8), Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
ψ_0	-0.017348	-0.248520	-0.092995	-0.448725
ψ_1	-0.069299	-1.638579	-0.140260	-2.560772
ψ_2	-0.021721	-1.134953	0.025670	0.858541
ψ_3	0.002691	0.988180	0.002915	0.563601
ξ_0	0.015596	2.470477	-0.027864	-0.668453
ξ_1	0.053363	4.079671	0.091590	4.141417
ξ_2	0.919098	44.074280	0.897479	34.497870
ρ_1	-0.000003	-0.009138	0.001634	1.139945

Test of dynamic volatility spillover between Sensex and Nikkei

Dynamic volatility spillover from Japan to Sensex was only significant for pre-recession period after which it has become statistically insignificant. Also, Sensex volatility seems to dynamically impact Nikkei volatility in the pre-recession era. Hence, dynamic spillover effect existed between Sensex and Nikkei in bi-directional relationship.

Table 7: Result of processed data from equation (5) and (6), Sensex and NIkkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
η_0	-0.193799	-1.394306	0.112297	0.491427
η_1	0.079624	1.882445	0.047994	0.947391
η_2	0.009208	0.248297	0.054727	1.218343
η_3	0.019867	2.858414	-0.001511	-0.229622
χ_0	0.085420	2.722669	-0.087819	-0.580088
χ_1	0.113343	5.667895	0.155542	4.697133
χ_2	0.838018	31.566610	0.813992	18.584460
ω_1	0.000136	0.107504	0.009855	1.327765

Table 8: Result of processed data from equation (7) and (8), Sensex and Nikkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
ψ_0	0.210620	1.975067	-0.210391	-0.763466
ψ_1	0.003652	0.082072	-0.107616	-2.110110
ψ_2	0.049375	2.177348	0.076073	2.476572
ψ_3	-0.006171	-1.343571	0.004331	0.681940
ξ_0	-0.000447	-0.020356	0.080356	0.910576
ξ_1	0.093990	5.148870	0.143839	4.730969
ξ_2	0.867408	29.667760	0.816869	21.353140
ρ_1	0.002025	1.466252	0.002295	0.730578

Consolidated results

Contemporaneous spillover

		Sensex -S&P		S&P-Sensex		Sensex - Nikkei		Nikkei-Sensex	
		05-07	08-09	05-07	08-09	05-07	08-09	05-07	08-09
Contemporaneous	Constant							Sig.	
	Lagged Domestic Return	Sig.		Sig.	Sig.				Sig.
	Foreign Return	Sig.	Sig.	Sig.	Sig.				
	Foreign Volatility					Sig.			
	Variance Equation								
	Constant			Sig.		Sig.			
	Squared residual	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Lagged Domestic Volatility	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Foreign Volatility								

Dynamic spillover

		Sensex -S&P		S&P-Sensex		Sensex - Nikkei		Nikkei-Sensex	
		05-07	08-09	05-07	08-09	05-07	08-09	05-07	08-09
Dynamic	Constant								
	Lagged Domestic Return				Sig.	Sig.		Sig.	Sig.
	Foreign Return	Sig.	Sig.						Sig.
	Foreign Volatility					Sig.		Sig.	
	Variance Equation								
	Constant			Sig.	Sig.	Sig.			
	Squared residual	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Lagged Domestic Volatility	Sig.	Sig.	Sig.		Sig.	Sig.	Sig.	Sig.
	Foreign Volatility		Sig.						

Sig. = Significant with degree of significance of 5%

Greyed areas denote those parameters for which have changed their behaviour after recession

Conclusion

Contemporary volatility of the Japan capital market (Nikkei 225) influenced the Indian capital market (Sensex) in the pre-recession period which is in line with the first hypothesis. But in the post recession there was no significant (level of significance = 5%) contemporaneous spillover from USA and Japan capital markets to Sensex. However, US became a significant factor while considering dynamic spillover in the post recession era. Also, there was no bidirectional volatility spillover from India to US. But, the study showed evidence of dynamic volatility spillover from Indian market to Japanese Capital market.

There is considerable impact of the recession which is evident from the fact that various factors lost significance as determinants of returns and volatility in the considered capital markets. The factors which showed change in behaviour are:

Factors which became insignificant after recession:

- Lagged domestic return for Sensex , while examining the contemporaneous spillover effect with USA
- Impact of contemporaneous volatility spillover from Japan to India
- Lagged domestic volatility in US market, while examining dynamic spillover effects from Sensex
- Impact of dynamic volatility spillover from Japan to India

Factors which became significant only after recession (Modelling without inflation):

- Lagged domestic return for Japanese capital market while examining contemporaneous spillover effect of Indian capital markets
- Lagged domestic return for USA capital market while examining dynamic spillover effects of Sensex
- Impact of dynamic volatility spillover from USA to India

The probable economic fundamentals guiding the results could be several. The extent of Foreign Institutional Investments and Foreign Direct Investment which moves from one capital market to another capital market, given existing volatilities could explain the observed results. Also, there could be intermediate linkages between capital markets through other capital markets, instead of direct causal relationships. Additionally, the time zone differences could also be impacting the extent of correlation between capital markets. The investigation of these causes is beyond the scope of this work, and is a matter of future research.

References

Abraham, A., & Seyyed, F. (2006). Information Transmission between the Gulf Equity Markets of Saudi Arabia and Bahrain. *Research in International Business and Finance* , 20(3): 276-285.

Al-Deehani, T. (2005). Modelling Volatility Spillover . *Journal of Accountig and Finance* , 4:35-44.

Baele, L. (2003). Volatility Spillover Effects in European Equity Markets. *Faculteit Economie En Bedrijfskunde Working Paper* .

Balasubramanyan, L. (2004). Do Time-Varying Covariances, Volatility Comovement and Spillover Matter? *Pennsylvania State University Paper* .

Balasubramanyan, L., & Premaratne, G. (2003). Volatility Spillover and Comovement: Some New Evidence from Singapore. *National University of Singapore Working Paper* .

Baur, D., & Jung, R. (2006). Return and Volatility Linkages between the US and the German Stock Markets. *Journal of International Money and Finance* , 25(4): 598-613.

Bekaert, G., & Wu, G. (2000). Asymetric Volatility and Risk in Equity Markets. *Review of Financial Studies* , 13:1-42.

Bodie, Z., Kane, A., & Marcus, A. J. (2009). *Investments.* 8th ed. Boston: McGraw-Hill.

Brooks, C. (2007). *Introductory Econometrics for Finance.* UK: Cambridge University Press.

Ceylan, N. B., & Basci, S. (2004). Modelling Stock Returns and Volatility With Some Macroeconomic Variables: A Case for Turkey, *mimeo*.

Cha, B., & Cheung, Y. (1998). The Impact of the US and the Japanese Equity Markets on the Emerging Asia-Pacific Equity Markets. *Asia Pacific Financial Markets* , 5(3): 191-209.

Christofi, A., & Pericili, A. (1999). Correlation in Price Changes and Volatility of Major Latin American Stock Markets. *Journal of Multinational Financial Management* , 9: 79-93.

Eun, C., & Shim, S. (1989). International Transmission of Stock Market Movements. *Journal of Finance and Quantitative Analysis* , 24:241-256.

Febrian, E., & Herwany, A. (2009). Volatility Forecasting Models and Market Co-integration: A Study on South-East Asian Markets. *Indonesian Capital Market Review* , 1: 27-42.

Francis, B., Hasan, I., & Hunter, D. (2002). Return Volatility Linkages in International Equity and Currency Markets. *Bank of Finaland Discussion Papers* .

Gagnon, L., & Karolyi, G. (2006). Price and Volatility Transmission Across Borders. *Financial Markets, Institutions and Instrument,* 5(3): 107-158 .

Hamao, Y., Masulis, R., & Ng, V. (1990). Correlations in Price Changes and Volatility Across International Stock Markets. *Review of Financial Studies* , 3: 281-307.

Harju, K., & Hussain, S. (2006). Intraday Linkages Across International Equity Markets. *Meddlelanden Working Papers* .

Janakiramanan, S., & Lamba, A. (1998). An Emperical Examination of Linkages between Pacific-Basin Stock Markets. *Journal of International Financial Markets* , 8: 155-173.

Khan, M., Ashraf, S., & Ahmed, S. (2005). Is Indian Stock Market Integrated with US and Japanese Markets? An Emperical Analysis. *South Asia Economic Journal* , 6(2): 193-207.

Kim, S. (2005). Information Leadership in the Advanced Asia-Pacific Stock Markets: Return, Volatility and Volume Information Spillovers from the U.S. and Japan. *Journal of the Japanese & International Economies* , 19(3): 338:365.

Kumar, K. K., & Mukhopadyay, C. (2002). Equity Market Interlinkages: Transmission of Volatility -A Case of US and India. *NSE Research Paper* .

Kupiec, P. (1991). Stock Market Volatility in OECD Countries. *Economic Studies* , 17: 31-62.

Lamba, A. An Analysis of the Dynamic Relationships Between South Asian and Developed Equity Markets. *Tenth Annual Conference of the Multinational Finance Society.* Montreal.

Lee, H., & Hong, W. (2008). International Transmission of Swap Market Movements: The US, Korea and China. *Sogang University Working Paper* .

Lin, W., Engel, R., & Ito, T. (1994). Do Bulls and Bears Move Across Borders? International Transmission of Stock Returns and Volatility. *Review of Financial Studies* , 7: 507-538.

Mougoue, M., & Bond, M. (1991). Interrelationships Among Exchange Rate Adjusted Total Equity Returns: A Causality Apporach. *Akron Business and Economic Review* , 22: 51-64.

Mukherjee, K., & Mishra, R. (2008). Stock Market Integration and Volatility Spillover: India and its Major Asian Counterparts. *Munich Personal Re-Pec Archive* .

Mulyadi, M. (2009). Volatility Spillover in Indonesia, USA and Japan Capital Markets. *Munich Personal Re-Pec Archive* , MPRA Paper No. 16914.

Nath, G. C., & Verma, S. (2003). Study of Common Stochastic Trend and Co-Integration in the Emerging Markets: A Case Study of India, Singapore and Taiwan. *NSE Research Paper* .

Ng, A. (2000). Volatility Spillover Effects from Japan and US to the Pacific-Basin. *Journal of International Money and Finance* , 19: 207-233.

Nicholas, S., & Zhu, Z. (2000). Correlations in Returns and Volatility in Pacific-Rim Stock Markets. *Open Economics Review* , 11: 27-47.

Peiro, A., Quesada, J., & Uriel, E. (1998). Transmission of Movements in Stock Markets. *The European Journal of Finance* , 4(4): 331-343.

Rigobon, R., & Sack, B. (2003). *Spillovers Across US Financial Markets.* MIT Sloan Working Paper 4304-03.

Tanizaki, H., & Hamori, S. (2009). Volatiltity Transmission Between Japan, UK and USA in Daily Stock Returns. *Emper Econ* , 36(1): 27-54.

Veiga, B. M. (2004). *Multivariate Volatility and Spillover Effects in Financial Markets.* International Environmental Modelling and Software Society.

Wang, Y., Gunasekarage, A., & Power, D. (2005). Return and Volatility Spillovers from Developed to Emerging Capital Markets: The Case of South Asia. *Contemporary Studies in Economic and Financial Analysis* , 86: 139-166.

Worthington, A., & Higgs, H. (2000). A Multivariate GARCH Analysis of Equity Returns and Volatility in Asian Equity Markets. *Queensland Institute of Technology Working Paper*

Data source: finance.yahoo.com (retreived on January 29, 2010)

Appendix: Eviews Results

Results for equation (1) and (2), Sensex and S&P, 2005-2007

Dependent Variable: RETSEN
Method: ML - ARCH
Date: 03/03/10 Time: 00:44
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 27 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.041544	0.131100	-0.316885	0.7513
RETSEN(-1)	0.090798	0.041750	2.174800	0.0296
RETSNP	0.160036	0.055377	2.889944	0.0039
VOLSNP	0.016684	0.009777	1.706479	0.0879
		Variance Equation		
C	0.039067	0.029989	1.302703	0.1927
ARCH(1)	0.115752	0.021005	5.510796	0.0000
GARCH(1)	0.823674	0.032282	25.51511	0.0000
VOLSNP	0.005232	0.003038	1.722136	0.0850

R-squared	0.019298	Mean dependent var	0.142616
Adjusted R-squared	0.010394	S.D. dependent var	1.409945
S.E. of regression	1.402598	Akaike info criterion	3.308021
Sum squared resid	1516.775	Schwarz criterion	3.355857
Log likelihood	-1280.474	F-statistic	2.167332
Durbin-Watson stat	2.080899	Prob(F-statistic)	0.035080

Results for equation (1) and (2), Sensex and S&P, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:43
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 20 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.028388	0.190873	-0.148728	0.8818
RETSEN(-1)	0.063755	0.048608	1.311623	0.1896
RETSNP	0.391963	0.056530	6.933713	0.0000
VOLSNP	0.002061	0.005917	0.348263	0.7276
		Variance Equation		
C	-0.088828	0.098520	-0.901629	0.3673
ARCH(1)	0.135067	0.029445	4.587107	0.0000
GARCH(1)	0.812787	0.037694	21.56296	0.0000
VOLSNP	0.012268	0.005738	2.138149	0.0325

R-squared	0.121484	Mean dependent var	-0.028751
Adjusted R-squared	0.109497	S.D. dependent var	2.476786
S.E. of regression	2.337255	Akaike info criterion	4.391283
Sum squared resid	2802.397	Schwarz criterion	4.456631
Log likelihood	-1135.929	F-statistic	10.13422
Durbin-Watson stat	2.184896	Prob(F-statistic)	0.000000

Results for equation (3) and (4), Sensex and S&P, 2005-2007

Dependent Variable: RETSNP
Method: ML – ARCH
Date: 03/03/10 Time: 00:59
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 18 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.036471	0.068817	-0.529967	0.5961
RETSNP(-1)	-0.123143	0.043242	-2.847798	0.0044
RETSEN	0.082884	0.018797	4.409342	0.0000
VOLSEN	0.002713	0.002686	1.010074	0.3125
		Variance Equation		
C	0.015654	0.007180	2.180277	0.0292
ARCH(1)	0.056888	0.015222	3.737308	0.0002
GARCH(1)	0.910630	0.026196	34.76161	0.0000
VOLSEN	8.67E-05	0.000311	0.278828	0.7804

R-squared	0.038018	Mean dependent var	0.025686
Adjusted R-squared	0.029284	S.D. dependent var	0.768137
S.E. of regression	0.756806	Akaike info criterion	2.165893
Sum squared resid	441.5944	Schwarz criterion	2.213729
Log likelihood	-835.6154	F-statistic	4.352933
Durbin-Watson stat	2.071881	Prob(F-statistic)	0.000096

Results for equation (3) and (4), Sensex and S&P, 2008-2009

Dependent Variable: RETSNP
Method: ML – ARCH
Date: 03/03/10 Time: 04:44
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 24 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.049623	0.207238	-0.239448	0.8108
RETSNP(-1)	-0.197384	0.052054	-3.791932	0.0001
RETSEN	0.205026	0.032664	6.276906	0.0000
VOLSEN	0.001701	0.005014	0.339276	0.7344
		Variance Equation		
C	-0.001838	0.041515	-0.044276	0.9647
ARCH(1)	0.091741	0.021829	4.202666	0.0000
GARCH(1)	0.897729	0.026113	34.37845	0.0000
VOLSEN	0.000873	0.001457	0.599420	0.5489

R-squared	0.140771	Mean dependent var	-0.052822
Adjusted R-squared	0.129047	S.D. dependent var	2.162954
S.E. of regression	2.018574	Akaike info criterion	3.837267
Sum squared resid	2090.290	Schwarz criterion	3.902614
Log likelihood	-991.6080	F-statistic	12.00674
Durbin-Watson stat	2.058531	Prob(F-statistic)	0.000000

Results for equation (1) and (2), Sensex and Nikkei, 2005-2007

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 00:46
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 25 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.169407	0.137682	-1.230426	0.2185
RETSEN(-1)	0.080071	0.041987	1.907028	0.0565
RETNKK	-0.007382	0.045577	-0.161961	0.8713
VOLNKK	0.018673	0.006883	2.712984	0.0067
		Variance Equation		
C	0.084454	0.030832	2.739194	0.0062
ARCH(1)	0.112846	0.019968	5.651388	0.0000
GARCH(1)	0.838648	0.026403	31.76302	0.0000
VOLNKK	0.000180	0.001269	0.142080	0.8870

R-squared	0.009693	Mean dependent var	0.142616
Adjusted R-squared	0.000702	S.D. dependent var	1.409945
S.E. of regression	1.409450	Akaike info criterion	3.315838
Sum squared resid	1531.630	Schwarz criterion	3.363674
Log likelihood	-1283.519	F-statistic	1.078073
Durbin-Watson stat	2.025172	Prob(F-statistic)	0.375458

Results for equation (1) and (2), Sensex and Nikkei, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:45
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 25 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.104242	0.229849	0.453526	0.6502
RETSEN(-1)	0.053331	0.048811	1.092605	0.2746
RETNKK	0.055292	0.048600	1.137688	0.2553
VOLNKK	-0.001183	0.006637	-0.178301	0.8585
		Variance Equation		
C	-0.095806	0.143666	-0.666870	0.5049
ARCH(1)	0.147464	0.030865	4.777687	0.0000
GARCH(1)	0.823236	0.039988	20.58686	0.0000
VOLNKK	0.009736	0.007006	1.389624	0.1646

R-squared	-0.002170	Mean dependent var	-0.028751
Adjusted R-squared	-0.015845	S.D. dependent var	2.476786
S.E. of regression	2.496331	Akaike info criterion	4.500146
Sum squared resid	3196.845	Schwarz criterion	4.565493
Log likelihood	-1164.288	Durbin-Watson stat	2.010762

Results for equation (3) and (4), Sensex and Nikkei, 2005-2007

Dependent Variable: RETNKK
Method: ML – ARCH
Date: 03/03/10 Time: 01:01
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 21 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.228946	0.107560	2.128537	0.0333
RETNKK(-1)	0.002095	0.044569	0.047006	0.9625
RETSEN	-0.005196	0.022894	-0.226936	0.8205
VOLSEN	-0.006659	0.004651	-1.431707	0.1522
		Variance Equation		
C	-0.006428	0.022906	-0.280609	0.7790
ARCH(1)	0.094497	0.018187	5.195824	0.0000
GARCH(1)	0.862447	0.029082	29.65544	0.0000
VOLSEN	0.002493	0.001420	1.755695	0.0791

R-squared	0.001881	Mean dependent var	0.042037
Adjusted R-squared	-0.007181	S.D. dependent var	1.076763
S.E. of regression	1.080623	Akaike info criterion	2.869258
Sum squared resid	900.3317	Schwarz criterion	2.917094
Log likelihood	-1109.576	F-statistic	0.207567
Durbin-Watson stat	1.995385	Prob(F-statistic)	0.983784

Results for equation (3) and (4), Sensex and Nikkei, 2008-2009

Dependent Variable: RETNKK
Method: ML – ARCH
Date: 03/03/10 Time: 04:47
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 39 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.179305	0.278149	-0.644636	0.5192
RETNKK(-1)	-0.104283	0.050490	-2.065412	0.0389
RETSEN	-0.001051	0.028396	-0.037009	0.9705
VOLSEN	0.003585	0.006417	0.558723	0.5764
		Variance Equation		
C	0.071975	0.085519	0.841636	0.4000
ARCH(1)	0.137161	0.029473	4.653833	0.0000
GARCH(1)	0.818903	0.038853	21.07718	0.0000
VOLSEN	0.002833	0.003254	0.870515	0.3840

R-squared	0.008336	Mean dependent var	-0.074556
Adjusted R-squared	-0.005195	S.D. dependent var	2.342794
S.E. of regression	2.348872	Akaike info criterion	4.165487
Sum squared resid	2830.323	Schwarz criterion	4.230834
Log likelihood	-1077.109	F-statistic	0.616057
Durbin-Watson stat	1.988734	Prob(F-statistic)	0.742834

Results for equation (5) and (6), Sensex and S&P, 2005-2007

Dependent Variable: RETSEN
Method: ML - ARCH
Date: 03/03/10 Time: 00:45
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 26 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.002081	0.132495	-0.015706	0.9875
RETSEN(-1)	0.054678	0.038146	1.433382	0.1517
RETSNP(-1)	0.499621	0.050621	9.869871	0.0000
VOLSNP(-1)	0.012216	0.009908	1.232930	0.2176
		Variance Equation		
C	0.050256	0.030688	1.637629	0.1015
ARCH(1)	0.110654	0.021734	5.091310	0.0000
GARCH(1)	0.828251	0.033825	24.48635	0.0000
VOLSNP(-1)	0.003611	0.002886	1.251171	0.2109

R-squared	0.116207	Mean dependent var	0.142616
Adjusted R-squared	0.108183	S.D. dependent var	1.409945
S.E. of regression	1.331496	Akaike info criterion	3.225729
Sum squared resid	1366.892	Schwarz criterion	3.273564
Log likelihood	-1248.421	F-statistic	14.48238
Durbin-Watson stat	2.107259	Prob(F-statistic)	0.000000

Results for equation (5) and (6), Sensex and S&P, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:43
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 18 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.039353	0.208088	-0.189116	0.8500
RETSEN(-1)	-0.005663	0.048104	-0.117724	0.9063
RETSNP(-1)	0.283437	0.055278	5.127445	0.0000
VOLSNP(-1)	0.002819	0.006858	0.411089	0.6810
		Variance Equation		
C	-0.242964	0.153283	-1.585071	0.1130
ARCH(1)	0.134927	0.035002	3.854870	0.0001
GARCH(1)	0.790752	0.052329	15.11109	0.0000
VOLSNP(-1)	0.021756	0.009945	2.187564	0.0287

R-squared	0.041309	Mean dependent var	-0.028751
Adjusted R-squared	0.028228	S.D. dependent var	2.476786
S.E. of regression	2.441579	Akaike info criterion	4.442022
Sum squared resid	3058.150	Schwarz criterion	4.507370
Log likelihood	-1149.147	F-statistic	3.157822
Durbin-Watson stat	2.111861	Prob(F-statistic)	0.002809

Results for equation (7) and (8), Sensex and S&P, 2005-2007

Dependent Variable: RETSNP
Method: ML - ARCH
Date: 03/03/10 Time: 01:00
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 25 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.017348	0.069804	-0.248520	0.8037
RETSNP(-1)	-0.069299	0.042292	-1.638579	0.1013
RETSEN(-1)	-0.021721	0.019138	-1.134953	0.2564
VOLSEN(-1)	0.002691	0.002723	0.988180	0.3231
		Variance Equation		
C	0.015596	0.006313	2.470477	0.0135
ARCH(1)	0.053363	0.013080	4.079671	0.0000
GARCH(1)	0.919098	0.020853	44.07428	0.0000
VOLSEN(-1)	-2.61E-06	0.000286	-0.009138	0.9927

R-squared	0.015725	Mean dependent var	0.025686
Adjusted R-squared	0.006789	S.D. dependent var	0.768137
S.E. of regression	0.765525	Akaike info criterion	2.185864
Sum squared resid	451.8279	Schwarz criterion	2.233700
Log likelihood	-843.3940	F-statistic	1.759711
Durbin-Watson stat	2.070493	Prob(F-statistic)	0.092322

Results for equation (7) and (8), Sensex and S&P, 2008-2009

Dependent Variable: RETSNP
Method: ML – ARCH
Date: 03/03/10 Time: 04:45
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 22 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.092995	0.207243	-0.448725	0.6536
RETSNP(-1)	-0.140260	0.054773	-2.560772	0.0104
RETSEN(-1)	0.025670	0.029900	0.858541	0.3906
VOLSEN(-1)	0.002915	0.005172	0.563601	0.5730
		Variance Equation		
C	-0.027864	0.041685	-0.668453	0.5038
ARCH(1)	0.091590	0.022116	4.141417	0.0000
GARCH(1)	0.897479	0.026015	34.49787	0.0000
VOLSEN(-1)	0.001634	0.001433	1.139945	0.2543

R-squared	0.017717	Mean dependent var	-0.052822
Adjusted R-squared	0.004313	S.D. dependent var	2.162954
S.E. of regression	2.158284	Akaike info criterion	3.912222
Sum squared resid	2389.652	Schwarz criterion	3.977569
Log likelihood	-1011.134	F-statistic	1.321797
Durbin-Watson stat	2.051613	Prob(F-statistic)	0.237608

Results for equation (5) and (6), Sensex and Nikkei 2005-2007

Dependent Variable: RETSEN
Method: ML - ARCH
Date: 03/03/10 Time: 00:47
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 23 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.193799	0.138993	-1.394306	0.1632
RETSEN(-1)	0.079624	0.042298	1.882445	0.0598
RETNKK(-1)	0.009208	0.037085	0.248297	0.8039
VOLNKK(-1)	0.019867	0.006950	2.858414	0.0043
		Variance Equation		
C	0.085420	0.031374	2.722669	0.0065
ARCH(1)	0.113343	0.019997	5.667895	0.0000
GARCH(1)	0.838018	0.026548	31.56661	0.0000
VOLNKK(-1)	0.000136	0.001263	0.107504	0.9144

R-squared	0.010560	Mean dependent var	0.142616
Adjusted R-squared	0.001576	S.D. dependent var	1.409945
S.E. of regression	1.408833	Akaike info criterion	3.314632
Sum squared resid	1530.289	Schwarz criterion	3.362468
Log likelihood	-1283.049	F-statistic	1.175475
Durbin-Watson stat	2.025108	Prob(F-statistic)	0.314338

Results for equation (5) and (6), Sensex and Nikkei, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:46
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 30 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.112297	0.228511	0.491427	0.6231
RETSEN(-1)	0.047994	0.050659	0.947391	0.3434
RETNKK(-1)	0.054727	0.044919	1.218343	0.2231
VOLNKK(-1)	-0.001511	0.006583	-0.229622	0.8184
	Variance Equation			
C	-0.087819	0.151388	-0.580088	0.5619
ARCH(1)	0.155542	0.033114	4.697133	0.0000
GARCH(1)	0.813992	0.043800	18.58446	0.0000
VOLNKK(-1)	0.009855	0.007422	1.327765	0.1843
R-squared	0.001558	Mean dependent var		-0.028751
Adjusted R-squared	-0.012066	S.D. dependent var		2.476786
S.E. of regression	2.491684	Akaike info criterion		4.500572
Sum squared resid	3184.955	Schwarz criterion		4.565919
Log likelihood	-1164.399	F-statistic		0.114322
Durbin-Watson stat	1.981187	Prob(F-statistic)		0.997408

Results for equation (7) and (8), Sensex and Nikkei, 2005-2007

Dependent Variable: RETNKK
Method: ML - ARCH
Date: 03/03/10 Time: 01:02
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 21 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.210620	0.106639	1.975067	0.0483
RETNKK(-1)	0.003652	0.044495	0.082072	0.9346
RETSEN(-1)	0.049375	0.022677	2.177348	0.0295
VOLSEN(-1)	-0.006171	0.004593	-1.343571	0.1791
	Variance Equation			
C	-0.000447	0.021943	-0.020356	0.9838
ARCH(1)	0.093990	0.018255	5.148870	0.0000
GARCH(1)	0.867408	0.029237	29.66776	0.0000
VOLSEN(-1)	0.002025	0.001381	1.466252	0.1426
R-squared	0.009968	Mean dependent var		0.042037
Adjusted R-squared	0.000980	S.D. dependent var		1.076763
S.E. of regression	1.076236	Akaike info criterion		2.866360
Sum squared resid	893.0365	Schwarz criterion		2.914196
Log likelihood	-1108.447	F-statistic		1.109011
Durbin-Watson stat	2.000112	Prob(F-statistic)		0.355223

Results for equation (7) and (8), Sensex and Nikkei, 2008-2009

Dependent Variable: RETNKK
Method: ML – ARCH
Date: 03/03/10 Time: 04:47
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 37 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.210391	0.275574	-0.763466	0.4452
RETNKK(-1)	-0.107616	0.051000	-2.110110	0.0348
RETSEN(-1)	0.076073	0.030717	2.476572	0.0133
VOLSEN(-1)	0.004331	0.006351	0.681940	0.4953
		Variance Equation		
C	0.080356	0.088248	0.910576	0.3625
ARCH(1)	0.143839	0.030404	4.730969	0.0000
GARCH(1)	0.816869	0.038255	21.35314	0.0000
VOLSEN(-1)	0.002295	0.003141	0.730578	0.4650

R-squared	0.010862	Mean dependent var	-0.074556
Adjusted R-squared	-0.002635	S.D. dependent var	2.342794
S.E. of regression	2.345879	Akaike info criterion	4.155538
Sum squared resid	2823.114	Schwarz criterion	4.220885
Log likelihood	-1074.518	F-statistic	0.804762
Durbin-Watson stat	1.994800	Prob(F-statistic)	0.583569