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Developed and Emerging Stock Markets during the Global Financial Crisis

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Abstract

In this paper, we examine 22 benchmark stock market indices of developed and emerging countries during the period 31 December 1999-26 February 2010. We study stock market behaviour focusing on the persistence of market volatility, the leverage effect, structural breaks or shocks, and market integration and efficiency. The paper finds that most markets in the two groups behaved similarly in the GFC period. In comparison to the pre-GFC period, markets became efficient and many experienced a fall in the persistence of their volatility. The leverage effect, on the other hand, intensified during the GFC. The dates associated with the structural breaks in stock price indices are found to be same for all countries on two occasions - February 2007 and August 2008. This is an indication that market reactions were synchronised. This is unique to the GFC, as our pre-GFC analysis, which also captures the 2002 market downturns, fails to show similar synchronous behaviour.

Keywords: Global Financial Crisis (GFC); Stock markets; Efficient capital market hypothesis; Structural shocks, Leverage effects; Persistence of market volatility
JEL Classifications Codes: C22, G01, G14, G15

1. Introduction

On the GFC and stock markets, there is currently evidence that 11 major European share markets experienced significantly higher volatility levels during the GFC covering the period July 2003 to September 2010 (Milunovich, 2011); for Jordan's stock returns, volatility is unaffected by the GFC (2008 and 2009) and the positive relationship between risk and return is preserved in the crisis period (Al Rjoum, 2011); 8 developed and 2 emerging stock markets are co-integrated during September 2008 to August 2009 (Assidenou, 2011);there is a dramatically stronger correlation between stock markets of 10 industrialised countries during crisis period from July 2007 to February 2009 and DJ and DAX were not exerting as much influence on the other 8 indices in the same period (Gklezakoa and Mylonakis, 2011); for 17 financial markets, volatility plays a key role in explaining the changing nature of correlations among stock markets over the global financial crisis period from February 2007 to February 2010 (Mun and Brooks, 2012); and for 8 stock markets of Asia-Pacific, the volatility spillover effects intensified in the financial crisis period covering the period June 2007 to February 2009 (Chakrabarti, 2011). Further to this, Olowe (2009) documented leverage effect and strong persistent volatility effect in Nigerian stock markets especially during the GFC period while Mahmood *et al.* (2011) indicated that the Chinese stock market was efficient during the GFC.

The focus of our study is on the behaviour of markets during the GFC in terms of, conditional volatility, market integration, efficiency, and structural breaks in stock prices. Our study is distinct from the above literature in the following ways. First, to the best of our knowledge, our paper is first to show synchronization of the major stock markets using structural break analysis and provide insights about stock market behaviour surrounding the market crash. In particular, our structural break analysis suggests that that markets had already started to become increasingly synchronised before the stock market crash in 2008. The structural break dates, derived using the Carrion-*i*-Silvestre *et al.* (2005) test, for all markets converge in February 2007 and/or in August 2008. When these dates are compared with the stock market indices, we find that by February 2007, markets had not peaked and were still trending up. Taken together, this is an indication that stock markets began to synchronise well before markets crashed in 2008. Some recent studies (see above) show market integration from 2007 onwards. However, it is clear from our results that market reactions were synchronised before and during the latest stock market crashes. Furthermore, this behaviour is unique to the GFC period when compared with the 2002 market downturns.

Second, while there are several studies that have gauged market behaviour in the GFC period, only limited countries have been examined during the GFC period. We examine stock market behaviour for 22 developing and emerging countries. Furthermore, given that empirical analyses are often sensitive to the econometric technique or data, it is worthwhile re-examining a bigger set of countries against different sets of tests.

This paper examines market efficiency using a battery of stationarity tests that test the null of mean reversion in stock prices against the alternative of a random walk before and during the crisis period. There is currently on only study on China, that shows mean reversion of stock returns. Our results indicate that the conventional stationarity tests, Kwaitkowski *et al.* (KPSS 1992) univariate test and the Hadri (2000) panel test, provide limited case of mean reversion in stock prices. This result is consistent with the extant literature, which shows limited case of stationarity. In the traditions of Perron (1989) to increase power, we use another KPSS type test – the Carrion-*i*-Silvestre *et al.* (2005) test - that allow for endogenous structural breaks in the stock price series to test for mean reversion in stock prices for all individual countries as well as for two panels – OECD panel and the Asian panel. The panel tests with structural breaks indicate that market become efficient in the GFC period.

Forth, our paper uses the Exponential Generalised Autoregressive Conditional Heteroskedasticity (EGARCH) model of Nelson (1991) to examine the volatility of shock returns. This framework according to Surgailis and Viano (2002:311) '… is one of the most successful ARCH models which may exhibit characteristic asymmetrics of financial time series, as well as long memory. ' Our results suggest that the volatility of stocks became less persistence for several countries during the GFC period. The leverage effect is found to be stronger in the GFC period for most stocks.

In what follows, we explain the empirical analysis of this paper. Our empirical results are discussed in section 4 and some final remarks in the final section.

2. Empirical Analysis

2. 1. Mean Reversion Property and Structural Breaks Tests

It is important to examine market efficiency, as it unravels important information about how the market behaves. An efficient stock market implies that stock prices are random or that changes in prices are unpredictable. Mean reverting stock prices have the opposite effect and it implies that short-term investors would prefer to buy equity when prices are perceived to be lower than their fundamental levels. This is also consistent with the contrarian view (DeBondt and Thaler 1989). For long-horizon investors, this means that the stock market is less risky and that they should invest in equities (Poterba and Summers 1987). When one examines the empirical literature on the time series properties of stock market, it becomes clear that evidence in favour of mean reverting stock returns is ample (see, for instance, Narayan and Smyth 2007; Narayan and Narayan 2007). However, the same is not true for share prices, which is the focus of the paper here.

Our analysis of the mean reverting property of stock prices includes an array of time series and panel stationarity tests. The conventional test, the KPSS test, is applied here. However, the short sample periods, such as ours, does not have enough variability to detect mean reversion. As a result, panel data models, popularised by the work of Quah (1993) and Levin and Lin (1992) are used to gain power. In this study we use the Hadri (2000) panel test. Because this test does not guarantee us individual country results, we apply another test. This is a recent stationarity test with multiple breaks proposed by Carrion-i-Silvestre *et al.* (2005). This test follows from the work of Perron (1989), who showed that the structural break is a source of nonstationarity in a time series process. Carrion-i-Silvestre et al. (2005) test is chosen for a number of reasons. First, it is flexible enough to cater for stationarity test with a levels break (or a break in the intercept) and is, therefore, able to test the null of mean stationarity. Second, unlike other tests with breaks, this test allows for multiple structural breaks. Third, it allows for heterogeneity in the panel data setting, and in doing so provides the individual country result as well as the panel result.

In all, the univariate tests applied in this study includes a stationarity test without breaks, namely the Kwaitkowski *et al.* (KPSS, 1992), and a stationarity test with breaks, namely the Carrion-*i*-Silvestre *et al.* (2005) test. A panel stationarity test without structural break includes the Hadri (2000) test and a panel test with breaks include Carrion-*i*-Silvestre *et al.* (2005) test. [1] We explain each of these tests below.

The KPSS test, developed by Kwaitkowski *et al.* (1992), is designed to test the null hypothesis of stationarity in a series. This test is often seen as a complement to the ADF type tests and is used as a confirmatory analysis (see Carrion-i-Silvestre, *et al.* 2005). This technique simply defines the data generating process of the industrial average stock price series as

$$SP_t = \alpha_t + \varepsilon_t \tag{1}$$

SP_t is described as a sum of a random walk, α_t, and a stochastic process, ε_t; where, $\alpha_t = \alpha_{t-1} + \upsilon_t$; υ_t is a white noise process $(0, \sigma^2)$, and $\alpha_0 = \alpha$, is the intercept. Since υ_t and ε_t are assumed to be mutually independent, the null hypothesis for mean stationarity is tested:

$$SP_t = \alpha + \varepsilon_t \tag{2}$$

The test statistic is defined as:

$$\eta_i = T^{-2}\hat{\omega}^{-2}\sum \hat{S}_t^2 \tag{3}$$

where $\hat{S}_t = \sum_{j=1}^{t}\hat{\varepsilon}_j$ denotes the partial sum process derived from the OLS residuals after estimating equation (3. 18); $\hat{\omega}_i^2 = T^{-1}\sum_{t=1}^{T}\varepsilon_t^2 + 2T^{-1}\sum_{s=1}^{l} w(s,l)\sum_{t=s+1}^{T}\hat{\varepsilon}_t\hat{\varepsilon}_{t-s}$ is the non-parametric estimate of the disturbance variance; $w(s,l)$ is the spectral window; the subscript i denotes any deterministic function (constant and/or trend). In the case of a test of mean stationarity: $f(t) = u$ with $i = 1$; and T is the sample size.

The KPSS test is constructed with the null hypothesis that SP_t is stationary and the alternate hypothesis that SP_t is nonstationary. The null is rejected if the test statistic is greater than the critical

[1] The Carrion-*i*-Silvestre *et al.* (2005) test performs univariate as well as panel stationarity tests.

value. In other words, SP_t is accepted as a stationary process (in levels or first difference) if the test statistic is smaller than the critical value.

In a panel setting, the stock price variable is defined as $SP_{i,t}$ with $i = 1,....., N$ individual current accounts and $t = 1,....., T$. Here, the null hypothesis of stationarity is tested based on:

$$SP_{i,t} = \alpha_i + \varepsilon_{i,t} \tag{4}$$

Hadri (2000) developed the test of the null hypothesis of stationarity in the panel setting by averaging the univariate stationarity test of the KPSS test.

If levels shift (or shift in the intercept) is allowed in the above panel setting, the null hypothesis of stationarity becomes:

$$SP_{i,t} = \alpha_i + \sum_{k=1}^{m} \theta_{i,k} DU_{i,k,t} + \varepsilon_{i,t} \tag{5}$$

Here, $DU_{i,k,t}$ is the dummy variable defined as $DU_{i,k,t} = 1$ for $t > T_{b,k}^i$ and 0, otherwise; $\varepsilon_{i,t}$ is assumed to be a stationary process; and $T_{b,k}^i$ denotes the kth date of the break for the *i*th individual, $k = (1,..., m_i), m_i \geq 1$. As noted above, the model includes individual shifts in the mean caused by structural breaks. $\theta_{i,k}$ measures the effect of structural breaks on individual series. [2]

Carrion-i-Silvestre *et al*. (2005) extended the Hadri (2000) test of the null hypothesis of stationarity by accounting for breaks:

$$LM(\lambda) = 1/N \sum_{i=1}^{N} \left(\hat{\omega}_t^{-2} T^{-2} \sum_{t=1}^{T} \hat{S}_{i,t}^2 \right) \tag{6}$$

Here, $\hat{S}_{i,t} = \sum_{j==1}^{t} \hat{\varepsilon}_{i,j}$, the partial sum process is derived from the OLS residuals after estimating equation 5. The long run variance of $\varepsilon_{i,t}$ calculated as above is, $\hat{\omega}_i^2 = \lim_{T \to \infty} T^{-1} E(S_{i,T}^2), i = 1,......, N$, which allows for heterogeneity across countries. [3] λ suggests that the test is dependent on the dates of the breaks. For each country, *i*, it is defined as the vector $\lambda_i = (\lambda_{i.1},........, \lambda_{i,m}) = (T_{b,1}^i / T,....., T_{b,m_i}^i / T)'$ - this indicates the relative positions of the dates of the breaks on the entire time period, *T*.

For the estimation of the break dates, Carrion-i-Silvestre *et al*. (2005) applied the Bai and Perron (1998) technique which essentially involves three steps. The first step involves the identification of the maximum number of break points $(m^{\max})$ in individual series, which involves estimating their positions for each $m_i \leq m^{\max}, i = 1,...., N$. The second step involves testing for the significance of the breaks for each individual country, *i*. The third step involves choosing the optimum number and position for breaks for each country.

As a first step, the Bai and Perron (1998) procedure computes the sum of the squared residuals (SSR) that is minimized globally. In other words, the arguments chosen for the estimates of the break dates are the ones that minimize the sequence of individual $SSR(T_{b,1}^i,....,T_{b,m}^i)$. These are computed from: $(\hat{T}_{b,1}^i,......,\hat{T}_{b,m_i}^i) = \arg\min_{T_{b,1}^i,.......,T_{b,m_i}^i} SSR(T_{b,1}^i,....,T_{b,m}^i)$. Trimming is necessary when computing for estimates of break dates. The trimming region used here is $T[0.1,0.9]$. Once all possible dates are identified, the optimal m_i is selected either based on the Bayesian Information Criterion (BIC) and the

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[2] Hence, a common restriction on the date of the break, such as $T_{b,k}^i = T_{b,k}, \forall i = \{1,..., N\}$ is not allowed, nor is the restriction on the number of breaks that an individual time series can have is allowed - $m_i \neq m_j, \forall i \neq j, \{i, j\} = \{1,...., T\}$.

[3] This test can also be performed by assuming homogeneity of the long-run variance across individuals. In this case, $\hat{\omega}_i^2 = 1/N \sum_{i=1}^{N} \omega_i^2$.

modified Schwarz Information Criterion of Liu, Wu and Zidek (LWZ, 1997) or on the sequential computation method. Following the Bai and Perron (1998) study, Carrion-i-Silvestre *et al*. (2005) recommend LWZ and BIC procedure for trending series and the second approach for non-trending variables. This second method involves sequential computation and detection of the breaks using the pseudo F-type test statistic. The number of breaks in this study is chosen using the second procedure.

2. 2. EGARCH Model

Next, we describe the EGARCH model developed by Nelson (1991). [4]. We use this framework to capture the effects of the GFC on the persistence of market volatility and the asymmetric behaviour in stock prices. [5] A mean equation takes the following form:

$$\ln SP_t = \beta_1 + \beta_2 \ln SP_{t-1} + \varepsilon_t \tag{7}$$

Here, β_1 and β_2 are the parameters to be estimated and ε_t captures disturbances to the dependent variable that is not observed. The log of the variable, SP_t in period *t* is determined by share prices of the previous year $(t-1)$.

The variance of the EGARCH model (1, 1)takes the following form:[6]

$$Log\left(\delta_t^2\right) = C_3 + \gamma \frac{\varepsilon_{t-1}}{\delta_{t-1}} + C_4\left[\frac{\left|\varepsilon_{t-1}\right|}{\left|\sqrt{\delta_{t-1}^2}\right|}\right] + C_5 \frac{\varepsilon_{t-1}}{\sqrt{\delta_{t-1}^2}} + C_6 \log\left(\delta_{t-1}^2\right) \tag{8}$$

where, C_3 is a constant; and C_4-C_6 are the other parameters to be estimated. The existence of asymmetric effects is tested by the hypothesis that $C_5 \neq 0$. If C_5 is found to be significantly different from 0 and $C_5 < 0$, then the leverage effect is present. This is when negative shocks make stock prices more volatile than positive shocks. And in the case, $C_5 > 0$, positive shocks will make stock prices more volatile than the negative shocks.

The parameter, C_6, provides information on persistence of stock price volatility. If C_6 is close to one, then, volatility of the share price is implied to be persistent. In other words, shocks to share prices have long-term effects. If C_6 is closer to zero, then, volatility of share prices is persistent and that the effects of the shocks are felt by short-run share price movements.

3. Empirical Results

3. 1. Data

This study employs daily share price indices from 31 December 1999 to 26 February 2010. The time series data used for the study is sourced from DataStream. The market indices for the respective countries are as follows: ASX300I, Australia;ATXWBIX, Austria; BGBEL20, Belgium;TTOCOMP, Canda; COSEASH, Denmark;HEXINDX, Finland;FSBF120, France;DAXINDX, Germany;MEREXPI, Italy;TSET100, Japan;KOR200I, South Korea;POPSI20, Portugal;IBEX35I, Spain; SWEDOMX, Sweden;TRKISTB, Turkey;FTSE100, UK;S&PCOMP, US;CHSCOMP, China;IBOMBSE, India;FBMKLCI, Malaysia;BNGKS50, Thailand; and TOTXTSG, Singapore. This data is divided into two sub-samples. Sub-sample 1 covers the pre-GFC period from 4 January 2000 –

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[4] Engle (1982) first introduced the volatility theory in the form of the autoregressive conditional heteroskedasticity (ARCH) model. This was later expanded by Bollerslev (1986), who introduced the generalized ARCH (or GARCH) framework - see Kim and Wang (2006) for details on the ARCH and GARCH models.

[5] See, Engle and Ng (1993) for discussion on asymmetric behaviourin stock prices and Chou (1988) for persistence of conditional volatility.

[6] EGARCH (1, 1) is chosen as the preferred model in the interest of parsimony of parameters (see Kim and Wang, 2006).

30 August 2008, while sub-sample 2 covers the GFC period from 1 September 2008 – 29 January 2010.

3. 2. Descriptive Statistics

We begin our analysis of stock prices in the pre-GFC and the GFC periods using descriptive statistics. A summary of these statistics for these series as well as the difference between the two periods are provided in Table 1. The key differences between the GFC period and the pre-GFC period are as follows. First, the mean values of stock price indices fell for seven countries (the US, UK, Belgium, Finland, France, Italy and Japan) and increased for rest during the GFC period. Portugal and Sweden experienced a one per cent increase; Australia, Canada, Denmark, Spain, and Singapore experienced a 20 to 29 per cent increase; Austria and Malaysia experienced a 30 to 40 per cent increase; Thailand saw a 53 per cent increase; China and Turkey experienced a 83 and 87 per cent increase, respectively; and India experienced the largest increase at 135 per cent.

Second, the standard deviation of the stock price series, which is a simple measure of volatility of stocks, did not increase for all the stock market as it is generally assumed during the crisis period. We find that the standard deviation was higher only for five countries during the GFC period. These were highest for China (63 per cent) and the US (30 per cent). In terms of the coefficient of variation (CV), with the exception of Belgium, Italy, Japan, and the US, all the other stock markets experienced a fall in the CV in the GFC period.

Third, all stocks were positively skewed in the two sample periods but most stock price indices display a lower coefficient for skewness in the GFC period. The only exceptions to this were France, Germany and Portugal. Similarly, the kurtosis coefficient for all, except, the UK, Thailand, and France, fell in the GFC period. This suggests that the tails became thinner during the crisis for most countries.

Table 1: Descriptive Statistics for the period, 31 December 1999 - 26 February 2010
Table 1 reports the mean, standard deviation, skewness, kurtosis and the coefficient of variation (CV) of 17 Industrialized and 5 Asian countries during the GFC and pre-GFC period. It also reports the proportionate change between the two periods.

	AUS	**AUT**	**BEL**	**CA**	**DEN**	**FIN**	**FRA**	**GER**	**ITA**	**JAP**	**KOR**
Pre-GFC											
Mean	3889.1	849.3	2974.8	9303.8	274.0	8491.0	3222.8	5155.9	8439.1	974.7	118.1
Std.Dev.	970.4	452.2	747.7	2132.3	85.8	3056.9	743.7	1450.3	1860.7	239.8	43.7
Skewness	1.1	0.9	0.6	0.6	0.9	1.2	0.1	0.1	1.1	0.4	0.9
Kurtosis	3.1	2.3	2.7	2.3	2.9	3.9	1.8	2.0	3.1	2.2	2.9
CV	0.250	0.532	0.251	0.229	0.313	0.360	0.231	0.281	0.220	0.246	0.370
GFC											
Mean	4807.4	1106.6	2836.9	11679.1	333.2	7669.5	2957.7	5913.6	7434.0	778.9	200.0
Std.Dev.	978.2	386.4	865.8	2039.4	83.9	2398.8	659.4	1156.6	1802.8	210.6	33.0
Skewness	0.3	0.3	0.4	-0.2	0.3	0.6	0.4	0.2	0.9	0.5	-0.4
Kurtosis	2.1	1.6	1.8	1.8	1.9	2.0	2.0	2.0	2.6	1.7	2.3
CV	0.203	0.349	0.305	0.175	0.252	0.313	0.223	0.196	0.243	0.270	0.165
GFC/Pre-GFC (% change)											
Mean	24	30	-5	26	22	-10	-8	15	-12	-20	69
Std.Dev.	1	-15	16	-4	-2	-22	-11	-20	-3	-12	-24
Skewness	-73	-67	-33	-133	-67	-50	300	100	-18	25	-144
Kurtosis	-32	-30	-33	-22	-34	-49	11	0	-16	-23	-21
CV	-18.5	-34.4	21.4	-23.8	-19.6	-13.1	-3.4	-30.5	10.0	9.9	-55.4
	POR	**SPA**	**SWE**	**TUR**	**UK**	**US**	**CHI**	**IND**	**MAL**	**SINGA**	**THAI**
Pre-GFC											
Mean	8712.9	9593.1	873.7	21810.2	5275.6	1201.1	1768.9	3297.6	842.7	393.1	361.9
Std.Dev.	2307.2	2481.7	263.6	12579.5	869.3	180.3	681.6	1865.1	180.4	124.0	128.8
Skewness	0.5	0.6	0.4	0.8	-0.1	-0.1	2.5	1.0	1.1	1.4	0.0
Kurtosis	2.3	2.5	2.2	2.3	1.8	2.3	10.0	2.7	4.2	4.3	1.4
CV	0.265	0.259	0.302	0.577	0.165	0.150	0.385	0.566	0.214	0.315	0.356

Table 1: Descriptive Statistics for the period, 31 December 1999 - 26 February 2010 - continued

GFC											
Mean	8828.3	11502.7	882.8	40812.1	5184.3	1140.2	3239.6	7759.2	1158.9	476.9	552.7
Std.Dev.	2217.5	2265.2	159.3	10220.5	831.7	233.7	1112.0	1835.6	180.2	113.3	135.7
Skewness	0.6	0.1	0.1	-0.2	0.0	0.1	0.9	-0.4	-0.3	-0.3	-0.2
Kurtosis	2.1	2.1	2.5	1.9	1.9	1.8	2.8	2.3	2.0	1.9	2.1
CV	0.251	0.197	0.180	0.250	0.160	0.205	0.343	0.237	0.155	0.238	0.246
GFC/Pre-GFC (% change)											
Mean	1	20	1	87	-2	-5	83	135	38	21	53
Std.Dev.	-4	-9	-40	-19	-4	30	63	-2	0	-9	5
Skewness	20	-83	-75	-125	-100	-200	-64	-140	-127	-121	-
Kurtosis	-9	-16	14	-17	6	-22	-72	-15	-52	-56	50
CV	-5.1	-23.9	-40.2	-56.6	-2.6	36.5	-10.9	-58.2	-27.4	-24.7	-31.0

3. 3. Mean Reversion

The results on the KPSS (1992) test (without structural breaks) are presented in column 2 of Tables 2, 3 and 4 for the full sample, the Pre-GFC, and the GFC, respectively. These results indicate that stock prices are generally random walk processes. For the full sample period, the null hypothesis of stationarity is rejected for all countries at the 1% level of significance, except France, Portugal, the UK and the US. During the pre-GFC period, the null hypothesis of stationarity is rejected for all the countries' stock prices series. And, in the GFC period, all countries stock prices, except Turkey and India, are found to be non-stationary.

Next, to increase the power of the stationarity test, we group the series into two panels, namely, the OECD and the Asian panels. The two panels are created for each of the three sample periods considered in this paper. We then apply Hadri (2000) to test for panel stationarity. The results on the OECD and Asian panels across the three sample periods are presented in column 2 of Table 5. Our results show that the null hypothesis of panel stationarity is rejected by the Hadri (2000) test for both the panels across the full and two sub-sample periods.

The conventional tests generally suggest that most of the stock price indices are random walk. The absence of evidence of stationarity in time series and panel stock price data is generally consistent with the literature (see, also for instance, Pindyck 1984; Chou 1988; Narayan and Narayan 2007).

Table 2: Stationarity test results on stock prices (SP) using univariate KPSS tests with and without breaks (full sample)

Tables 2, 3 and 4 reports the stationarity test results for the full sample period. These are based on univariate KPSS test (column 2) and the Carrion-i-Silvestre *et al.* (2005) test with breaks (column 3-6). The specification contains country specific intercepts only. The number of break points has been estimated using the LWZ information criteria, allowing for a maximum of 5 structural breaks. The bootstrap critical values for this test with breaks are based on 10000 replications and are provided in the last three columns. The critical values for the KPSS test without breaks at the 5% (1%) level are 0. 463 (0. 739). The KPSS test is constructed with the null hypothesis that SP_t is stationary and the alternate hypothesis that SP_t is nonstationarity. The null is rejected if the test statistic is greater than the critical value. *** and ** denote the level of statistical significance at the 1 % and 5 % level, respectively.

Country	KPSS test (without structural breaks)	Carrion-i-Silvestre test (with structural breaks)	Bootstrap Critical Values		
	t-statistic [Bandwidth=41]	t-statistic	(1%)	(5%)	(10%)
Australia	4. 08**	0. 012	0. 063	0. 049	0. 043
Austria	4. 271***	0. 008	0. 092	0. 068	0. 058
Belgium	0. 979***	0. 013	0. 061	0. 048	0. 042

Table 2: Stationarity test results on stock prices (SP) using univariate KPSS tests with and without breaks (full sample) - continued

Canada	3. 507***	0. 014	0. 092	0. 068	0. 058
Denmark	3. 188***	0. 009	0. 063	0. 048	0. 042
Finland	0. 887***	0. 014	0. 064	0. 049	0. 043
France	0. 672	0. 013	0. 070	0. 052	0. 044
Germany	1. 151***	0. 013	0. 061	0. 049	0. 042
Italy	1. 083***	0. 010	0. 061	0. 048	0. 042
Japan	0. 906***	0. 012	0. 062	0. 049	0. 043
South Korea	5. 362***	0. 015	0. 061	0. 049	0. 042
Portugal	0. 737	0. 011	0. 069	0. 052	0. 045
Spain	2. 361***	0. 011	0. 087	0. 065	0. 055
Sweden	0. 854***	0. 015	0. 069	0. 051	0. 044
Turkey	5. 310***	0. 011	0. 061	0. 048	0. 042
UK	0. 677	0. 017	0. 062	0. 049	0. 043
US	0. 542	0. 012	0. 089	0. 066	0. 057
China	2. 264***	0. 014	0. 067	0. 051	0. 043
India	5. 518***	0. 009	0. 060	0. 047	0. 042
Malaysia	4. 368***	0. 015	0. 060	0. 048	0. 042
Singapore	4. 154***	0. 009	0. 061	0. 049	0. 043
Thailand	4. 270***	0. 014	0. 061	0. 048	0. 042

Table 3: Stationarity test results on stock prices (SP) using univariate KPSS tests with and without breaks (Pre-GFC)

Country	KPSS test (without structural breaks)	Carrion-i-Silvestre test (with structural breaks)	Critical Values		
	t-statistic [Bandwidth=36]	t-statistic	(1%)	(5%)	(10%)
Australia	4. 601***	0. 015	0. 13	0. 094	0. 077
Austria	5. 378***	0. 009	0. 133	0. 095	0. 079
Belgium	2. 666***	0. 018	0. 148	0. 101	0. 083
Canada	3. 240***	0. 018	0. 212	0. 138	0. 107
Denmark	3. 734***	0. 018	0. 148	0. 102	0. 084
Finland	1. 473***	0. 016	0. 165	0. 11	0. 088
France	1. 348***	0. 025	0. 22	0. 138	0. 107
Germany	1. 314***	0. 017	0. 156	0. 105	0. 085
Italy	3. 854***	0. 010	0. 133	0. 095	0. 078
Japan	1. 313***	0. 019	0. 112	0. 083	0. 071
South Korea	4. 532***	0. 037	0. 162	0. 108	0. 087
Portugal	2. 252***	0. 018	0. 124	0. 091	0. 076
Spain	1. 337***	0. 010	0. 16	0. 108	0. 087
Sweden	4. 844***	0. 022	0. 219	0. 14	0. 108
Turkey	1. 367***	0. 015	0. 129	0. 094	0. 078
UK	1. 387***	0. 022	0. 112	0. 086	0. 072
US	4. 601***	0. 037	0. 217	0. 139	0. 109
China	0. 792***	0. 017	0. 112	0. 082	0. 07
India	4. 575***	0. 020	0. 164	0. 107	0. 086
Malaysia	3. 442***	0. 054	0. 189	0. 125	0. 099
Singapore	4. 138***	0. 015	0. 14	0. 097	0. 079
Thailand	4. 980***	0. 011	0. 193	0. 126	0. 099

Table 4: Stationarity test results on stock prices (SP) using univariate KPSS tests with and without breaks (GFC Period)

Country	KPSS test (without structural breaks)	Carrion-i-Silvestre test (with structural breaks)	Critical Values		
	t-statistic [Bandwidth =21]	t-statistic	(1%)	(5%)	(10%)
Australia	1. 698***	0. 03	0. 192	0. 136	0. 11
Austria	1. 885***	0. 039	0. 184	0. 131	0. 108
Belgium	2. 038***	0. 03	0. 182	0. 129	0. 105
Canada	1. 385***	0. 05	0. 188	0. 131	0. 107
Denmark	1. 902***	0. 025	0. 178	0. 126	0. 104
Finland	2. 270***	0. 018	0. 18	0. 126	0. 104
France	1. 951***	0. 025	0. 185	0. 127	0. 105
Germany	1. 727***	0. 025	0. 183	0. 129	0. 106
Italy	2. 469***	0. 026	0. 274	0. 181	0. 14
Japan	2. 358***	0. 042	0. 186	0. 132	0. 108
South Korea	0. 889***	0. 048	0. 23	0. 153	0. 122
Portugal	1. 829***	0. 032	0. 192	0. 132	0. 108
Spain	1. 468***	0. 026	0. 182	0. 129	0. 106
Sweden	1. 025***	0. 054	0. 188	0. 131	0. 107
Turkey	0. 718	0. 019	0. 18	0. 126	0. 104
UK	1. 521***	0. 039	0. 194	0. 137	0. 112
US	1. 789***	0. 029	0. 193	0. 132	0. 11
China	1. 319***	0. 045	0. 185	0. 131	0. 106
India	0. 738	0. 042	0. 178	0. 125	0. 102
Malaysia	0. 917***	0. 027	0. 239	0. 158	0. 125
Singapore	1. 054***	0. 055	0. 179	0. 128	0. 104
Thailand	1. 075***	0. 030	0. 183	0. 125	0. 102

To test whether this non-stationarity is a result of structural breaks, we allow for endogenous structural breaks in the stock price series. We include five breaks in the full sample, three in the pre-GFC period and two breaks in the GFC period. The number of breaks selected is dictated by the sample size. The country specific results on mean stationarity for each of the three sample periods are presented in column 3 of Tables 2, 3, and 4. The critical values for the full sample, pre GFC and GFC periods are presented in columns 4-6 of each of the aforementioned tables. Once breaks are introduced in the stationarity test model, all the series are found to be stationary in all the three samples. This suggests that markets remained inefficient in the crisis period.

We also provide results on the panel stationarity test with structural breaks. These are presented in Table 5, columns 3 and 4. We find that markets were inefficient in the period prior to the GFC. These results are consistent with the univariate results (with breaks) for the full sample and pre-crisis period. However, for the GFC period, the panel results with structural breaks indicate the OECD and Asian stock markets were random walks. This test provides some signs that a weak form of market efficiency may have prevailed during the 2008 financial crisis.

Table 5: Results from the panel KPSS type tests with and without breaks (full sample)
The Hadri (2000) panel test results for Pre GFC, and GFC period for the Asian and OECD panels are presented in column 2 and the Carrion-i-Silvestre *et al.* (2005) panel test results are presented in columns 3 and 4 in this table. *** denote statistical significance at 1% level. The probabilities are reported in parenthesis. The number of break points has been estimated using the LWZ information criteria, allowing for a maximum of 5 structural breaks for the full sample; 3 structural breaks for the Pre-GFC period; and 2 structural breaks for the GFC period.

Panel (sample)	**KPSS type test (without breaks)**	**Carrion-i-Silvestre test (with breaks)**	
	Hadri Z-stat [prob.]	**Homogeneous Bartlett [prob]**	**Heterogeneous Bartlett [prob]**
OECD (full sample)	82. 531*** [0. 000]	-1. 3360 [0. 9092]	-1. 0021 [0. 8418]
Asian (full sample)	64. 525*** [0. 000]	-0. 500 [0. 692]	-0. 350 [0. 637]
OECD (Pre GFC)	88. 135*** [0. 000]	0. 055 [0. 478]	-0. 315 [0. 624]
Asian (Pre GFC)	57. 707*** [0. 000]	0. 249 [0. 402]	0. 916 [0. 180]
OECD (GFC)	44. 903*** [0. 000]	2. 446*** [0. 007]	3. 090*** [0. 001]
Asian (GFC)	13. 480*** [0. 000]	3. 532*** [0. 000]	3. 309*** [0. 000]

3. 4. Structural Breaks in Stock Prices

In this section, we further examine the structural break dates for the 22 markets. A structural break has been traditionally seen as a long-term widespread change of the fundamental structure which warrants a shift in the series, referred to as a structural or regime shift in the series (Hansen 2001). To Hansen (2001), ‘structural change is a statement about parameters, which only has meaning in the context of a model’ (p11). As a result, a structural change is captured in a model as a shift in the intercept (known as a levels shift) or a shift in the trend or both. This view is reflected in the Carrion-i-Silvestre test which is used in the paper to derive structural breaks in benchmark stock price indices for 22 countries.

Allowing for structural breaks in the study of stock price behaviour is natural given that stock prices series are, by nature, volatile and sensitive to economic and financial shocks, be it internal or external. Recent shocks, such as financial crisis, the resulting recession in the US, the economic slowdown in the US and other Western countries after the September 11 terrorist attacks, and the oil price hikes may have induced significant levels shifts in the series. Nonetheless, the concept of structural breaks has been applied, but, only in limited empirical studies relating to empirical asset pricing and market efficiency (see, Pastor and Stambaugh 2001; Timmermann 2001; Bahng, 2004; Karoglou, 2010). [7] A recent study by Karoglou (2010) sheds some light on the importance of including structural breaks in equity markets. This study applies structural breaks in the examination of the benchmark stock market indices of 27 OECD countries.

The Carrion-i-Silvestre *et al.* (2005) test allows us to account for a maximum of five breaks in the intercept for each series. The break dates for the structural shocks are endogenously determined and are also used in deriving the critical values for the individual and panel tests. The break dates are presented in Table 6.

These break dates reveal information about market synchronization. First, notice that structural breaks around the GFC period are same for all the countries. In particular, the February 2007 and

[7] Timmermann (2001) provides empirical evidence on the existence of structural breaks in the fundamental process underlying US stock prices. This paper shows that investor’s knowledge about breaks can strongly affect the dynamics of asset pricing. Pastor and Stambaugh (2001), on the other hand, estimate the equity premium using the structural breaks, while Bahng (2004) develops a new mixture-of-normal model in an attempt of applying two-period structural break analysis.

August 2008 break dates are same. This means that markets were facing similar shocks or became synchronized in the period surrounding the crisis.

If these dates are examined against the individual stock price indices, one would notice that markets were still experiencing an upward trend around the break date in February 2007. Around this period, there was a striking difference between the developed and emerging markets – while markets were experiencing increasing returns, the rate of return was already falling in the developed stock markets but still increasing rapidly in emerging markets. This implies that stock markets had already begun factoring the future fallout from early 2007. This also implies that markets began to synchronise well before the markets began to suffer losses.

The market crash from 2008 to early 2009 is captured by the August 2008 break. Recent papers (highlighted in the introduction) do show increased correlation or co-movement in the GFC period beginning from 2007. However, our results clearly point out that the integration of the stock market began before the market crash.

Unlike the structural breaks that relate to the GFC period, the breaks associated with the pre-GFC period occurred at different times from early 2000s for all the markets examined here. This pre-GFC period in fact also captures the market downturn of 2002 following the burst of the dot-com bubble and the 11 September terrorist attacks in the US. These breaks coincided with worldwide shocks, such as the economic slowdown in the US, the burst of the IT bubble, or oil price shock. Others have coincided with country-specific shocks relating to the business cycle.

Table 6: Break dates for the full sample period

Table 6 displays the significant structural break dates derived from the Carrion-i-Silvestre *et al.* (2005) test for the 22 stock markets for the full sample. The number of break points has been estimated using the LWZ information criteria, by allowing for a maximum of 5 structural breaks.

Country	No of breaks	Break 1	Break 2	Break 3	Break 4	Break 5
Australia	5	12/11/2001	26/05/2003	26/11/2004	12/2/2007	20/8/2008
Austria	4	19/09/2002	15/6/2005	12/2/2007	20/8/2008	0
Belgium	5	25/10/2001	5/5/2003	15/4/2005	12/2/2007	20/8/2008
Canada	4	17/09/2002	27/4/2004	12/2/2007	20/8/2008	0
Denmark	5	9/07/2001	11/4/2003	15/6/2005	1/2/2007	20/8/2008
Finland	5	19/10/2001	29/4/2003	4/11/2004	12/2/2007	20/8/2008
France	5	9/7/2001	16/1/2003	26/7/2004	12/2/2007	20/8/2008
Germany	5	20/11/2001	29/5/2003	13/7/2005	12/2/2007	20/8/2008
Italy	4	22/7/2002	21/1/2005	12/2/2007	20/8/2008	0
Japan	5	15/8/2001	13/6/2003	4/8/2005	12/2/2007	20/8/2008
South Korea	5	22/11/2001	11/6/2003	22/7/2005	12/2/2007	20/8/2008
Portugal	5	19/7/2002	27/1/2004	4/8/2005	12/2/2007	20/8/2008
Spain	4	18/7/2002	1/7/2004	6/2/2007	20/8/2008	0
Sweden	5	10/7/2002	16/1/2004	26/7/2005	12/2/2007	20/8/2008
Turkey	5	25/10/2001	11/9/2003	4/8/2005	12/2/2007	20/8/2008
UK	5	9/10/2001	17/4/2003	30/6/2005	12/2/2007	20/8/2008
US	4	9/7/2002	28/4/2004	12/2/2007	20/8/2008	0
China	5	27/7/2001	2/1/2004	4/8/2005	12/2/2007	20/8/2008
India	5	14/11/2001	7/8/2003	21/7/2005	1/2/2007	20/8/2008
Malaysia	5	3/12/2001	11/6/2003	17/3/2005	22/1/2007	20/8/2008
Singapore	5	3/12/2001	11/6/2003	28/7/2005	5/2/2007	20/8/2008
Thailand	5	21/12/2001	1/7/2003	10/3/2005	12/2/2007	20/8/2008

3. 5. Leverage and Persistence

The EGARCH results are summarised in Table 7. Our main results are as follows. We find strong evidence of leverage effect across all the equity markets studied here. Generally, during bad times one is inclined to think that negative shocks would lead to more volatility than positive shocks (see, Engle, 1990; Anderson and Bollerslev, 1997; Bollerslev *et al*. 2006). In this paper, we find evidence in favour of the view - that the leverage effect is magnified during bad times - for most of the major stock markets. With the exceptions of Austria, Sweden, India and Thailand, all the other markets experienced an increase in the leverage effect during the GFC.

Table 7: E-GARCH framework results

Table 7 displays results derived from the variance of the EGARCH model (1, 1). C(3) is a constant and C(4)-(6) are the other estimated parameters. Of interest to this paper are C(5) and C(6). The existence of asymmetric effects is tested by the hypothesis that $C(5) \neq 0$. The parameter, $C(6)$, provides information on persistence of stock price volatility. The probability associated with each of the estimated parameters is zero.

	Full Sample				**Pre-crisis**				**Crisis**			
	C(3)	**C(4)**	**C(5)**	**C(6)**	**C(3)**	**C(4)**	**C(5)**	**C(6)**	**C(3)**	**C(4)**	**C(5)**	**C(6)**
AUS	-0. 297	0. 144	-0. 114	0. 981	-0. 473	0. 120	-0. 136	0. 962	-0. 484	0. 139	-0. 142	0. 956
AUT	-0. 530	0. 254	-0. 093	0. 964	-1. 167	0. 273	-0. 117	0. 901	-0. 340	0. 169	-0. 101	0. 974
BEL	-0. 358	0. 179	-0. 116	0. 976	-0. 412	0. 189	-0. 113	0. 972	-0. 435	0. 159	-0. 136	0. 963
CA	-0. 181	0. 103	-0. 070	0. 989	-0. 188	0. 086	-0. 063	0. 987	-0. 220	0. 123	-0. 102	0. 985
DEN	-0. 293	0. 129	-0. 071	0. 979	-0. 460	0. 141	-0. 078	0. 963	-0. 180	0. 090	-0. 084	0. 987
FIN	-0. 104	0. 076	-0. 050	0. 994	-0. 084	0. 069	-0. 034	0. 996	-0. 158	0. 086	-0. 086	0. 989
FRA	-0. 238	0. 103	-0. 123	0. 982	-0. 233	0. 088	-0. 121	0. 982	-0. 306	0. 136	-0. 139	0. 976
GER	-0. 244	0. 112	-0. 116	0. 982	-0. 237	0. 106	-0. 104	0. 983	-0. 247	0. 128	-0. 145	0. 982
ITA	-0. 771	0. 3122	-0. 057	0. 945	-1. 088	0. 427	-0. 022	0. 927	-0. 247	0. 2975	-0. 182	0. 999
JAP1	-0. 303	0. 149	-0. 073	0. 978	-0. 379	0. 153	-0. 073	0. 970	-0. 213	0. 086	-0. 104	0. 982
KOR	-0. 252	0. 135	-0. 075	0. 982	-0. 249	0. 145	-0. 067	0. 983	-0. 212	0. 076	-0. 114	0. 981
POR	-0. 456	0. 191	-0. 091	0. 967	-0. 463	0. 171	-0. 070	0. 966	-0. 644	0. 209	-0. 161	0. 944
SPA	-0. 252	0. 112	-0. 107	0. 982	-0. 246	0. 103	-0. 093	0. 982	-0. 312	0. 128	-0. 149	0. 974
SWE	-0. 187	0. 089	-0. 096	0. 986	-0. 217	0. 093	-0. 102	0. 983	-0. 100	0. 080	-0. 082	0. 995
TUR	-0. 265	0. 160	-0. 044	0. 981	-0. 248	0. 163	-0. 035	0. 984	-0. 443	0. 128	-0. 086	0. 956
UK	-0. 219	0. 109	-0. 115	0. 986	-0. 261	0. 099	-0. 131	0. 981	-0. 247	0. 089	-0. 122	0. 979
US	-0. 188	0. 083	-0. 114	0. 987	-0. 198	0. 064	-0. 113	0. 984	-0. 207	0. 095	-0. 128	0. 984
China	-0. 194	0. 132	-0. 026	0. 988	-0. 207	0. 130	-0. 021	0. 987	-0. 572	0. 139	-0. 097	0. 939
India	-0. 564	0. 274	-0. 091	0. 958	-0. 857	0. 296	-0. 114	0. 927	-0. 560	0. 246	-0. 089	0. 951
Malaysia	-0. 320	0. 167	-0. 066	0. 980	-0. 285	0. 155	-0. 056	0. 982	-0. 402	0. 196	-0. 095	0. 973
Singapore	-0. 304	0. 170	-0. 072	0. 981	-0. 352	0. 170	-0. 069	0. 976	-0. 235	0. 161	-0. 083	0. 987
Thailand	-0. 932	0. 178	-0. 090	0. 904	-1. 200	0. 176	-0. 087	0. 873	-0. 418	0. 173	-0. 062	0. 964

The other key result for the GFC is to do with persistence of volatility. Across all three periods, our results consistently suggest that shocks had a persistent effect on the volatility of major equity markets of the world. [8] However, for the GFC, we notice a slight change in persistence for almost all countries. In comparison with the pre-crisis period, we find that volatility was less persistent during the GFC period for 14 out of 22 countries. These countries are Australia, Belgium, Canada, Finland, France, Germany, Korea, Portugal, Spain, Turkey, UK, China, Malaysia, and Thailand. For the other 6 out of 22 countries, volatility became more persistent during the GFC period than the pre-GFC period. This indicates that shocks continued to have a persistent effect on the market in the financial crisis period.

4. Concluding Remarks

In this study, we examined the behaviour of financial markets in the developed and emerging world in the period leading to the GFC as well as during the GFC. We found that stock markets in both groups behaved similarly during the crisis period. We showed that during the GFC, markets in both groups experienced a fall in persistence of conditional volatility. The leverage effect became more pronounced during the GFC for markets in the developed and emerging countries. We also found that these markets became unpredictable or efficient during the GFC.

Our analysis of the structural breaks suggested that structural break dates converged in February 2007 and August 2008. This synchronization of the markets since February 2007, suggests

[8] Poterba and Summers (1986) claimed that shocks to the volatility are transitory and hence, these do not have much impact on the market. However, later studies (such as, Chou (1988)) that use ARCH-GARCH framework to study the persistence of stock volatility, generally find that stock volatility is persistent.

that markets had begun factoring the impending crisis before the fallout in 2008. Market integration during a financial crisis is commonly found. However, our analysis clearly points out that this integration between markets around the world began well before the stock market crash. While we did not find similar patterns during the 2002 market crashes, it may be the case that this is unique to the GFC period.

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