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Pre & Post-Recession Stock Markets Integration: Some Empirical Evidence

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Abstract

The financial markets across globe have become distinctly integrated owing to liberalization and globalsiation policy as well as advancement of information technology. The contagion effect of macroeconomic disturbances or financial crisis, internally and externally, is rapidly disseminating across various economies. The recent global recession of 2007-09 started with US subprime crises and subsequently followed by Lehman brother crisis affected all most all major economies of the world. In this contenxt, the present paper explores the stock market integration of leading stock exchanges across various countries during pre and post economic crisis of 2007-09. Thus for empirical analysis, it uses the data since 2004-2012. It attempts to find out the breaks point, if any, in the pattern of stock price movements endogenously. Further efforts have also been made to examine changing pattern of relationship among stock prices using bivariate and multivariate cointegration techniques. The study suggests that although stock markets are integrated globally, the integration is very weak. This proposes that stock prices as well as returns are not strongly interrelated across markets. The Granger casualty results also provides mixed evidences, although some changes are noticed about the causality between stock prices from pre-recession to post recession period in Chinese stock markets.

Keywords: recession, stock prices, volatility, stationary, cointegration, causality

1. Introduction

The trailblazing advancement of science and information technology and development of infrastructure, have resulted in substantial integration of world economies. Countries have become more interdependent in various ways. Therefore, any macroeconomic disturbances or crisis in one part of the globe has a quick contagion effect on others with different intensity and degree. In the recent past the Argentina's crisis, Asian financial crisis, US subprime crises followed by US recession are the burning episode. As prevention is better than cure, a fair understanding of interdependencies is certainly helpful for the policy makers to safeguard their economies. The stock market, which is considered to be highly volatile and integrated, often reacts faster than any other markets. Since stock price movements are very sensitive to market information, any such news affects the market immediately. Despite this, stock market considered to be the most efficient market. Thus investors diversify the portfolio to reduce systematic risk. The fact is that there is no dearth of information, although in an imperfect world, accumulation of full and perfect information is quite expensive. In a perfectly integrated market, scope of arbitrage opportunity for an investor due to price differentials is very limited as law of one price holds. Based on asset pricing model, stocks with similar risk in future cash flows should be similarly priced regardless of where they are listed (Adler, 1995; Bekaert and Harvey, 1995; and Bekaert et al., 2002). Other implications of highly interlinked stock markets could be the cost of borrowing, which discourage foreign listings. Similarly, from fund managers and investors perspective, stock markets inter-linkage is more stimulating as they explore the possibility of portfolio diversification to reduce risk and maximize profit.

Integration of global financial markets in general and stock market in particular have received considerable attention among investors, researchers and policy makers. The empirical studies on inter-linkage of stock market present mixed result. The earlier studies by Ripley (1973), Lessard (1976), and Hilliard (1979) largely found low correlations between national stock markets. On the other hand, recent studies like Janakiramanan (1998), Hsiao (2003), Morana and Beltratti (2008), Wang et.al (2005) etc. found significant unidirectional linkages among

stock markets. While contrary to this, there are good number of studies like Gilmorea (2002), Egert and Kocenda (2007), Nath (2003), Koop (1994), Sharma and Kennedy (1977) etc. found no cointegration or very weak linkage among different stock markets. Lack of consensus could be attributed to time period of the study, differential stocks markets structure and different methodology applied in these studies. Chronologically, compared to pre 1980s; post 1980s shows higher inter-linkage across various stock markets. This perhaps owes to advancement in technology, development in infrastructure, implementation of liberalization policies across various countries.

It is also evident from the exiting literature that studies conducted over different time period could be one of the reasons why controversial results arises. These mixed evidences pose an important empirical question; are inter-linkage among stock markets time sensitive? In this context, it is worthwhile to mention few noteworthy studies namely Sheng(2000), Cifarelli (2000), Hashmi (2001), Tan (2001), Ratanapakorna (2002), Jang (2002), Yang(2002), Kim (2005), Fan (2003), Melle (2002), Click and Plummer (2005), Lucey and Voronkova(2008) etc. These studies have concentrated on the stock market integration during 1997-1998 Asian financial crises and found that there is shift in the pattern of return and volatility transmission during crisis period.

Another possible reason could be the choice of research methodology used in time series analysis. The choice of unit root tests that are widely used for examining time series properties has its own weakness in the presence of structural breaks. In such a situation, the conventional unit root tests such as ADF (1979) and Phillip-Perron (1988) are biased towards non rejection of the null hypothesis as pointed out by Perron (1989). Subsequently, Zivot and Andrews (1992), Perron and Vogelsgang (1992), Perron (1997), Lee and Strazicich (2004) suggested a test statistics that allow endogenous single structural break in the series while testing unit roots tests in a time series data.

This paper tries to explore the inter-linkages of stock markets by carefully selecting the time periods endogenously as pre and post recession using unit root test with structural breaks. Further the study investigates if there are any changes in the causal direction and integration among the stock markets of different countries using Johansen cointegration and Granger causality test which is considered as one of the most important contemporary technique for such kinds of studies. Rest of the paper is organized as follows; the second section focuses on data and methodology, third section presents the empirical findings and final section focuses on the conclusion of the paper.

2. Data and Empirical Methodology

The study uses five world stock markets, namely SSE50 (Shanghai, China), BSESensex (India), Nasdaq (USA), FTSE100 (UK), and Nikkei225 (Japan) as they are the leading global stock markets in the world. The daily closing price data is collected from yahoo finance over the period Jan 4, 2004 to March 23, 2012. The time period is divided into two sub-periods i.e. pre-recession period from Jan 4, 2004 to Dec 31, 2007 and post-recession period as Jan 1, 2008 to March 23, 2012. The starting point of the crisis period is taken as 2008 due to the fact that the symptoms of recession started appearing in 2008 (Note 1). It is further verified by scatter plot the indices of different stock markets taken in this study which is shown in Fig-1. Apart from this, the study also used endogenous structural break of each series to verify empirically the break using test proposed by Zivot and Andrews (1992). The values of stock index are expressed in natural logarithms, the first difference of which provides the returns. Variables name prefix with 'l' stands for variable with natural log and 'dl' stands for first difference in log which is the return.

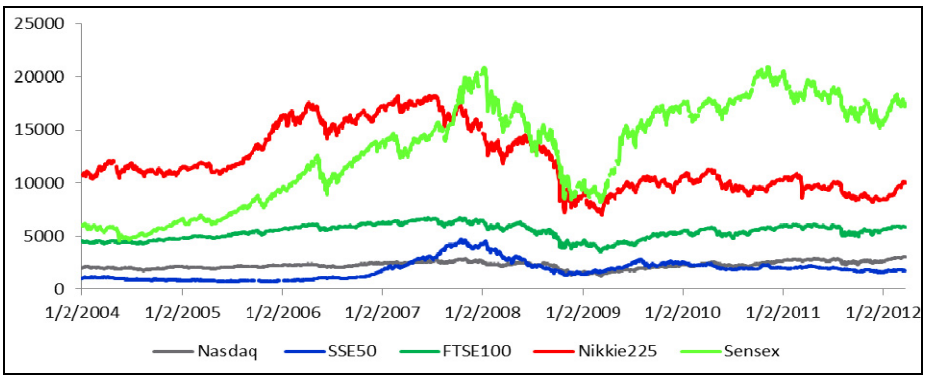

Figure 1. Graph of selected stock indices of world's leading stock market

The descriptive statistics such as average, standard deviation, skewness and kurtosis as well as simple correlation coefficient provides some preliminary understanding about nature of data and interrelationship among the stock indices. The estimated correlation coefficient provides contemporaneous relationship among these variables. However, since simple correlation coefficient doesn't provide sufficient information about the long-run and short-run relationship among variables with dynamic features, the cointegration and causality tests is applied to fill the gap.

2.1 Unit Root Tests with Structural Break

The study begins with applying Augmented Dickey Fuller test (Dickey-Fuller, 1979, 1981), and subsequently applies Ng Perron (2001) and Zivot and Andrews (1992) unit root tests. A brief overview of these tests and their relevance are discussed as follows. The ADF test is the extended version of the Dickey Fuller (Dickey-Fuller, 1979, 1981), unit root tests. It is augmented by lagged period of the dependent variable. The test constructs a parametric correction of the higher order serial correlation by assuming that the series follows an AR(k) process. The test controls for higher order correlation by adding lagged difference in terms of the dependent variable to the right hand side of the regression. The model in its intercept and trend version may be specified as follows

$$\Delta Y_t = \Phi + \delta T + \alpha Y_{t-1} + \sum_{j=1}^{k} dj\, \Delta Y_{t-j} + \epsilon t \tag{1}$$

The ADF test formulates the null and alternative hypothesis in the following way, H_0: α=0, H_1: α <0 $\forall\, y$ and tests the hypothesis using 't' statistics after selecting the appropriate lag length through minimum of AIC criteria. However the main problem of ADF test is that, it neither considers serial correlation problem of the residual term nor takes care structural break.

On the other hand, the Ng-Perron (2001) tests statistics are modified form of Phillips (1987) and Phillips-Perron (1998) test Zα and Zt statistics. They construct four M-test statistics which are based upon the GLS de-trended data (MZ_α^{GLS}, MSB^{GLS}, MZ_t^{GLS}= MZ_α^{GLS}. MSB^{GLS} and MP_t^{GLS}). It tests the stationary or non-stationery through four unit root tests statistics that are calculated using generalized least square de trended data for a series, which has better power and size compared to DF, ADF, PP, DFGLS tests. Considering the data generating process $y_t=\alpha y_{t-1}+\varepsilon_t$, where $\{\varepsilon_t\} \sim$ I.I.D $(0, \sigma_\varepsilon^2)$, using the GLS detrended data $\tilde{y}_t$,, the Ng-Perron tests statistics are defined as,

$$MZ\alpha^{GLS} = (T^{-1}, \tilde{y}_t - f_0)/2k \tag{2}$$

$$MSB^{GLS} = \left(\frac{k}{f_0}\right)^{1/2} \tag{3}$$

$$MZ_t = MZ\alpha^{GLS} \times MSB^{GLS} \tag{4}$$

$$MPT = \begin{cases} \bar{c}^2 k - \bar{c} T^{-1} \tilde{y}_t^{\,2})/\, f_0 & \text{if } x_t=\{1\} \\ \bar{c}^2 k + (1-\bar{c}) T^{-1} \tilde{y}_t^{\,2})/f_0 & \text{if } x_t=\{1,t\} \end{cases} \tag{5}$$

Where $K = \sum_{t=2}^{T} \tilde{y}_{t-1}^{\,2}/T^2$ and f_0 is an estimate of the residual spectral density at the zero frequency. $\bar{c}$ is the local-to-unity parameter selected by ERS, (Elliott, Rothenberg, and Stock., 1996) as,

$$\bar{C} = 1\text{-}7/T, \quad \text{if } x_t=\{1\}$$

$$\text{Or, } \bar{C} = 1\text{-}13.5/T, \quad \text{if } x_t=\{1,t\}$$

The tests also address the problem of sensitivity of unit root testing to choice of lag. They propose modified information criteria (MIC), which takes into account the bias in the sum of the autoregressive coefficients which is highly dependent on number of lags that the general Akaike and Schwarz Bayesian criteria do not. Further, they also formulate the null hypothesis that the series has unit root.

Both the ADF and Ng-Perron tests provide misleading result about unit root tests when the series have one or more structural break. These tests assumes structural break as an exogenous phenomena. However, Zivot and Andrews (ZA, 1992) propose a new tests statistics by modifying the Perron's original tests and suggest that break could be endogenously determined. Zivot and Andrews (ZA, 1992) suggested three model for testing unit root. They are as follows:

a. One time break at level: $$\Delta Y_t = \phi + \alpha Y_{t-1} + \beta_t + \gamma DU_t + \sum_{j=1}^{k} dj\Delta Y_{t-j} + \epsilon t \quad (6)$$

b. One time break at trend: $$\Delta Y_t = \phi + \alpha Y_{t-1} + \beta_t + \theta DT_t + \sum_{j=1}^{k} dj\Delta Y_{t-j} + \epsilon t \quad (7)$$

c. One time break at both level & trend: $$\Delta Y_t = \phi + \alpha Y_{t-1} + \beta_t + \gamma DU_t + \theta DT_t + \sum_{j=1}^{k} dj\Delta Y_{t-j} + \epsilon t \quad (8)$$

Where DU_t is an indicator dummy variable for shifting in mean at each possible break date (TB) and DTt is similarly variable as shift in trend. They may be deified as

$$DUt = \begin{cases} 1 \ldots\ldots if\ T>TB \\ 0 \ldots\ldots Other\ wise \end{cases} \text{ and } DTt = \begin{cases} 1 \text{-----} if\ T>TB \\ 0 \ldots\ldots Other\ wise \end{cases}$$

For all these three model specifications, the null hypothesis of unit root test is $\alpha=0$, indicating that the particular series is non-stationary with drift excluding structural break, whereas the alternative hypothesis is $\alpha<0$ implies that the series is trend stationary with one time break at an unknown time. Considering every point as a break the model is estimated with multiple regression models for every possible break date sequentially. The break date is specified with minimum of one sided t statistics.

2.2 Cointegration

Conceptually, cointegration implies if linear combinations of any two non-stationary time series are stationary then the two series are cointegrated. They follow equilibrium relationship in long-run. The Engel-Granger (1987) bivariate and Johansen (1988, 1991) Johansen-Juselius (1990, 1992) multivariate cointegration tests are two most powerful contemporary tests. While the former is suitable for one to one contemporaneous relationships, the latter is appropriate for simultaneous relationships with dynamic features.

The Engel Granger cointegration test follows two steps simple regression model procedure estimated through ordinary least square principles. In the first step, it specifies a linear regression mode considering any one variable as dependent and other as independent variable. Then it estimates coefficients with least squares methods. In the second step, it obtains residuals of the regression model and tests whether it is stationary or not. If the residual series is stationary then it is concluded that both the variables are cointegrated or else not. The mathematical model can be expressed as

$$Y_t = \alpha + \beta X_t + \varepsilon_t \quad (9)$$

Here Y_t is the dependent variable, X_t is the independent variable and ε_t is the error term. As per model both Y_t and X_t should be non-stationary. If their linear combinations ε_t is stationary, then both the series are cointegrated. The stationary of ε_t can be tested by applying unit root tests.

On the other hand, the multivariate cointegration test of Johansen (1988, 1991) and Johansen-Juselius (1990, 1992) tests are applied here (Note 2). The test is popularly known as Johansen-Juselius cointegration tests. It apples maximum likelihood estimation procedure to determine the presence of number of cointegrating vectors in a set of non-stationary time series variables expressed as a vector autoregressive (VAR) process. Then tests whether variable are cointegrated or not using maximum eigen value and trace tests statistic. Mathematically the model can be expressed as,

$$\Delta Y = A + \sum_{i=1}^{k} \tau_i \Delta Y_{t-1} + \pi Y_{t-1} + \boldsymbol{\varepsilon_t} \quad (10)$$

Where, Y_t is a vector of non-stationary variables and A is a vector of intercept term. The information on the coefficient matrix between the levels of the π is decomposed as $\pi = \alpha\beta$ where the relevant elements α matrix are adjustment coefficient and the β matrix contains cointegrating vectors. Johansen and Juselius tests specify two likelihood ratio test statistics in order to test presence of number of cointegrating vectors. The first likelihood ratio test statistics for the null hypothesis of exactly r cointegrating vectors against the alternative of r+1 cointegrating vectors is the trace statistic. The second test statistic for the hypothesis of at most r cointegrating vectors against the alternative of less than r+1 cointegrating vector is the maximum eigen values statistic. Critical values for both test statistics are can be obtain from MacKinon-Haug-Michelis (1999) tabulated values.

Gonzalo and Lee (1998) analyzed the robustness of these two cointegration tests. They found that Engel-Granger (EG) test is more robust than Johansen LR tests because misspecifications of the long-memory components of the variables affect their correlation structure more than their variances. But when the model is misspecified with *I*(1) variables whose VAR representation has a singular or near-singular error covariance

matrix, then a proper use of the LR test in applied cointegration analysis requires a deeper data analysis than the standard unit root test. In that case Johansen test is more robust than the EG tests. However, they have also recommended the use of both the EG and Johansen tests of cointegration. Similarly, Gonzalo (1994) analyzed the statistical performance of three cointegration tests such as, Engel-Granger, the Stock and Watson tests, and Johansen's test and found that Johansen's is superior to the other tests under consideration. It is because this test ensures that coefficients estimates are symmetrically distributed and median unbiased and that hypothesis test may be conducted using standard asymptotic chi-squared tests.

Cointegration tests themselves cannot establish the direction of causality but tests can be applied to cointegrating VARs such as those estimated using the Johansen procedure (Johansen and Juselius, 1990). However, an advantage of cointegration analysis is that if any integrated variables are omitted from the cointegrating relationship, which should be included in it, then the remaining variables will fail to cointegrate. Thus, if two variables share a common trend, there will be Granger causality in one or more directions between them (Cuthbertson *et al*., 1992). But in the absence of cointegration between the variables a Granger causality test in levels is invalid. Therefore it is essential to test the cointegration before applying Granger Causality tests for testing the causality.

2.3 Granger Causality Test

Granger causality test as mentioned by Granger (1986) has been applied here to find out the unidirectional or bidirectional causality among stock prices. According to Granger (1986) if two variables are cointegrated then they are necessarily causally related at least in one direction. The Granger causality test tries to find out if one variable precedes the other variable or if they are contemporaneous. Granger causality test is suitable for stationary data. Empirically the Granger causality test can be specified as a form of VAR model expressed for stationary data.

$$Y_t = \alpha_{10} + \sum_{i=1}^{m} \alpha_{1i} Y_{t-i} + \sum_{i=1}^{m} \beta_{1i} X_{t-i} + \varepsilon_{1t} \quad (11)$$

$$X_t = \alpha_{20} + \sum_{i=1}^{m} \alpha_{2i} X_{t-i} + \sum_{i=1}^{m} \beta_{2i} Y_{t-i} + \varepsilon_2 t \quad (12)$$

Where, ε_{1t} and ε_{2t} are white noise error terms in both equations. In this equation, the constant term $\alpha_{10,}$ α_{20} represents the growth rate of Y and X in the respective equations, whereby, error term represents the effects of changes in other variables on the X and Y. The number of lags 'm' can be decided based on AIC or SBC criteria. The decision to choose VAR model is based on diagnostic checking. The empirical results presented in this paper are all calculated within a VAR-model. The causality is tested applying Granger causality test based on F statistics. All the estimations are done using Eviews and STATA software.

However, the Granger causality test has been severely criticized in the econometrics literature. Roberts and Nord (1985) found that the functional form of the time series affected the sensitivity of the Granger's tests. According to them logarithmically transformed data shows no sign of causality whereas untransformed data yielded significant results. It is because perhaps the logarithmic transformation tends to reduce heteroskedasticity and increase the stationarity of the variables. Similarly, Chowdhury (1987) found more disturbing results that give support to those who have doubted whether Granger causality was related to philosophical causality or economic exogeneity in any meaningful way.

3. Empirical Analysis

Some missing observations observed in the data sets as stock markets do not trade during holidays, which distinctly vary across countries. Table-1 shows the number of missing observations in each stock market, which is highest for China and lowest for USA. A graphical representation of stock indices presents in graph-1 indicates that the stock price doesn't moves in similar direction in long run.

The descriptive statistics presented in table-1. It shows that Jarque-Bera statistic, defined over skewness and kurtosis measures, is very high for all five stock markets, implying that stock returns differ significantly from normal distribution. As per the JB tests, null hypothesis of normality is rejected at 1% significance level for all five indices for complete and two-sub periods. The lowest and highest coefficient of variation (CV) implies lowest and highest volatility of stock price respectively. The coefficients of skewness are different from zero for all indexes except Nikkei225 during pre-recession period. This reflects the asymmetry of returns. The FTSE100 (UK) is the lowest volatile and SSE50 (Shanghai) is the highest volatile stock price over the years 2004 - 2012. Similarly during pre-crisis period highest and lowest volatile stock prices are SSE50 (Shanghai) and Nasdaq

(USA), whereas during post crisis period they are FTSE100 (UK) and Sensex (India) respectively.

Table 1. Descriptive statistics of stock indices

Year	Stock Indices	Mean	Max	Min.	Std. Dev.	Sk.	Kurtosis	Jarque -Bera	P. value of JB	C.V.	Obs	Missing Obs.*
2004-2007	NASDAQ	2231.6	2859.1	1752.5	245.5	0.5	2.3	61.2	0.000	0.11	1006	36
	NIKKEI225	14180.0	18262.0	10365.4	2601.5	0.0	1.3	113.5	0.000	0.18	984	58
	SENSEX	9975.5	20375.9	4505.2	4118.9	0.6	2.4	76.1	0.000	0.41	996	46
	SSE50	1513.9	4731.8	700.4	1081.5	1.6	4.2	469.1	0.000	0.71	958	84
	FTSE100	5500.4	6732.4	4287.0	743.3	-0.1	1.6	83.0	0.000	0.14	1011	31
2008-2012	NASDAQ	2292.6	3078.3	1268.6	401.7	-0.5	2.6	59.8	0.000	0.18	1064	40
	NIKKEI225	10177.4	14691.4	7055.0	1665.2	1.0	3.2	164.8	0.000	0.16	1032	72
	SENSEX	16127.7	21005.0	8160.4	3009.8	-1.1	3.5	206.4	0.000	0.19	1039	65
	SSE50	2126.7	4499.1	1305.7	507.5	1.8	7.6	1460.9	0.000	0.24	1025	79
	FTSE100	5299.6	6479.4	3512.1	639.6	-0.8	2.7	120.0	0.000	0.12	1067	37
2004-2012	NASDAQ	2262.9	3078.3	1268.6	336.3	-0.3	2.9	25.1	0.000	0.15	2070	76
	NIKKEI225	12131.1	18262.0	7055.0	2953.8	0.6	2.0	184.4	0.000	0.24	2016	130
	SENSEX	13116.6	21005.0	4505.2	4731.3	-0.3	1.8	162.7	0.000	0.36	2035	111
	SSE50	1830.7	4731.8	700.4	889.8	1.0	3.8	356.6	0.000	0.49	1983	163
	FTSE100	5397.3	6732.4	3512.1	699.1	-0.3	2.2	83.3	0.000	0.13	2078	68

* Number of missing trading days (due to holidays excluding weekends) from Jan 2, 2004- March 23, 2012
Source: Computed from the data set from www.yahoofinance.com

Similarly a preliminary understanding about cotemporaneous relationship among stock prices is estimated through correlation coefficient. The estimated correlation coefficient for the period 2004-2007, 2008-2012 and 2004-2012, results are reported in table-2. The correlation coefficient shows that there is over all fall in the correlation coefficient between stock markets after recession. It is interesting to note that except for SSE50-Nikkei225, for all other combinations the correlation coefficient has decreased from pre to post crisis period which indicates that during pre-crisis period the stock prices are highly correlated. For the year 2004-2012, the Sensex and Nikkei225 show negative correlation and others positive. The Nasdaq and FTSE100 are having highest positive correlation coefficients. However, result of simple correlation does not provides sufficient information about the dynamic relation when the times are non-stationary having unit root problem.

Table 2. Correlation coefficients of stock indices

Correlation between	2004-2007	2008-2012	2008-2012	Consequence
Nasdaq-Sensex	0.94	0.82	0.68	Decreased
Nasdaq-SSE50	0.84	0.11	0.45	Decreased
Nasdaq-FTSE100	0.91	0.90	0.84	Decreased
Nasdaq-Nikkei225	0.84	0.25	0.29	Decreased
Sensex-SSE50	0.84	0.34	0.72	Decreased
SensexFTSE100	0.94	0.84	0.59	Decreased
Sensex-Nikkei225	0.86	0.26	-0.05	Decreased
SSE50 –FTSE100	0.68	0.38	0.49	Decreased
SSE50–Nikkei225	0.58	0.71	0.20	Increased
FTSE100-Nikkei225	0.95	0.52	0.67	Decreased

3.1 Unit Root Tests and Structural Break

As discussed earlier, three different unit root tests namely, the Augmented Dickey Fuller (Dickey-Fuller, 1979, 1981), Ng-Perron (2001) and Zivot-Andrews (1992) tests are applied for testing the stationary and non-stationary properties of stock indices expressed in natural logs. All models are expressed with constant and with constant & trend term in the regression equation. The results of ADF tests are reported in table-3. It shows that all variables are non-stationary at level but stationary at first difference for entire three periods. The figures in brackets denotes lag length of the model selected based on lowest of SBC and the figures in parenthesis shows probability values of tests statistics to reject the null hypothesis.

Table 3. ADF unit root tests

Variables	2004-2007		2008-2012		2004-12	
	C	CT	C	C	CT	C
lnasdaq	-1.33(0)	-3.57(0)	1.541(0)	-2.87(0)	-2.10(0)	-2.49(0)
	(0.614)	(0.033)	(0.512)	(0.172)	(0.244)	(0.331)
lnikkei225	-1.494 (0)	-1.074 (0)	-1.769(1)	-1.054(1)	-0.968(0)	-1.584(0)
	(0.536)	(0.951)	(0.395)	(0.934)	(0.766)	(0.799)
lsensex	0.264 (0)	-3.592 (0)	-0.91(0)	-1.681(0)	-1.509(0)	-1.280(0)
	(0.974)	(0.031)**	(0.785)	(0.789)	(0.528)	(0.892)
lsse50	2.420 (0)	-0.384 (0)	-2.945(0)	-2.756(0)	-0.585(0)	-0.276(0)
	(1.000)	(0.988)	(0.041)	(0.214)	(0.871)	(0.991)
lftse100	-0.881(1)	-3.598(1)	-1.428(1)	-2.279(5)	-1.471(5)	-1.432(5)
	(0.794)	(0.030)	(0.569)	(0.444)	(0.548	(0.851)
dlnasdaq	-30.55 (0)	-30.84(0)	-35.1(0)	-35.20 (0)	-33.2(1)	-33.28(1)
	(0.00)*	(0.00) *	(0.00)*	(0.00) *	(0.00) *	(0.00) *
dlnikkei225	-29.72 (0)	-29.757(0)	-30.72(0)	30.792(0)	-42.87(0)	-42.879(0)
	(0.000) *	(0.000) *	(0.000) *	(0.000) *	(0.000) *	(0.000) *
dlsensex	-28.73 (0)	-28.764(0)	-29.49(0)	-29.57(0)	-41.21(0)	-41.210(0)
	(0.000) *	(0.000) *	(0.000) *	(0.000) *	(0.000) *	(0.000) *
dlsse50	-31.06 (0)	-31.583(0)	-32.05(0)	-32.066(0)	-44.47(0)	-44.469(0)
	(0.000) *	(0.000) *	(0.000) *	(0.000) *	(0.000) *	(0.000) *
dlftse100	-34.35(0)	-34.337(0)	-14.94(4)	-15.06(14)	-20.57(4)	-20.570(4)
	(0.000) *	(0.000)	(0.000) *	(0.000) *	(0.000) *	(0.000) *

*,**,*** denotes 1%, 5% and 10% significance level respectively. The critical values are from DF table.

Similarly Ng-Perron tests results reported in table-4 provides similar result. The null hypothesis of unit root is rejected at various significance levels at first difference but accepted at level.

Table 4. Ng Perron unit root tests

Years	Variables	With Constant				With Constant and Trend			
		Mza	Mzt	MSR	MPT	Mza	Mzt	MSR	MPT
2004-07	lnasdaq	-s0.35	-0.19	0.48	16.80	-13.23	-2.55	0.19	7.02
	lNikkeii225	-0.03	-0.02	0.84	48.68	-6.28	-1.63	0.26	14.56
	lsensex	1.86	2.31	1.24	122.70	-3.29	-1.15	0.35	25.22
	lsse50	2.54	3.14	1.24	136.40	0.26	0.23	0.90	166.60
	lftse100	0.68	0.67	0.98	63.72	-17.02	-2.89	0.17	5.55
2008-12	lnasdaq	-2.77	-1.13	0.41	8.70	-2.83	-1.10	0.39	29.61
	lNikkeii225	-6.70	-466.00	0.66	24.25	-4.81	-1.44	0.30	18.32
	lsensex	-1.57	-0.86	0.55	15.02	-2.15	-1.02	0.47	41.10
	lsse50	0.28	0.31	1.09	69.35	-1.72	-0.88	0.51	48.97
	lftse100	-1.81	-0.93	0.52	13.26	-2.79	-1.10	0.40	31.32
2004-12	lnasdaq	-3.58	-1.03	0.29	6.91	-9.40	-2.10	0.22	10.11
	lnNikkeii225	-3.59	-1.32	0.37	6.53	-3.61	-1.34	0.37	25.18
	lsensex	0.41	0.44	1.07	69.75	-4.59	-1.46	0.32	19.45
	lsse50	-0.40	-0.33	0.83	36.92	-1.81	-0.86	0.48	43.84
	lftse100	-2.04	-0.87	0.43	10.78	-6.03	-1.74	0.28	15.09
2004-07	dlnasdaq	-6.72***	-1.73***	0.26	4.02	-32.91*	-4.05*	0.12	2.82
	dlNikkeii225	-441.85*	-14.84*	0.03	0.07	-442.59*	-14.85*	0.03	0.25
	dlsensex	-466.18*	15.26*	0.03	0.05	-465.84*	-15.26*	0.03	0.20
	dlsse50	-10.49**	-2.33**	0.66	25.58	-14.80***	-2.85***	0.49	45.90
	dlftse100	-483.24*	-15.54*	0.03	0.05	-406.67*	14.25*	0.06	0.25
2008-12	dlnasdaq	-496.08*	-15.78	0.03	0.04	497.50*	-15.77*	0.03	0.18
	dlNikkeii225	-5.77***	-1.68	0.30	4.32	-328.68*	-12.82*	0.04	0.28
	dlsensex	-440.51*	-14.84	0.03	0.60	-291.15*	-12.06*	0.04	0.32
	dlsse50	-469.76*	-15.33	0.03	0.05	-21.87**	-3.28**	0.15	0.34
	dlftse100	-27.21*	3.68	0.14	0.92	-195.56*	-9.89*	0.05	0.47
2004-12	dlnasdaq	-7.42***	-1.89	0.25	3.43	-14.2***	-2.7***	0.19	6.42
	dlNikkeii225	-872.73*	-20.89	0.02	0.03	-140.93*	-8.39*	0.06	0.65
	dlsensex	-939.15*	-21.67	0.02	0.03	-28.02*	-3.74*	0.13	3.28
	dlsse50	-9.67**	-1.89	0.35	6.70	-14.96**	-2.63**	0.31	18.16
	dlftse100	-1649.56*	-28.72	0.02	0.01	-553.53*	-16.63*	0.03	0.17

*,**,*** denotes 1%, 5% and 10% significance level respectively from NaPerron(2001) critical values.

The Zivot-Andrew test is applied for the year 2004-2012. The model has been specified to identify endogenous break with intercept, trend and both intercept & trend. The results show that the null hypothesis of unit root are rejected for all the series with first difference but accepted for level data at various significance levels. This is evident from rejecting the null hypotheses of unit root and accepting the alternative of no unit root at first difference at appropriate significance level. This result is surprisingly quite consistent with the result of unit root tests without structural break. At the same time the test identifies single possible breaks (TB) in data series endogenously and the results are reported in table-5. The tests identify different dates as break point for various series which is quite obvious as the structure of different countries' economies and thereby characteristics of stock markets are different. However, most of the breaks at intercept and trend occurred during the year 2008 except for China SSE50. In case of China the break period is in the year 2006. The break dates in the year 2008 also vary from 11th January 2008 in case of Sensex to 28th August 2008 in case of Nasdaq. The figures in the brackets denoted the lag length of the model selected based on lowest of SBC for ADF tests, MIC for Ng-Perron tests and t tests for ZA test**.**

Table 5. Zivot-Andrew unit root tests

Variables	Break with Trend	Break date	Break with Intercept	Break date	Break with Trend and intercept	Break date
lnasdaq	-2.346(2)	13/2/2009	-3.54(2)	26/2/2007	-5.237(2)	28/8/2008
lNikkeii225	-2.5021(5)	17/11/2005	-3.630(5)	18/6/2008	-3.221(5)	15/10/2007
lsensex	-2.837(2)	10/3/2006	-2.804(6)	16/5/2008	-3.797(6)	11/1/2008
lsse50	-2.709(6)	25/5/2007	-3.540(6)	26/9/2006	-3.684(6)	23/10/2006
lftse100	-2.216(6)	29/6/2005	-4.574(6)	19/5/2008	-4.341(6)	11/5/2008
dlnasdaq	-35.361(1)*		-35.634(1) *		-35.635(1) *	
dlNikkeii225	-21.702(4) *		-21.928(4) *		-21.922(4) *	
dlsensex	-20.049(5) *		-20.261(5) *		-20.338(5) *	
dlsse50	-18.549(5) *		-19.065(5) *		-19.291(5) *	
dlftse100	-20.632(5) *		-20.975(5) *		-20.978(5) *	

The Z-A critical values are Implies for (a) trend at 1% is -4.93 and 5% is -4.42 (b) intercept at 1% is -5.43 and 5% is -4.80 and (c) for trend and intercept at 1% is -5.57 and 5% is -5.80. The figures are minimum of t statistics and figure in brackets are lag length. *,**,*** denotes 1%, 5% and 10% significance level respectively.

3.2 Cointegration Test

The first step of applying cointegration test is to check stationary of the series. It is found through unit root test that the series are non-stationary at levels but stationary at first difference. Therefore, the cointegration tests can be applied at level data. The paper first applies bivariate cointegration tests of Engel and Granger (1987).

Table 6. Engel-Granger bivariate cointegration tests

Dependent Variable	Independent variables	2004-2007			2008-2012			2004-2012		
		Regression model		ADF for Residual	Regression model		ADF for Residual	Regression model		ADF for Residual
		α	β	Without C&T	α	β	Without C&T	α	β	Without C&T
lftse100(t)	lnasdaq(t)	-0.272	01.152	-2.119(1)	3.722	0.628	-2.887(4)	2.55	0.743	-1.516(4)
		(0.000)	(0.000)	(0.032)**	(0.000)	(0.000)	(0.003) *	(0.000)	(0.000)	(0.121)
lsse50(t)	lnasdaq(t-1)	-25.44	4.23	-1.205(0)	5.604	0.255	-2.818(0)	-2.425	1.273	-0.597(0)
		(0.000)	(0.000)	(0.208)	(0.000)	(0.000)	(0.004)*	(0.000)	(0.000)	(0.458)
lsensex(t)	lnasdaq(t-1)	-18.06	3.528	-3.375(0)	-1.997	0.993	-1.517(1)	-3.840	1.716	-1.217(1)
		(0.000)	(0.000)	(0.001)*	(0.000)	(0.000)	(0.121)	(0.000)	(0.000)	(0.187)
lNikkei225(t)	lnasdaq(t-1)	-1.668	1.455	-1.305(1)	7.010	0.285	-2.047(1)	5.465	0.506	-0.186(1)
		(0.000)	(0.000)	(0.176)	(0.000)	(0.000)	(0.039)**	(0.000)	(0.000)	(0.619)
lftse100(t)	lNikkei225(t-1)	1.970	0.695	-2.363(1)	4.412	0.450	-3.161(0)	5.165	0.364	-3.414(0)
		(0.000)	(0.000)	(0.018) **	(0.000)	(0.000)	(0.001)*	(0.000)	(0.000)	(0.000)*
lsse50(t)	lNikkei225(t)	-10.59	1.859	0.909(0))	-1.317	0.482	-3.539(0)	6.965	0.085	-1.007(0)
		(0.000)	(0.000)	(0.903)	(0.000)	(0.000)	(0.000)*	(0.000)	(0.000)	(0.282)
lsensex(t)	lNikkei225(t)	-10.05	2.010	-0.459(0)	5.217	0.482	-0.720(0)	10.015	-0.065	-1.472(0)
		(0.000)	(0.000)	(0.516)	(0.000)	(0.000)	(0.404)	(0.000)	(0.000)	(0.132)
lsensex(t)	lsse50(t)	4.907	0.588	-1.055(0)	6.108	0.465	-0.677(0)	4.114	0.714	-1.3789(0)
		(0.000)	(0.000)	(0.263)	(0.000)	(0.000)	(0.424)	(0.000)	(0.000)	(0.156)
lsensex(t)	lftse100(t-1)	-15.83	2.900	-2.727(1)	-2.709	1.444	-3.049(1)	-7.150	1.927	-1.038(0)
		(0.000)	(0.000)	(0.009) *	(0.000)	(0.000)	(0.188)	(0.000)	(0.000)	(0.269)
lsse50(t)	lftse100(t)	-16.20	2.71	-1.758(1)	1.739	0.688	-3.133(0)	-5.582	1.512	-0.674(1)
		(0.000)	(0.000)	(0.737)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.425)

*,**,*** denotes 1%, 5% and 10% significance level respectively. Figure in the brackets are lag length and in the parenthesis are p values.

The result reported in table-6 indicates mixed evidences. Few stock markets are integrated and few are not as seen from significance levels of Augmented Dickey Fuller tests on the residuals term. For entire period (2004-2012), the stock prices of only UK-Japan, are cointegrated, but rests of the combinations are not. Similarly, during pre-crisis period (2004-2007), the stock prices of UK(FTSE100)–USA(Nasdaq), India(Sensex)-USA(Nasdaq), UK(FTSE100)-Japan(Nikkei 225), India(Sensex)-UK(FTSE100) are cointegrated and the other combinations are not. While, during post crisis (2008-2012) period the stock prices of USA(Nasdaq)-UK(FTSE100), USA(Nasdaq)-China(SSE50), USA(Nasdaq)-Japan(Nikkei225), UK(FTSE100)-Japan(Nikkei225), Japan(Nikkei225)-China(SSE50) are cointegrated and they follow long run equilibrium relationships. It seems that there has been a significant change during post-recession period and the impact of recession has observed significantly in the interrelationship among stock markets.

However, bivariate cointegration test has a problem of specifying a-prior dependent and independent variable and thereby results can be different. The problem can be avoided through multivariate cointegration tests of Johansen-Juselius. The estimated results are reported in table-7, where l_0 and l_2 stands for 0 and 2 period lag respectively.

Table 7. Johansen-Juselius multivariate cointegration tests

Year		Hypothesis for λ-max Tests				Hypothesis for λ-trace Tests			
	H_0	r = 0	r ≤ 1	r ≤ 2	r ≤ 3	r = 0	r = 1	r = 2	r = 3
	H_1	r = 1	r ≤ 2	r ≤ 3	r ≤ 4	r = 1	r = 2	r = 3	r = 4
2004-07					No Deterministic Trends				
	l_0	28.10	26.28	14.17	6.51	75.34	47.24	20.96	6.79
	l_2	28.72	8.89	6.89	5.04	51.95	23.23	14.35	7.45
					Linear Deterministic Trend				
	l_0	27.02	24.87	13.23	0.63	66.03	39.01	14.14	0.91
	l_2	27.68	7.35	5.10	2.43	43.73	16.05	8.70	3.60
					Linear deterministic trend (restricted)				
	l_0	43.49**	24.88	14.76	9.72	93.26**	49.77	24.88	10.13
	L_2	28.40	17.07	7.15	4.27	58.67	30.27	13.20	6.04
2008-2012					No Deterministic Trends				
	l_0	54.52*	22.41	11.54	7.72	96.61*	42.09	19.67	8.14
	l_1	28.30	13.97	10.84	3.90	57.94	29.64	15.66	4.82
					Linear Deterministic Trend				
	l_0	54.11*	22.10	10.63	6.56	93.67*	39.56	17.46	6.83
	l_1	28.24	13.79	7.82	3.40	53.76	25.52	11.72	3.89
					Linear deterministic trend (restricted)				
	l_0	67.77*	29.89	21.78	10.61	135.81*	68.04**	38.15	16.37
	l_1	39.40**	16.46	11.58	7.61	78.16	38.75	22.29	10.71
2004-2012					No Deterministic Trends				
	l_0	75.28*	10.04	4.07	2.01	91.95*	16.67	6.64	2.56
	l_2	30.21	13.48	5.63	2.59	52.33	22.12	8.64	3.00
					Linear Deterministic Trend				
	l_0	74.98*	9.44	4.07	2.01	90.61*	15.63	6.19	2.12
	l_2	29.94	13.28	5.24	1.07	49.94	19.99	6.72	1.48
					Linear deterministic trend (restricted)				
	l_0	76.62*	23.74	4.25	4.05	108.94*	32.32	8.58	4.33
	l_2	35.13	17.92	5.63	1.84	61.59	26.46	8.54	2.91

*,**,*** denotes 1%, 5% and 10% significance level respectively. The critical values are from MacKinon-Haug-Michelis (1996).

The necessary steps of estimating JJ cointegration have been applied judiciously. As the model is based on VAR specification, first and foremost step is to select the order of VAR model and thereby specification of cointegration equation. Due to geographical location there is some time difference in the operation of stock market across globe. To make it uniform the study has taken the order of VAR model and cointegrating equation in ascending order of opening time of the stock market. Thus Nikkei225, SSE50 Sensex are considered at current time and FTSE100, Nasdaq are considered with one period lag. So the cointegrating equation and order of VAR model is specified as lNikkei225 (t), lsse50(t), lsensex(t), lftse100(t-1), lnasdaq(t-1).

Having established the unit root characteristics of the data and identified relevant ranges for lag length, the paper proceeded with the examination of cointegration. The test is performed for both pre and post-recession period. As the test is based on VAR model and applies the maximum likelihood estimation procedure, the next step is to select the lag length of the model (Note 3). To select the appropriate lag length in the system, several lag selection criteria such as likelihood ratio (LR), final prediction error (FPE), Akaike information criterion (AIC), and Schwarz information criterion (SC) are used (Note 4). The optimal lag length is selected as 2 for the period 2004-2008 and 2004-2012, and 1 for the period 2008-2012. The cointegration model is estimated with alternative combinations of the models such as no constant, no trend, no deterministic trend etc.

For the period 2004-2008, both λ max and λ trace statistics suggest only one cointegrating vectors when the cointegration model is specified with linear deterministic trend. While for other form of model specification as well as both lag length 0 and 2, both the tests statistics suggest zero cointegrating vector. This clearly indicates that stock indices do not follow any systematic pattern in the long run. They are independent of each other. The markets are not integrated. Similarly during post-recession period, stock market shows some sorts of integration contemporaneously in the long run although poorly. With zero lag length, almost all form of cointegration model suggest one or at best two cointegrating vector by both the test statistics. But with one lag length, they suggests zero cointegrating vectors except the case whether max statistics suggest only one cointegrating vector when the cointegration equation specified with liner deterministic trend. This suggested that, stock markets are to some extent integrated during post crisis period but poorly. Similar results are also found for the whole period i.e. 2004-2012. It indicates that stock prices moves independent of each other. Only the internal structure of the economy could significantly affect the respective countries stock prices. Thus overall conclusion is that indices are poorly cointegrated. It does not systematically follow long run equilibrium relationship for the entire period, as the number of cointegration vector found to be very less. The similar result also found from bivariate cointegration tests.

3.3 Granger Causality Test

The evidence of co-integration implies that variable rules out spurious correlation and suggests the presence of at least one directions of causality. Engel and Granger (1987) argue that if two time series are co-integrated then they are necessarily causally related. Therefore once it is established that there is cointegration among stock indices Granger causality test is applied. The result of pair wise Granger causality test is presented in table-8, which reports mixed evidence. The model-1, representing pre-recession period, shows that causality mostly run from NASDAQ to other stock markets and also causality runs from FTSE100 to Nikkei 225, Sensex and SSE50. There is unidirectional causality from Sensex to SSE50 and Nikkei 225. It is interesting to note that Shanghai and Tokyo stock market does not Granger cause any other markets but are affected by others. In model-2 which represents post-recession (2008-12) period with one lag, the result is slightly dissimilar as compared to model-1. Interestingly, it is found that Japanese stock market Granger causes US and UK stock market. Similarly Shanghai's stock market causes Indian and Japanese market. So there is some change in the casual direction among the stock prices during post-recession period. The causal direction in model-3 for the whole period is almost similar with the first model. However, for few stock markets the causality has changed for pre and post-recession. From Nikkei 225→Nasdaq, Nikkei 225→SFTSE, SSE50→Sensex, SSE50→Nikkei 225, Nasdaq→ FTSE100 there was no causal relationship in pre-recession period but for post-recession there is significant causality between them. This shows that causality has something to do with study period. Changing direction of causality in the post-recession period is mainly dominated by Chinese stock market.

Table 8. Granger causality test

Direction of Causality	2004-2007 lag length =2			2008-2012 lag length= 1			2004-2012 lag length=2		
	Obs	F-Stat	P value	Obs	F-stat	P value	Obs	F-stat	P value
NIKKEI225 does not GC NASDAQ	741	1.074	0.342	836	468.481	0.000*	1504	1.673	0.188
NASDAQ does not GC NIKKEI225		107.707	0.000*		0.971	0.325		330.976	0.000*
SENSEX does not GC NASDAQ	767	2.988	0.051**	846	0.488	0.485	1538	0.171	0.843
NASDAQ does not GC SENSEX		37.137	0.000*		55.213	0.000*		59.986	0.000*
SSE50 does not GC NASDAQ	751	1.719	0.180	864	1.618	0.204	1555	0.289	0.749
NASDAQ does not GC SSE50		3.690	0.025**		35.105	0.000*		21.028	0.000*
FTSE100 does not NASDAQ	852	0.818	0.442	945	142.153	0.000*	1749	0.462	0.630
NASDAQ does not GC FTSE100		41.593	0.000*		0.405	0.524		127.779	0.000*
SENSEX does not GC NIKKEI225	716	7.894	0.000*	780	38.146	0.000*	1413	16.479	0.000*
NIKKEI225 does not GC SENSEX		0.650	0.522		0.060	0.807		1.091	0.336
SSE50 does not GC NIKKEI225	740	0.114	0.892	827	3.248	0.072**	1505	1.036	0.355
NIKKEI225 does not GC SSE50		0.996	0.370		1.439	0.231		0.791	0.454
FTSE100 does not GC NIKKEI225	788	63.788	0.000*	871	0.744	0.389	1600	207.887	0.000*
NIKKEI225 does not GC FTSE100		0.431	0.650		284.105	0.000*		0.477	0.621
SSE50 does not GC SENSEX	738	0.798	0.451	819	6.054	0.014**	1489	2.232	0.108
SENSEX does not GC SSE50		0.655	0.519		9.714	0.002*		6.106	0.002*
FTSE100 does not GC SENSEX	806	8.077	0.000*	868	2.989	0.084***	1608	17.812	0.000*
SENSEX does not GC FTSE100		0.117	0.890		14.146	0.000*		2.206	0.110
FTSE100 does not GC SSE50	790	4.674	0.010**	901	32.492	0.000*	1646	22.845	0.000*
SSE50 does not GC FTSE100		0.357	0.700		2.608	0.107		1.702	0.183

*,**,*** denotes 1%, 5% and 10% significance level respectively.

4. Conclusion

The study designed at investigating long run-relationship among various stock markets by segregating the time period into pre and post recentrecession period. The idea was to tests whether inter relationship among leading stock market indices is time sensitive. The paper started with simple correlation coefficient which showed that correlation coefficient has declined during recession in most cases. The paper further investigated the relationship using time series techniques like cointegration and causality test to verify the time sensitive relationship. The cointegration result showed that there is only one or two cointegrating vector with various lag length and hence confirms weak form of cointegration. However, Granger causality test revealed that there are few cases where Granger causality have changed during post-recession period as compared to pre-recession period. At the same time, in many cases there are no changes in causation between different stock markets. Based on this study it is difficult to out rightly reject the initial believe that the the cause and effect relationship have changed over different periods. At the same time we can conclude that in case of Chinese stock market the direction of Granger casuality have changed during recession.

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Notes

Note 1. 'NBER Makes it Official: Recession Started in December 2007' Wall Street Journal, Dec 1, 2008.

Note 2. For details of the methodology one can refer their original article or any standard time series textbook.

Note 3. The results of diagnostic checking of the VAR models is not reported here due to space constraints and can be obtained from the author upon request.

Note 4. The result can be obtained from the author upon request.