*International Journal of Arts & Sciences,*
CD-ROM. ISSN: 1944-6934 :: 09(02):211–224 (2016)

# THE ROLE OF STRUCTURAL BREAK AND VOLATILE INNOVATIONS ON COINTEGRATION TESTS: TSUNAMI AND GLOBAL ECONOMICS CRISIS

**Berhan Çoban and Esin Firuzan**

*Dokuz Eylul University, Turkey*

This paper examines the impact of structural break and volatile innovations on contegration tests. It is suggested that eartquake-tsunami effects and Standard and Poor's downgrades US credit rating from AAA to $AA^-$ might be considered as a structural break or breaks on stock market indexes of the some countries. The evidences of structural break/breaks are investigated on Turkey, Japan, United Kingdom, United States of America and China economy for period 2011. By dealing with these two challenges in this study, we find evidence to support the failure of Engle-Granger (E-G), Gregory-Hansen (G-H) and conventional Lagrange-Multiplier (LM) cointegration tests to identify stuructural break. This failure may arise from their not taking into account potential structural breaks and volatile innovations. We conclude that if heteroscedasticity is more prominent than structural break, Westerlund-LM test should be performed.

**Keywords:** Structural break, Heteroscedasticity, Stock market, Cointegration, ARCH effect.

## I. Introduction

Economic and finance theory usually indicates the existence of long-run equilibrium relationships among nonstationary time series variables. Most economic time series behaves nonstationary in clearly for two distinct reasons: heteroscedasticity (i.e. inconstant variance) and level shift (i.e. structural break). Even if some transformations and differentiations may fix the instable variance and imbalance mean, to stabilize the series could be difficult due to persistent effects of unexpected shocks to economic activity. Cointegration analysis in the presence of structural break/breaks is basically relevant, when existence of long-run relationships among economic variables has still engaged the attention of full spread of researchers from economics, econometrics, statistics and probability.

Gregory and Hansen (1996) developed residual-based tests for cointegration that explicitly allow one structural break in the cointegrating vector. Then, Leybourne and Newbold (2003) and Cook (2004) combined that misspecification of the structural breaks may be more challenging, in hypothesis testing, than ignorance of them. Perron (2006) revealed that two types of structural change have occurred in relation to cointegration testing. Recently, Westerlund and Edgerton (2007) have proposed cointegration tests for the case of no break, a break in the intercept as well as a break in the intercept and cointegrated vector. These tests are derived from Lagrange Multiplier (LM)-based unit root tests of Schmidt and Phillips (1992). LM test takes into account both structural breaks and volatility of the series. The organization of this paper proceeds as follows: In Section II we review the unit root tests: Augmented-

Dickey Fuller (ADF) and Zivot-Andrews which takes into account structural break/breaks. Section III outlines Engle Granger (EG), Gregory Hansen (GH), Engle's ARCH test, LM Test of Westerlund-Edgerton (LM-Test-WE) cointegration tests. In Section IV we present application of these tests on stock market price index. This empirical part of the study includes macro economical impacts of earthquake and tsunami disasters in Japan and downgrades USA credit rating in 2011. We suggest that the important international issue of whether economic growth paths of different countries converge in some sense over time. These extraordinary events considered as structural break as exogenous variables and known time period. In Section V we give some brief remarks.

Here, we address a proposition in detail with the motivation that, if one can identify the presence of structural break correctly and heteroscedasticity, one can in principle aware of the importance the selection of the proper cointegration test. Hereby, we may suggest a route map for practitioners when they use cointegration test.

## II. Unit Root Analyses

### Augmented Dickey Fuller

Unit roots of a series is a precondition to the existence of cointegration relationship, originally, the Augmented Dickey-Fuller (1979) test was extensively used to test for stationarity. The ADF test which analyzes whether any series included has unit root or not, gives information about whether the series are cointegrated or not, since a similar operation is applied on the error term in cointegration analysis. As the error terms obtained from the linear correlation between the series, under cointegration investigation, can be modeled with their lagged values, Dickey – Fuller test can be applied on this data. ADF test primarily concerned with the estimate of α. In the following equation, we test the null hypothesis of $\rho = 0$ against the alternative hypothesis of $\rho < 0$:

$$\Delta y_t = u + \beta t + \rho y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-1} + \varepsilon_t \tag{1}$$

where $y_t$ is the time series being tested, Δ denotes the first difference and $k$ is the number of lags which are added to the model to ensure that the residuals, $\varepsilon_t$ are white noise. When $\rho<0$, this model has a unit root and becomes a random walk process.

However, Perron (1989) demonstrated that failure to allow for an existing break leads to a bias that decreased the ability to reject a false unit root null hypothesis. A problem common with the conventional unit root tests —such as the ADF tests, is that they do not allow for the possibility of a structural break. Perron argues that most macroeconomic series are not characterized by a unit root but rather that persistence arises only from large and infrequent shocks, and that the economy returns to deterministic trend after small and frequent shocks Glynn et al.(2007). Perron (1989) test includes the time of break into the model externally. Zivot and Andrews (1992), on the other hand, developed a test that includes the time of the break internally.

## III. Cointegration Tests

### Engle-Granger

The residual-based cointegration test suggested by Engle and Granger have been used commonly in the literature. The basic approach in Engle – Granger method is the error terms of a linear combination between two non-stationary time series having the property of stationarity.

$$y_t = \mu_1 + \alpha x_t + \varepsilon_t \tag{2}$$

A general model that can be built between two series can be presented as in equation (2). In this model the dependent variable $y_t$, the independent variable $x_t$, and the error term $\varepsilon_t$, which is random, is presented.

In order to variables in the model to be cointegrated, it is both assumed that the difference of both variables are obtained (I(1) distributed) and at the same time the error term is non-differenced (I(0) distributed). In other words, the error term is $\varepsilon_t \sim IN(0,\sigma^2)$.

In order to determine the existence of the cointegraiton between the series Engle – Granger proposed a procedure comprising of two steps. According to this procedure, first a linear equation (ordinary least squares, OLS) is built and the parameter estimations are obtained by using the least square method. As the second step the unit root test is applied on the error terms obtained from the model. In order to determine whether the error terms are stationary or not, the Dickey-Fuller test is widely used.

**Gregory - Hansen**

The study results of Gregory et al. (1996) indicate that the power of the Engle–Granger (1987) test of the null of no cointegration is dramatically reduced if a break in the cointegrating relationship. In order to overcome this drawback, Gregory and Hansen (1996) extend the Engle–Granger test to allow for single structural break in either the intercept or the intercept and trend of the cointegrating relationship at an unknown time. The breaks are tried to be determined by adding dummy variables to the Engle - Granger method.

Gregory – Hansen (1996) test investigates the determination of structural breaks in long term relation under three different models. these models being specified and denoted as follows:

Model C : Level shift $$y_t = \mu_1 + \mu_2\varphi_\tau + \alpha x_t + \varepsilon_t \tag{3}$$

Model C/T : Level shift with trend $$y_t = \mu_1 + \mu_2\varphi_\tau + \beta t + \alpha x_t + \varepsilon_t \tag{4}$$

Model C/S : Regime shift $$y_t = \mu_1 + \mu_2\varphi_\tau + \alpha_1 x_t + \alpha_2\varphi_\tau x_t + \varepsilon_t \tag{5}$$

The dummy variable $\varphi_\tau$ which is included in the model for the determination of the structural break can be defined as below.

$$\varphi_\tau = \begin{cases} 1, & if \;\; t > \tau \\ 0, & otherwise \end{cases}$$

with $\tau$ is a coefficient which shows the break point occurs in the sample and takes the value of 0 or 1. Non-stationarity of the obtained residuals is controlled by the ADF test. Finding the test statistics to the minimum value of the ADF statistics in the sequence, we choosed the value that constitutes the powerful evidence against the null hypothesis of no cointegration.

**Lagrange Multiplier Cointegration Test**

Westerlund and Edgerton (2007) have proposed cointegration tests that are derived from the Lagrange Multiplier (LM)-based unit root tests of Schmidt and Phillips (1992). They consider the cases of no break, a break in the intercept as well as a break in the intercept and cointegrating vector of the cointegrating relationship (Tam, 2012). This test take into account heteroskedastic and serially correlated errors, deterministic time trends and a single break in both the intercept and slope.

Bivariate system of integrated series ($y_t$, $x_t$)

$$y_t = \mu_1 + \beta t + \mu_2 \varphi_\tau + \alpha_1 x_t + \alpha_2 \varphi_\tau x_t + \varepsilon_t \qquad t=1,..,T \qquad (6)$$

$$x_t = x_{t-1} + w_t$$

$$\varepsilon_t = \rho \varepsilon_{t-1} + v_t$$

$$\varphi_\tau = \begin{cases} 1, & if \;\; t > \tau \\ 0, & otherwise \end{cases}$$

where $t$ represents the time index, $\mu_1$ is the intercept, $\beta, \mu_2, \beta_1, \beta_2$ and $\alpha$ are coefficients, with $\varepsilon_t, w_t$ and $v_t$ are error process. Test use a t-statistics for testing the null of $\phi = 0$ against the alternative of $\phi < 0$ in the following regression:

$$\Delta \tilde{S}_t = \gamma + \phi \tilde{S}_{t-1} + \beta t$$

$$\tilde{S}_t = y_t - \tilde{\mu}_{e1} - \tilde{\beta} t - \tilde{\mu}_2 \varphi_t - x_t \tilde{\alpha}_1 - \varphi_t x_t \tilde{\alpha}_2 \qquad t=2, 3, 4, \ldots, T \qquad (7)$$

with $\tilde{S}_1 = 0$, $\tilde{\mu}_{e1} \equiv \tilde{\mu}_1 + e_0$, $\phi = \alpha - 1$ and $\tilde{S}_t$ being the regression errors. The parameter estimates can be obtained by an ordinary least squares regression of the equation.

**Engle's ARCH Test**

Financial time series often display some well-known property. First, large changes tend to be followed by large changes and small changes tend to be followed by small changes. Secondly financial time series often exhibit leptokurtosis and volatility clastering, which means that the distribution of their returns is fat-tailed.

The standard warning is that in the presence of heteroskedasticity, the regression coefficients for an ordinary least squares regression are still unbiased, but the standard errors and confidence intervals estimated by conventional procedures will be too narrow, giving a false sense of precision. ARCH and GARCH models treat heteroskedasticity as a variance to be modelled (Engle,1982).

Various tests have been developed in order to determine the heteroscedasticity in time series model. These test are; Goldfeld – Quandt Test (GQ), Breusch – Pagan – Godfrey Test (BPG) ARCH (LM) and GARCH, Mcleod and Li's Q . The most widely used, among these tests, Robert Engle' ARCH-LM. The test's null hypothesis is there is no ARCH up to order q in the residuals. We use ARCH LM test in order to understand whether the standardized residuals exhibit additional ARCH.

The general ARCH model is;

$$\varepsilon_t = v_t \sqrt{h_t}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 \qquad (8)$$

$v_t$ ~WN ($0, \sigma^2 = 1$) $v_t$ and $\varepsilon_{t-1}$ independent each other. In addition $\alpha_0, \alpha_1$ are constant $\alpha_0 > 0, 0 < \alpha_1 < 1$

Thus ARCH process have zero mean, uncorrelated, unconditional variance is constant (if exist) but conditional variance varying depends on time. If the coefficient of variance equation are not significant, there is no ARCH effect in the residual series. Otherwise it can be said that, series have ARCH component.

## IV. Empirical Study

Earthquake and tsunami hit Japan in March 11$^{th}$, 2011, both were having a large negative economic impact on Japan. Than, not the exactly same date, but in the same year, USA credit rating was decreased in August 5$^{th}$, 2011. As a consequence of these events, global crisis had spreaded all around the world. We consider that these large disasters' might reveal a structural break or breaks on Japan economy and also world economy. For this reason, some stock markets which were thought in related with Japan and USA economy had examined for detecting structural break. Stock market indexes were represented on a daily basis ranging from January 2011 and December 2011. The sample was chosen reflect the periods on the basis of common working hours for all markets of countries, so that the data was gathered by paying attention to the local time difference between countries. The sample was performed with 223 observations in Eviews Version 7, R, Gauss 15, MATLAB.

As you see in Figure 1, the impacts of Earthquake & Tsumai disasters and global crisis are shown up in the series.

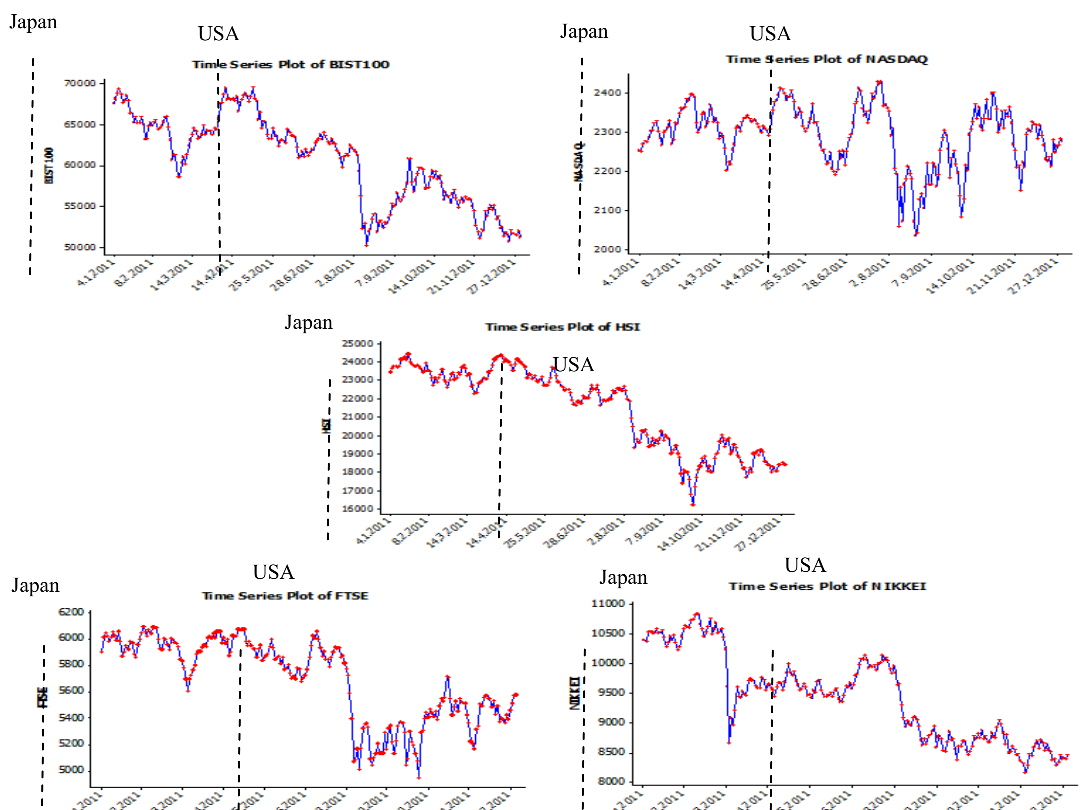



**Figure 1.** Time series graphs of BIST, NASDAQ, HSI, FTSE and NIKKEI in 2011

Examining the stock price indexes of five countries, we can observe that all the series have sharply decreasing in their level, occurring in March 11$^{th}$ and August 5$^{th}$, 2011, but the decreasing degrees are not similar to each other. First sharp rush in NIKKEI on 43$^{th}$ data can be explained by the impact of earthquake and tsunami, infact same sharply impacts of them are more difficult to see on the other stock market price index series. However, the second sharply decreasing on 135$^{th}$ data has been shown up on the all series. All series seem to be affected by global crisis.

**Testing for unit root in stock market series under structural break**

Before performing cointegration test, the data should be controlled by unit root tests. ADF is the mostly used unit root test in literature. Unfortunately it does not take into account any structural break. The results of ADF test in Table 1 show that for the natural logarithm of each stock market index turns out to be stationary in first differences therefore is integrated of order 1, I(1).

Residual plots have examined for checking assumptions of white noise and normality of each series. It is realized that normality assumption has been violated for all the series. A structural break may cause normality problem even if ADF conclude absence of a unit root, so ADF conclusion can be biased. Therefore, Zivot-Andrews unit root test in the presence of a structural break should be applied to the series.

**Table 1.** ADF Unit Root test results

| Variables | ADF | p-value |
|---|---|---|
| $\nabla^1$ *lnBIST* | -14.827 | 0.000 |
| $\nabla^1$ *lnFTSE* | -14.428 | 0.000 |
| $\nabla^1$ *lnNASDAQ* | -16.467 | 0.000 |
| $\nabla^1$ *lnNIKKEI* | -14.677 | 0.000 |
| $\nabla^1$ *lnHSI* | -14.728 | 0.000 |

While allowing for structural break/breaks in the series Zivot-Andrews' unit root test with unknown timing of the structural break is performed. The results of the Zivot-Andrews test in Table 2 suggest two clear breaks in two distinct time points. Thus, one can conclude that all series are I(0) stationary with at least one clear break. According to Zivot-Andrews test results, $\nabla^1$ *lnBIST* and $\nabla^1$ *lnNIKKEI* are stationary with one structural break on $41^{th}$ and $47^{th}$ data, respectively. Besides, $\nabla^1$ *lnFTSE*, $\nabla^1$ *lnNASDAQ* and $\nabla^1$ *lnHSI* are stationary with one structural break on $134^{th}$, $135^{th}$ and $136^{th}$ data, respectively. The structural break in BIST data is less likely linked to eartquake and tsunami, whereas there is logical connection on $47^{th}$ data. Because NIKKEI stock market had closed as soon as earthquake had occurred.

**Table 2.** Zivot-Andrews Unit Root test results

| **Variables** | **Zivot -Andrews** | **p-value** | **Potential Break** | **Break date** |
|---|---|---|---|---|
| $\nabla^1$ *lnBIST* | -3.688 | 0.010 | 41 | 08.03.2011 |
| $\nabla^1$ *lnFTSE* | -6.345 | 0.000 | 134 | 03.08.2011 |
| $\nabla^1$ *lnNASDAQ* | -5.190 | 0.002 | 135 | 04.08.2011 |
| $\nabla^1$ *lnNIKKEI* | -3.931 | 0.031 | 47 | 16.03.2011 |
| $\nabla^1$ *lnHSI* | -4.713 | 0.000 | 136 | 05.08.2011 |

Interesting point is that HSI has been affecting by global crisis not Japan's tsunami. $134^{th}$, $135^{th}$ and $136^{th}$ are logical points for global crisis of USA core, because the rule of "purchase expectations, realities sold" is valid in stock market. "The market's already been shaken out," said Harvey Neiman, a portfolio manager of the Neiman Large Cap Value Fund. "It knew it was coming." (*http://www.thejournal.ie*).

According to these discussions, downgrade of US credit was not surprise, so these points may show the prior flag of expectations.

### Diagnosting Checking of Cointegration Under Structural Break

To implement the Engle-Granger method on stock markets data set, we begin by regressing one series on each other and then assess the model fit. If variables cointegrate, the resulting OLS regression yields a "super-consistent" estimator of the cointegrating parameters. By this we mean that there is a very strong relationship between the estimated parameters. For example, taking the $\nabla^1$lnBIST series as the dependent variable and the other $\nabla^1$lnFTSE series as the independent variable, we yield the following regression equation:

$$\text{lnBIST} = -0.42 + 1.32\ \text{lnFTSE} \quad (9)$$

There is no unit root on the residuals of (9) model –ADF test statistics=-2.126 p-value=0.03. The p-values of the independent variables are very small; this means that these regression coefficients are statistically significant at the 0.05 level of significance.

When lnFTSE and lnBIST series are taken to be the dependent and independent variables, respectively, the following regression equations are obtained: To determine if the variables actually cointegrate, we test whether the residuals from the regression relationship(s) are stationary.

$$\text{lnFTSE} = 2.80 + 0.53\ \text{lnBIST} \quad (10)$$

There is no unit root on the residuals of (10) model –ADF test statistics=-2.64 p-value=0.09. As a result of these models in Table 3, FTSE and BIST are cointegrated each other, so do FTSE and NASDAQ series. Test represents the NASDAQ series have cointegrated with all other series. Generally the test was able to capture a total of six cointegration relationship. Symmetry is expected in the cointegration system, but in this example it does not exist. Hence, we conclude that EG cointegration test is not suitable for the data set.

One of the most commonly used cointegration tests in presence of a structural break is Gregory – Hansen (GH). This test is similar to the Engle – Granger cointegration method. The breaks are tried to be determined by adding dummy variables to the model apart from the Engle - Granger method. Gregory – Hansen test investigates the determination of structural breaks in long term relation under three different models: Level Shift (C), Level Shift with trend (C/T) and Regime Shift (C/S). $\alpha$ and $\tau$ is including to the model for determination of the structural break.

The results of GH test are shown in Table 4. According to GH results, the test captures the cointegration at different models. For example NASDAQ is cointegrated just in level shift model, but the break point shows up on 174th point instead of 135th point. It means even if there exist little bit shifting on the NASDAQ and BIST modeling residuals, there is another dominant point and that is the 174th point. BIST index does not have any cointegration relationship with other index series. However, in level shift with trend model, break has been detected in 46th observation in cointegration with NIKKEI series. But this break is not statistically significant. All the same time in all three models, FTSE and NASDAQ series are cointegrated along with structural break in 132th observation. Similarly, FTSE and NIKKEI are cointegrated along with structural break in 105th observation for C/T model. Also cointegrated relation was determined FTSE and HSI series in 160th and 163th observations. For all models NASDAQ and FTSE are cointegrated along with structural breaks at 132th observation. Similarly same series have relation with HSI index.

**Table 3.** Cointegration test results of all stock market price indexes.

| **NDEPENDENT VARIABLES** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **LnBIST** | | | **LnFTSE** | | | **LnNASDAQ** | | | **LnNIKKEI** | | | **LnHSI** | | |
| | **$\beta_0$** | **$\beta_1$** | **ADF** | **$\beta_0$** | **$\beta_1$** | **ADF** | **$\beta_0$** | **$\beta_1$** | **ADF** | **$\beta_0$** | **$\beta_1$** | **ADF** | **$\beta_0$** | **$\beta_1$** | **ADF** |
| **nBIST** | | | | -0.42 | 1.32 | -2.13 | 0.78 | 1.32 | -1.87 | 3.04 | 0.87 | -2.50 | 3.93 | 0.71 | -2.279 |
| *-value* | | | | *0.00* | *0.00* | ***0.03*** | *0.49* | *0.00* | *0.05* | *0.00* | *0.00* | *0.12* | *0.00* | *0.00* | *0.18* |
| **nFTSE** | 2.80 | 0.53 | -2.64 | | | | 0.64 | 1.20 | -2.18 | 3.20 | 0.60 | -1.68 | 4.04 | 0.46 | -2.690 |
| *-value* | *0.00* | *0.00* | *0.09* | | | | *0.25* | *0.00* | ***0.03*** | *0.00* | *0.00* | *0.44* | *0.00* | *0.00* | *0.08* |
| **nNASDAQ** | 5.51 | 0.20 | -3.89 | 3.78 | 0.46 | -3.83 | | | | 5.77 | 0.22 | -3.75 | 6.26 | 0.15 | -3.710 |
| *-value* | *0.00* | *0.00* | ***0.00*** | *0.00* | *0.00* | ***0.00*** | | | | *0.00* | *0.00* | ***0.00*** | *0.00* | *0.00* | ***0.00*** |
| **nNIKKEI** | 1.67 | 0.68 | -2.27 | -0.86 | 1.16 | -1.39 | 0.67 | 1.10 | -1.26 | | | | 2.75 | 0.64 | -2.466 |
| *-value* | *0.00* | *0.00* | *0.19* | *0.06* | *0.00* | *0.15* | *0.51* | *0.00* | *0.19* | | | | *0.00* | *0.00* | *0.13* |
| **nHSI** | -1.39 | 1.03 | -2.17 | -4.47 | 1.67 | -1.98 | -0.90 | 1.40 | -1.13 | -0.98 | 1.20 | -2.21 | | | |
| *-value* | *0.00* | *0.00* | *0.22* | *0.00* | *0.00* | *0.30* | *0.53* | *0.00* | *0.23* | *.02* | *0.00* | *0.20* | | | |

.**Table 4.** Gregory-Hansen cointegration results

| | **INDEPENDENT VARIABLES** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **lnBIST** | | **lnFTSE** | | **lnNASDAQ** | | **lnNIKKEI** | | **lnHSI** | |
| | **Critical Values** | **MODEL** | **break point** | **GH-ADF statistics** | **break point** | **GH-ADF statistics** | **break point** | **GH-ADF statistics** | **break point** | **GH-ADF statistics** | **break point** | **GH-ADF statistics** |
| **lnBIST** | -4.69 | **C** | | | 183 | -3.625 | 174 | -3.940 | 43 | -3.402 | 156 | -3.699 |
| | -5.03 | **C/T** | | | 50 | -3.435 | 45 | -4.086 | 46 | -3.694 | 156 | -3.567 |
| | -5.23 | **C/S** | | | 157 | -3.796 | 174 | -3.945 | 95 | -3.601 | 149 | -4.029 |
| **lnFTSE** | -4.69 | **C** | 132 | -4.144 | | | 132 | **-6.640** | 132 | -4.489 | 163 | **-5.783** |
| | -5.03 | **C/T** | 132 | -4 | | | 132 | **-6.778** | 105 | **-5.008** | 160 | **-5.894** |
| | -5.23 | **C/S** | 162 | -4.666 | | | 132 | **-6.873** | 133 | -4.844 | 163 | **-5.802** |
| **lnNASDAQ** | -4.69 | **C** | 174 | **-4.886** | 123 | **-6.376** | | | 172 | **-5.185** | 156 | **-5.635** |
| | -5.03 | **C/T** | 174 | -4.845 | 123 | **-6.620** | | | 97 | **-6.176** | 156 | **-6.154** |
| | -5.23 | **C/S** | 177 | -4.895 | 123 | **-6.384** | | | 172 | **-5.319** | 156 | **-5.698** |
| **lnNIKKEI** | -4.69 | **C** | 46 | -4.036 | 177 | -4.104 | 172 | -4.362 | | | 46 | -3.828 |
| | -5.03 | **C/T** | 134 | -3.923 | 105 | **-5.327** | 97 | **-5.848** | | | 46 | -3.850 |
| | -5.23 | **C/S** | 46 | -4.188 | 55 | -4.061 | 160 | -4.396 | | | 43 | -4.033 |
| **lnHSI** | -4.69 | **C** | 154 | -4.357 | 160 | **-6.026** | 156 | **-5.224** | 138 | -3.626 | | |
| | -5.03 | **C/T** | 138 | -4.556 | 160 | **-6.192** | 156 | **-5.840** | 138 | -4.269 | | |
| | -5.23 | **C/S** | 162 | **-5.439** | 160 | **-5.999** | 156 | -5.140 | 104 | -3.717 | | |

Investigation of relation between NASDAQ and NIKKEI series, for C and C/S models break points indicated 172th observation and for C/T model, 97th observation is the break point. When GH test examination results for the NIKKEI stock market, it can be said that for C/T model, cointegration relation with FTSE and NASDAQ series along with break points at 105th and 97th observations respectively. 46th observation is reflected tsunami disaster date, test could find out this break point. Although the break point has determined correctly by test, this is not affected by cointegration relationship between series. When the considering China's HSI index, it can be expressed that series cointegrated with BIST along with break point 162th observation for C/S model. Moreover, HSI is cointegrated with FTSE and NASDAQ series along with the break point 160th and 156th observation respectively for all models.

In the overall, GH test is able to capture more cointegrated relationship than the EG test. The nature of mutually relations in the series caused the variation of the break point location is the reason of the good performance of GH test. While FTSE and NASDAQ series are affected by break point 132th observation, NIKKEI series is affected from 46th observation. For HSI index, break points are significant which is located around 160th observations.

**Engle's ARCH Test Result**

We check out the cointegration relationship, this implies that residuals are stationary after modeling cointegration system. Even if residuals are stationary, we believe in some dominant points may cause the wrong decision (i.e. actually there is no cointegrated relationship, but the test could conclude that there exist cointegration, we can call it Type I and Type II error). Having a structural break may mask on the data, so we must suspect about the correct decision on GH cointegration test. That's why we check them out for heteroscedasticity of residuals which produced by regression models.

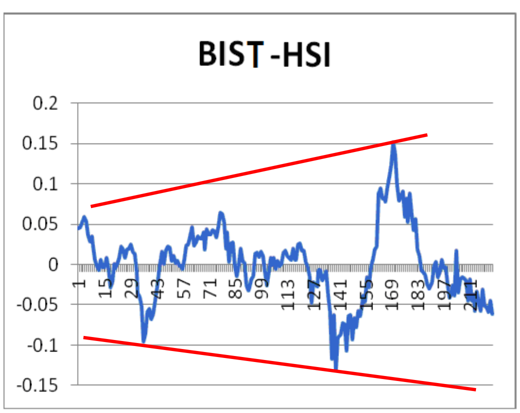
This section will examine volatility in series with Robert Engle ARCH test. Hypotheses are:

$H_o$: Residuals do not have volatility. There is a not ARCH effect

$H_a$: Residuals have volatility. There is an ARCH effect

Previous analyses show that series have structural breaks and this component affects cointegration test's performance. Besides the break, the series were investigated whether they have heteroscedasticity.

Some residual plots of series are shown as follows:



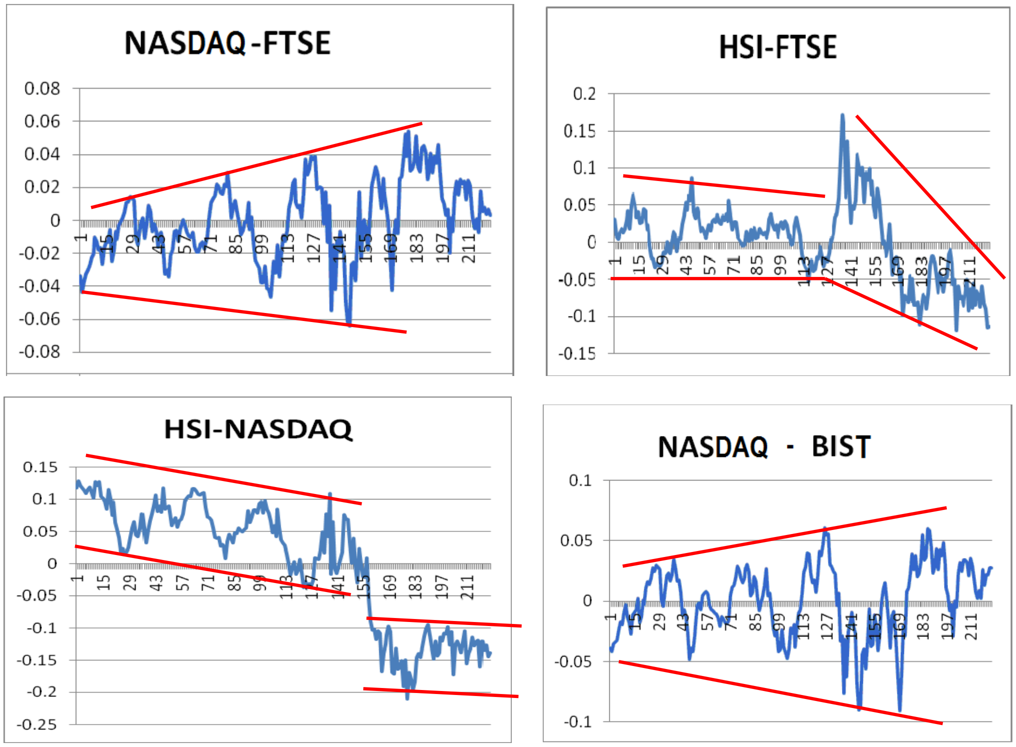




**Figure 2.** Time series graph of residuals produced by regression models

**Table 5.** Engle's ARCH test result

| | | **lnBIST** | **lnFTSE** | **lnNASDAQ** | **lnNIKKEI** | **lnHSI** |
|---|---|---|---|---|---|---|
| **lnBIST** | Hypothesis | | NO ARCH EFFECT | NO ARCH EFFECT | ARCH EFFECT | ARCH EFFECT |
| | *Test Stat.* | | *0.061* | *0.733* | *24.55* | *15.565* |
| | *p-value* | | *0.805* | *0.391* | *0.000* | *0.000* |
| **lnFTSE** | Hypothesis | ARCH EFFECT | | ARCH EFFECT | ARCH EFFECT | ARCH EFFECT |
| | *Test Stat.* | *8.403* | | *47.88* | *19.33* | *17.22* |
| | *p-value* | *0.003* | | *0.000* | *0.000* | *0.000* |
| **lnNASDAQ** | Hypothesis | ARCH EFFECT | ARCH EFFECT | | ARCH EFFECT | ARCH EFFECT |
| | *Test Stat.* | *10.49* | *17.77* | | *8.403* | *14.702* |
| | *p-value* | *0.001* | *0.000* | | *0.003* | *0.000* |
| **lnNIKKEI** | Hypothesis | ARCH EFFECT | ARCH EFFECT | ARCH EFFECT | | ARCH EFFECT |
| | *Test Stat.* | *44.17* | *42.02* | *71.94* | | *63.47* |
| | *p-value* | *0.000* | *0.000* | *0.000* | | *0.000* |
| **lnHSI** | Hypothesis | ARCH EFFECT | ARCH EFFECT | ARCH EFFECT | ARCH EFFECT | |
| | *Test Stat.* | *21.73* | *30.98* | *50.77* | *66.78* | |
| | *p-value* | *0.000* | *0.000* | *0.000* | *0.000* | |

*Critical value: 3.841*

**Table 6.** LM Cointegration test result

| | **LnBIST** | | | **LnFTSE** | | | **LnNASDAQ** | | | **LnNIKKEI** | | | **LnHSI** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MODEL** | **break point** | **LMCOINT statistics** | | **break point** | **LMCOINT statistics** | | **break point** | **LMCOINT statistics** | | **break point** | **LMCOINT statistics** | | **break point** | **LMCOINT statistics** | |
| | | **t** | **ϕ** | | **t** | **ϕ** | | **t** | **ϕ** | | **t** | **ϕ** | | **t** | **ϕ** |
| **C/T** | | | | 136 | -1.614 | -7.146 | 161 | -1.932 | -10.228 | 136 | -2.526 | ***-15.032*** | 155 | -2.308 | ***-15.069*** |
| **C/S** | | | | 136 | -1.681 | -7.670 | 161 | -1.956 | -10.359 | 134 | -2.148 | -14.459 | 136 | -2.395 | -12.788 |
| **C/T** | 171 | -2.249 | -9.285 | | | | 135 | -2.283 | ***-19.680*** | 135 | -1.809 | -12.465 | 134 | -2.211 | ***-16.703*** |
| **C/S** | 135 | -1.836 | -8.956 | | | | 135 | -2.283 | ***-19.681*** | 134 | -1.883 | -12.656 | 135 | -2.287 | ***-18.051*** |
| **C/T** | 171 | ***-3.367*** | ***-24.207*** | 150 | ***-4.017*** | ***-46.850*** | | | | 144 | ***-3.279*** | ***-26.842*** | 144 | ***-3.260*** | ***-23.898*** |
| **C/S** | 92 | ***-3.088*** | ***-25.656*** | 150 | ***-3.970*** | ***-45.640*** | | | | 144 | ***-3.298*** | ***-25.914*** | 144 | ***-3.080*** | ***-22.792*** |
| **C/T** | 45 | -2.438 | -12.912 | 45 | -2.140 | -12.425 | 45 | -2.140 | -12.425 | | | | 45 | -2.593 | ***-15.939*** |
| **C/S** | 45 | -2.454 | -13.154 | 45 | -2.038 | -11.118 | 45 | -2.038 | -11.118 | | | | 45 | -2.589 | ***-15.968*** |
| **C/T** | 178 | -2.072 | -10.300 | 137 | ***-3.044*** | ***-22.244*** | 137 | ***-2.929*** | ***-19.797*** | 45 | -2.558 | -12.447 | | | |
| **C/S** | 178 | -2.074 | -10.377 | 137 | ***-3.059*** | ***-22.424*** | 137 | ***-2.952*** | ***-20.106*** | 108 | -2.615 | -12.662 | | | |

%10 critical values for t and ϕ -2.75 and -15.00, respectively

This test searches residuals which are obtain regression equation of stock exchange indexes. Having the volatile residuals means that series are under ARCH effects. As a result of analyses, all residuals have an ARCH effect except residuals of BIST-FTSE and BIST-NASDAQ models. Being under the ARCH effects has also affected unit root and cointegration tests performance according to the literature (Guidi, 2012).

**Lagrange Multiplier Cointegration Test**

LM test suggested by Westerlund J. ve Edgerton D.L. in 2006. This test take into account both structural breaks and volatility of the series. Former analyses demonstrated that the stock market index have all of two components. Therefore LM cointegration test has applied and results are shown in the Table 6.

According to the result BIST and NIKKEI series are cointegrated for level shift model with trend (C/T) along with break point $136^{th}$ observation. Similarly BIST has a relationship with HSI index. When results are examined, FTSE series were cointegrated with NASDAQ along with break point $135^{th}$ observation. In addition to FTSE series are cointegrated NIKKEI and HSI index. NASDAQ series has cointegrated relationship all index along with the different break points such as $171^{th}$ observation for BIST in C/T model and $92^{th}$ observation in regime shift model (C/S). In addition, it is cointegrated with FTSE for C/T and C/S model in same break point. The NIKKEI and the HSI in the series were cointegrated along with the break point $144^{th}$.

HSI series are cointegrated FTSE and NASDAQ series along with the breakpoint 137 for C/T and C/S models.When the results are analyzed, Nikkei series has a structural break point in $45^{th}$ observation for all models. But this break is not statistically significant.

**V. Conclusion**

In this paper, we have investigated the impact of structural break and volatile innovations on contegration tests via Turkey, Japan, United Kingdom, United States of America and China stock market indexes for period 2011.By applying the unit root test we find that all stock prices are nonstationary. According to Zivot Andrews test series two clear breaks in two distinct time points for all stock markets. Result of unit root tests all series are I(0) stationary with at least one clear break. Overview the cointegration test results, conventional EG test failed to catch cointegrated relations because of structural break. The results of GH test indicates that there are many long-run relationship between the stock markets with break.captures the cointegration at different models.GH and LM test have some outcome under some condition. The nature of mutually relations in the series caused the variation of the break point location is the reason of the good performance of GH test. While FTSE and NASDAQ series are affected by break point $132^{th}$ observation, NIKKEI series is affected from $46^{th}$ observation. EG and GH cointegration analyses show that series have structural breaks and this component affects cointegration test's performance. Besides the break, the series were investigated whether they have heteroscedasticity. We have performed Engle's ARCH test to obtain heteroscedasticity of error term. Test results show that most of the residuals series are under ARCH effects. Then we investigate the long-run relationship between the series by Westerlun&Edgerton LM test. This test takes into account heteroskedastic and serially correlated errors. when we compare GH and LM test results. LM test more accurate than GH test with regard to estimate of break date. Furthermore LM test determined more cointegration relationship according to GH test. Consequently if the heteroscedasticity is more prominent than structural breaks, LM test result should be preferred.

## References


1. Cook S. (2004) Spurious rejections by cointegration tests incorporating structural change in the cointegrating relationship Applied Economics Letters, 2004, 11, 879-884
2. Engle, R. F. and Granger, C. W. J. (1987) Cointegration and error correction: representation, estimation, and testing, Econometrica, 55, 251–76
3. Engle Robert F. (1982). *Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation*. Econometrica, Vol. 50, No.4 (july, 1982)
4. GAUSS™ Language Reference, Version 13, Aptech Systems, Inc
5. Glynn, J., Perera, N. and Verma, R. 2007. Unit root tests and structural breaks: A survey with applications. Revista de Metodos Cuantitativos para la Economia y la Empresa, 3: 63–79.
6. Gregory, A. W., & Hansen B. E. (1996) Residual-based tests for cointegration in models with regime shifts. *Journal of Econometrics*, 70, 99-126
7. Guidi F. (2012) Cointegration Relationship and Time Varying Co-movements Among Indian and Asian Developed Stock Markets, International Review of Financial Analysis Vol: 21, January 2012, Pages 10–32
8. Hörlung R. and Östemark R. (2001). Size and power of some cointegration tests under structural breaks and heteroskedastic noise. Statistical Papers 44,1-22
9. Leybourne S. J. & Newbold P. (2003) Spurious rejections by cointegration tests induced by structural breaks, Applied Economics,2003,35,1117-1121
10. Maddala, G. S. (1992). Introduction to econometrics (2nd ed.). New York: Macmillan Publishing Company
11. Perron, P.(1989). The great crash, the oil-price shock, and the unit-root hypothesis. Econometrica, 57 (6), 1361-1401.
12. Pfaff B. (2008) *Analysis of Integrated and Cointegrated Time Series with R.* (2nd ed.) New York: Springer Science Business Media, LLC
13. Phillips P. C.B., P. Schmidt (1992). *Testing for a Unit Root in the Presence of Deterministic Trends.* Oxford Bulletin of Economics and Statistics (1992), 54(3): 257-287
14. Tam P. S. (2011) Size properties of lagrange multiplier cointegration tests in the presence of structural breaks Applied Economics Letters, 19, 1061-1064
15. Westerlund J. and Edgerton D. L. (2006) *New Improved Tests for Cointegration with Structural Breaks.* Journal of Time Series Analysis, Vol:28, No:2
16. Zivot, E., & Andrews D.W.K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. Journal of Business & Economic Statistics 10 (3), 251-270 http://www.thejournal.ie/downgraded-us-loses-aaa-credit-rating-for-the-first-time-ever-194922-Aug2011/