INVESTIGATION OF CAUSAL RELATIONSHIP BETWEEN STOCK EXCHANGES LISTED IN G7, E7 AND BRICS

Swetadri SAMADDER* and Koushik GHOSH**

Abstract. *Purpose of the work is to search interrelationship analyzing pairwise causality between the stock exchanges within the countries listed in BRICS; within the countries listed in E7 and within the countries listed in G7 computing parametric as well as nonparametric Granger causality. Causal intergroup relations of G7 with BRICS & E7 have also been analyzed. Daily log return data of the stock exchange indices have been taken into consideration ranging from their first available date to the 31.12.2017. It is observed that number of internal causal relationships among G7 is far more compared to BRICS and E7. Brazil in BRICS, Mexico in E7 and France, UK and USA in G7 are most endogenous stock markets; China, Russia and South Africa in BRICS, China in E7 and Japan in G7 are most exogenous markets according to linear causality analysis. Italy and UK impact most of the BRICS countries while Italy, UK and USA influence most of the E7 countries; China and Russia among BRICS and Indonesia among E7 Granger cause most of the G7 countries by linear causality. By nonlinear Granger causality, India and South Africa in BRICS, India in E7 and UK in G7 exhibit most endogenous behavior; Brazil, China and Russia in BRICS, Brazil, Indonesia, Russia and Turkey in E7 and France and Japan in G7 show most exogenous behaviour. Japan has most impact on BRICS; Japan and Germany influence most E7 countries; Russia in BRICS and Indonesia E7 is the key factor to comprehend the G7 countries.*

Keywords: *Stock market return, Granger causality test, G7, E7, BRICS, Himerstra-Jones test, Diks-Panchenko test, Nonlinear Granger causality.*

1. Introduction

The Group of Seven (G7) consists of seven largest advanced economies in the world viz. Canada, France, Germany, Italy, Japan,

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* Department of Mathematics, Fakir Chand College, Diamond Harbour, South 24 Parganas, Pin-743331, India, Email: swetadri.iitm@gmail.com

** Department of Mathematics, University Institute of Technology, University of Burdwan, Golapbag (North), Burdwan-713104, India, Email: koushikg123@yahoo.co.uk
https://orcid.org/0000-0002-1631-5432

the United Kingdom and the United States. These countries embody over 62% of the global net wealth (Sawe, 2017), more than 46% of the global gross domestic product (GDP) based on nominal values and over 32% of the global GDP based on purchasing power parity (PPP) (IMF, 2018).

The E7 (abbreviation for 'Emerging 7') group consists of the seven countries viz. China, India, Brazil, Mexico, Russia, Indonesia and Turkey. These seven countries are assembled together because of their sharply budding and highly promising economies. Recent estimates furnish that the E7 were 80% of G7 in 2016 in PPP (Park, 2016). In 2016, another prophecy has been claimed that the E7's economies may be bulkier than the G7 in 2030 (Hodges, 2016). PricewaterhouseCoopers (PWC) forecasted that the E7 may inflate 75% larger than the G7 in terms of PPP by 2050 (Xing, 2016).

BRICS is the abbreviation coined for an association of five major emerging economies viz. Brazil, Russia, India, China and South Africa. The first four countries are already in E7. Only South Africa is a new inclusion here. The latest statistics reveals that these five countries possess a combined nominal GDP of US$18.6 trillion which is about 23.2% of the gross world product and combined GDP (PPP) of about US$40.55 trillion (32% of World's GDP PPP) (IMF, 2018).

In this scenario it can be an interesting topic of research to explore how the countries in G7 as well as countries in E7 and BRICS show symbiotic coherence in their respective groups to breed economic synergy and also how G7 and E7 and BRICS vie for global superiority. This can be well analyzed by means of intragroup study between G7, E7 and BRICS as well as intergroup study between G7 and the combined group of E7 and BRICS to find out statistical causality between different pairs of the prime share market indices of these countries.

There have been some communications in search of comparative scaling analysis (Samadder and Ghosh 2011; Samadder, Ghosh and Basu, 2012), periodicity (Samadder, Ghosh and Basu, 2015a), nonlinearity and chaos (Samadder, Ghosh and Basu, 2015b) and nonlinear correlation (Samadder, Ghosh and Basu, 2016) between different financial markets across the world. There was also an effort to find the causal relationship of USA stock markets over Indian stock markets (Samadder, Ghosh and Basu, 2015c). The present work is an extension in this regard to comprehend the pan world comparative economy in a better manner.

Granger causality (Granger, 1969) is an efficient tool to estimate the causal influence between two data. In particular, directional information extracted by Granger causality can play a pivotal role in engendering testable hypothesis to identify source and sink (Baccala and Sameshima, 2001; Albo et. al., 2004; Brovelli et. al., 2004; Chen et. al., 2004; Seth, 2005; Ding, Chen and Bressler, 2006; Wu, Liu and Feng, 2008). For the present analysis we have used usual parametric as well as non-parametric Granger causality analysis to hunt the interrelationship between the stock exchanges i) inside the countries listed in BRICS; ii) inside the countries listed in E7 and iii) inside the countries listed in G7. Moreover, causal relations between stock exchanges of each single country listed in G7 and each single country among actually eight countries listed in BRICS and E7 have also been evaluated to realize the intergroup relationship.

2. Methodology

2.1. Linear Granger Causality Analysis

Granger causality test is used to understand whether a signal *Y* influences another signal *X* or in other words whether *Y* can be employed to forecast *X*. It involves *F*-tests to test whether lagged information on a variable *Y* provides any statistically significant information about a variable *X* in the presence of lagged *X*. If not, then "*Y* does not Granger causes *X*", otherwise "*Y* Granger causes *X*" (Granger, 1969). For a bivariate stationary VAR (p) model, the test uses level values of the variables and for non-stationary models, first or higher differences are used. For linear Granger causality analysis, at first a particular autoregressive lag length *p* of the bivariate (Burnham and Anderson, 2002; Claeskens and Hjort, 2008) VAR (*p*) model is calculated. There are many procedures for testing lag length. In our work, Akaike Information Criterion (AIC), Schwartz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HQIC) have been calculated and lag corresponding to the minimum value of these 3 criteria has been considered as optimum lag length. First variate of the unrestricted VAR is then estimated by ordinary least squares (OLS):

$$x_t = \phi_1 + \sum_{i=1}^{p} \phi_{11}^{(i)} x_{t-i} + \sum_{i=1}^{p} \phi_{12}^{(i)} y_{t-i} + \varepsilon_{1t}. \quad (1)$$

Let the estimated equation be

$$x_t = c_t + \sum_{i=1}^{p} a_i x_{t-i} + \sum_{i=1}^{p} b_i y_{t-i} + u_t. \quad (2)$$

The Granger causality from Y to X is an F-test for the joint significance of $\overset{(1)}{\phi}_{12}, \overset{(2)}{\phi}_{12}, ..., \overset{(p)}{\phi}_{12}$ in (1). So, the null hypothesis is

$$H_0 : b_i = b_2 = ... = b_p = 0$$

which is equaivalent to the fact that Y does not Granger cause X.

An F-test of H_o is conducted by estimating the following restricted equation also by OLS:

$$x_t = \phi_1' + \sum_{i=1}^{p} \overset{(i)}{\phi_{11}'} x_{t-i} + \varepsilon_{1t}'. \tag{3}$$

Let the estimated equation be

$$x_t = c_t' + \sum_{i=1}^{p} d_i x_{t-i} + e_t. \tag{4}$$

Then their respective sum of squared residuals(RSS) are compared.

$$RSS_1 = \sum_{t=1}^{T} u_t^{\,2} \text{ and } RSS_0 = \sum_{t=1}^{T} e_t^{\,2}. \tag{5}$$

If the test statistic

$$S_1 = \frac{(RSS_0 - RSS_1)/p}{RSS_1/(T-2p-1)} \sim F_{p,T-2p-1} \tag{6}$$

is greater than the specified critical value, then null hypothesis that Y does not Granger causes X is rejected.

2.2. Necessity and Importance of Nonlinear Granger Causality Analysis

Though linear Granger causality tests have high power in exploring linear causal relation between two variables, their power against determining nonlinear causal relation may be low (Baek and Brook, 1992; Himestra and Jones, 1993). Due to this fact, linear Granger causality tests might overlook significant amount of nonlinear causal relationship between two variables. So, nonlinear Granger causality should be analyzed to understand the nonlinear association between them.

2.3. Himestra-Jones Test

Himestra and Jones developed a test (Himestra and Jones, 1994; Diks and Panchenko, 2005; Diks and Panchenko, 2006; Diks and Wolski,

2016) known as Himestra-Jones test to determine nonlinear Granger causality between two variables. In testing of Granger causality of $\{Y_t\}$ by $\{X_t\}$, the aim is to reject null hypothesis $H_o : \{X_t\}$ does not Granger cause $\{Y_t\}$ which implies that Y_{t+1} is conditionally independent on $X_t,\ X_{t-1},\ X_{t-2,}...,$ given $Y_t,\ \mathrm{Y}_{t-1},\ \mathrm{Y}_{t-2,}...$

As in nonparametric analysis, conditioning of infinite past is not possible without model restriction, we assume that order of the process is finite and conditional independence is tested using finite lags l_x and l_y :

$$Y_{t+1} \,|\, \left(X_t^{l_x}; \mathrm{Y}_t^{l_y}\right) \sim Y_{t+1} \,|\, \mathrm{Y}_t^{l_y} \tag{7}$$

where $X_t^{l_x} = \left(X_{t-l_x+1}, ..., X_t\right)$ and $Y_t^{l_y} = \left(Y_{t-l_y+1}, ..., \mathrm{Y}_t\right).$

If we take a $\left(l_x + l_y + 1\right)$-variate random variable $W = (\mathrm{X}, \mathrm{Y}, \mathrm{Z})$ which takes the value $W_t = (X_t^{l_x}, Y_t^{l_y}, Z_t)$, where $Z_t = Y_{t+1}$, (7) can be rewritten as $Z \,|\, ((X,Y) = (x,y)) = Z \,|\, (Y = y)$. So, under H_o, joint probability density function $f_{X,Y,Z}(x,y,z)$ and its marginal density functions must satisfy

$$\frac{f_{X,Y,Z}(x,y,z)}{f_{X,Y}(x,y)} = \frac{f_{Y,Z}(y,z)}{f_Y(y)}. \tag{8}$$

Or equivalently,

$$\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)} = \frac{f_{X,Y}(x,y)}{f_Y(y)} \frac{f_{Y,Z}(y,z)}{f_Y(y)}. \tag{9}$$

Correlation-integral estimators of each density function are employed to test whether left hand side and right hand side of (8) or equivalently (9) differs significantly or not. (8) implies

$$\frac{C_{X,Y,Z}(\varepsilon)}{C_{X,Y}(\varepsilon)} = \frac{C_{Y,Z}(\varepsilon)}{C_Y(\varepsilon)}. \tag{10}$$

And equivalently (9) implies

$$\frac{C_{X,Y,Z}(\varepsilon)}{C_Y(\varepsilon)} = \frac{C_{X,Y}(\varepsilon)}{C_Y(\varepsilon)} \frac{C_{Y,Z}(\varepsilon)}{C_Y(\varepsilon)}. \tag{11}$$

The estimator each correlation-integral is of the form $C_{W,n}(\varepsilon) = \frac{2}{n(n-1)} \sum\sum_{i<j} I_{ij}^W$ where $I_{ij}^W = I(\left\| W_i - W_j \right\| \le \varepsilon)$, I being the Indicator function and $\|.\|$ being maximum norm.

Assuming $\{X_t\}$ and $\{Y_t\}$ are strictly stationary, weakly dependent and satisfy mixing conditions of Denker and Keller (1983), if $\{X_t\}$ does not Granger cause $\{Y_t\}$, then

$$\sqrt{n}\left(\frac{C_{X,Y,Z}(\varepsilon)}{C_Y(\varepsilon)}-\frac{C_{X,Y}(\varepsilon)}{C_Y(\varepsilon)}\frac{C_{Y,Z}(\varepsilon)}{C_Y(\varepsilon)}\right)\sim N\left(0,\sigma^2\left(l_x,l_y,\varepsilon\right)\right). \tag{12}$$

One sided critical values are used. Based on this asymptotic result, null hypothesis is rejected when the observed value of the test statistics in (12) is too large.

2.4. Diks-Panchenko Test

It is evident that in some certain cases, rejection rate of Himestra-Jones test becomes too high under the null hypothesis. The main reason for this is that the assumption made by Himestra and Jones that (8) implies (10) or equivalently (9) implies (11) does not hold generally. This test suffers from severe size distortion due to a simple fact that measuring each density in (8) or (9) separately needs not deliver the same quantity implied by (10) or (11) respectively. Diks and Panchenko (Diks and Panchenko, 2005; Diks and Panchenko, 2006; Diks and Wolski, 2016) used a conditional dependence measure by incorporating a local weighting function *g(x,y,z)* and (9) is modified as

$$H_o:\mathrm{q}=\mathrm{E}\left[\left(\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)}-\frac{f_{X,Y}(x,y)}{f_Y(y)}\frac{f_{Y,Z}(y,z)}{f_Y(y)}\right)g_{X,Y,Z}(\mathrm{x,y,z})\right]=0. \tag{13}$$

As $\left(\frac{f_{X,Y,Z}(x,y,z)}{f_Y(y)}-\frac{f_{X,Y}(x,y)}{f_Y(y)}\frac{f_{Y,Z}(y,z)}{f_Y(y)}\right)$ vanishes under H_o, resulting value of the expectation is equal to zero.

$g(X,Y,Z)$ may not be unique. Taking $g_{X,Y,Z}(\mathrm{x,y,z})=f_Y{}^2(y)$, (13) reduces to

$$H_o:\mathrm{q}=\mathrm{E}\left[f_{X,Y,Z}(x,y,z)f_Y(y)-f_{X,Y}(x,y)f_{Y,Z}(y,z)\right]=0. \tag{14}$$

One of the advantages of choosing $g_{X,Y,Z}(\mathrm{x,y,z})=f_Y{}^2(y)$ is that it has a U-statistics representation of the corresponding estimator, which enables the analytically asymptotic distribution for the test statistics. A natural estimator of q based on indicator function is

$$T_n(\varepsilon) = \frac{(2\varepsilon)^{-d_x - 2d_y - d_z}}{n(n-1)(n-2)} \sum_i \left[\sum_{k,k\neq i} \sum_{\mathrm{j},\mathrm{j}\neq i} \left(I_{ik}^{XYZ} I_{ij}^{Y} - I_{ik}^{XY} I_{ij}^{YZ} \right) \right] \qquad (15)$$

where $I_{ij}^{W} = I\left(\left\|W_i - W_j\right\| < \varepsilon\right)$.

Denoting local density estimators of a d_W -variate random variable W at $\beta \in \left(\frac{1}{4}, \frac{1}{3}\right) W_i$ by $\widehat{f}_W(W_i) = \frac{(2\varepsilon)^{-d_W}}{n-1} \sum_{j,\mathrm{j}\neq i} I_{ij}^{W}$, the test statistics simplifies to

$$T_n(\varepsilon) = \frac{(n-1)}{n(n-2)} \sum_i (\widehat{f}_{X,Y,Z}(X_i, Y_i, Z_i)\widehat{f}_Y(Y_i) - \widehat{f}_{X,Y}(X_i, Y_i)\widehat{f}_{Y,Z}(Y_i, \mathrm{Z}_i)). \qquad (16)$$

If $\varepsilon = Cn^{-\beta}$ for any positive constant C and $\beta \in \left(\frac{1}{4}, \frac{1}{3}\right)$, the test statistics is asymptotically normally distributed in the absence of dependence between the vectors W_i. Under suitable mixing conditions (Denker and Keller, 1983) if the covariances between the local density estimators are taken into account we can have

$$\sqrt{n}\,\frac{T_n(\varepsilon_n) - \mathrm{q}}{S_n} \rightarrow N(0,1) \qquad (17)$$

where $S_n^{\,2}$ is an consistent estimator of asymptotic variance of $T_n(\varepsilon_n)$.

H_o is rejected at significance level α if $\sqrt{n}\,\frac{T_n(\varepsilon_n) - \mathrm{q}}{S_n} > z_{1-\alpha}$.

3. Results

The present work is based on logarithmic daily return series data of main stock exchanges of BRICS (Brazil, Russia, India, China, South Africa), E7 (Brazil, China, India, Indonesia, Mexico, Russia, Turkey) and G7 (Canada, France, Germany, Italy, Japan, UK, USA). If $X(t)$ represents daily closing value of a stock market at the day t, then data under consideration for our work is $\ln\left(\frac{X(t) - \mathrm{X(t-1)}}{X(t)}\right)$. The main reason to use logarithmic return series is that this type of data is useful to detrend time series. Also, generally log return data is expected to be stationary which is primary condition to fit Vector Autoregression (VAR) model which is used to check causal relationship between stock markets.

Main stock exchanges taken under considerations are listed in Table 1. The sources of the data are Investing (2018), Stooq (2018) and

Yahoo Finance (2018). Time interval of computation is first available data to 31st December, 2017. The data sets have unequal length as the holidays are different in different countries. To make uniform analysis of pairwise causality, we have deleted mismatched dates and corresponding log return values.

Table 1.
Considered Stock Markets for Granger causality Analysis

Category	**Country**	**Stock Exchange**	**Start Date (DD/MM/YY)**	**End Date (DD/MM/YY)**
BRICS	Brazil	Ibovespa	27.04.93	29.12.17
	China	SSE Composite Index	19.12.90	29.12.17
	India	Sensex	01.07.97	29.12.17
	Russia	RTSI	01.09.95	29.12.17
	South Africa	FTSE JSE	25.11.11	29.12.17
E7	Brazil	Ibovespa	27.04.93	29.12.17
	China	SSE Composite Index	19.12.90	29.12.17
	India	Sensex	01.07.97	29.12.17
	Indonesia	Jakarta Composite Index	01.07.97	29.12.17
	Mexico	IPC	08.11.91	29.12.17
	Russia	RTSI	01.09.95	29.12.17
	Turkey	XU100	02.01.90	29.12.17
G7	Canada	SandP Composite Index	29.06.79	29.12.17
	France	CAC40	01.03.90	29.12.17
	Germany	DAX	30.12.87	29.12.17
	Italy	FTSE MIB	14.10.09	29.12.17
	Japan	Nikkei225	04.01.84	29.12.17
	UK	FTSE All Share Index	04.01.00	29.12.17
	USA	Dow Jones	01.10.28	29.12.17

At first, pairwise Granger causality analysis has been examined internally within stock exchanges in countries listed in BRICS, E7 and G7 separately. Both linear and nonlinear Granger causality is tested and the result is illustrated in Table 2, Table 3 and Table 4 for BRICS, E7 and G7 respectively. To find optimal lag length, Akaike Information Criterion

(AIC), Schwartz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HQIC) (Burnham and Anderson, 2002; Claeskens and Hjort, 2008) have been calculated and the lag corresponding to the minimum value of these 3 criterions has been considered as optimum lag length. Recalling that bandwidth $\varepsilon = Cn^{-\beta}$ in Diks-Panchenko test, the value of β is taken as $-\frac{2}{7}$ as it asymptotically gives the estimator T_n with the smallest mean squared error (MSE). *C* is taken as 8 due to the fact that covariance between conditional concentrations for a bivariate time series are mainly due to ARCH/GARCH effects and for estimate of ARCH coefficient $a = 0.4$, C=8. This value is asymptotically optimal and value of the bandwidth may be large for small sample size *n*. To overcome this problem, ε is truncated as $.\varepsilon = \max(8n^{-\frac{2}{7}}, 1.5)$.

Table 2.

Pairwise Granger Causality Analysis between countries listed in BRICS

Independent	**Dependent**	**No. of observations (n)**	**Lag**	**Linear Granger Causality**	**Bandwidth** $\varepsilon = \max(8n^{-\frac{2}{7}}, 1.5)$	**Nonlinear Granger Causality**
				F-statistics [p value]		T-statistics [p value]
Brazil	China	5969	17	1.17[0.28]	0.67	-0.56[0.71]
China	Brazil			1.34[0.15]		0.29[0.55]
Brazil	India	4853	10	0.87[0.55]	0.71	1.10[0.13]
India	Brazil			**22.14[0.00]***		0.90[0.18]
Brazil	Russia	5406	13	1.57[0.09]	0.69	0.37[0.35]
Russia	Brazil			**26.76[0.00]***		0.32[0.37]
Brazil	South Africa	1447	1	1.14[0.28]	1.00	**2.27[0.01]***
South Africa	Brazil			**59.98[0.00]***		**3.99[0.00]***
China	India	4918	7	**3.90[0.00]***	0.70	**1.88[0.03]***
India	China			1.53[0.15]		**1.89[0.03]***
China	Russia	5548	15	**1.95[0.01]***	0.68	0.93[0.18]

Russia	China			**1.96[0.01]***		0.98[0.16]
China	South Africa	1405	8	1.82[0.07]	1.00	0.98[0.16]
South Africa	China			1.11[0.35]		1.04[0.15]
India	Russia	4942	20	1.31[0.16]	0.70	0.91[0.18]
Russia	India			**2.23[0.00]***		0.92[0.82]
India	South Africa	1432	2	**8.93[0.00]***	1.00	1.25[0.10]
South Africa	India			0.60[0.55]		**2.05[0.02]***
Russia	South Africa	1445	2	1.82[0.16]	1.00	**1.69[0.04]***
South Africa	Russia			2.44[0.09]		**2.10[0.02]***

* denotes rejection of the null hypothesis at the 0.05 level

Table 3.
Pairwise Granger Causality Analysis between countries listed in E7

Independent	**Dependent**	**No. of observations (n)**	**Lag**	**Linear Granger Causality**	**Bandwidth** $\varepsilon = \max(8n^{-\frac{2}{7}},\ 1.5)$	**Nonlinear Granger Causality**
				F-statistics [p value]		T-statistics [p value]
Brazil	China	5969	17	1.17[0.28]	0.67	-0.56[0.71]
China	Brazil			1.34[0.15]		0.55[0.29]
Brazil	India	4853	10	0.87[0.55]	0.71	1.10[0.13]
India	Brazil			**22.14[0.00]***		0.90[0.18]
Brazil	Indonesia	4797	13	1.15 [0.31]	0.71	0.80[0.21]
Indonesia	Brazil			**30.60 [0.00]***		0.58[0.28]
Brazil	Mexico	5977	19	**2.20[0.00]***	0.67	0.56[0.29]
Mexico	Brazil			**2.21[0.00]***		0.62[0.73]
Brazil	Russia	5406	13	1.57[0.09]	0.69	0.37[0.35]
Russia	Brazil			**26.76[0.00]***		0.32[0.37]
Brazil	Turkey	5885	10	1.77 [0.06]	0.67	0.22[0.41]
Turkey	Brazil			**8.94 [0.00]***		0.28[0.61]
China	India	4918	7	**3.90[0.00]***	0.70	**1.88[0.03]***
India	China			1.53[0.15]		**1.89[0.03]***
China	Indonesia	4845	13	1.57[0.09]	0.71	1.35[0.09]
Indonesia	China			1.47[0.12]		1.41[0.08]
China	Mexico	6406	10	**2.55[0.00]***	0.65	1.09[0.14]
Mexico	China			1.60[0.10]		1.58[0.06]
China	Russia	5548	15	**1.95[0.01]***	0.68	0.93[0.18]
Russia	China			**1.96[0.01]***		0.98[0.16]
China	Turkey	6604	12	**1.74[0.05]***	0.65	1.30[0.10]
Turkey	China			0.66[0.79]		0.17[0.43]
India	Indonesia	4771	19	**1.60[0.05]***	0.71	-0.48[0.68]

Indonesia	India			**3.63[0.00]***		-0.64[0.74]
India	Mexico	4929	3	**79.65[0.00]***	0.70	**4.45[0.00]***
Mexico	India			1.41[0.24]		**3.80[0.00]***
India	Russia	4942	20	1.31[0.16]	0.70	0.91[0.18]
Russia	India			**2.23[0.00]***		0.92[0.82]
India	Turkey	4898	23	**2.71[0.00]***	0.71	-0.62[0.73]
Turkey	India			0.77[0.77]		0.59[0.28]
Indonesia	Mexico	4850	26	**15.83[0.00]***	0.71	0.29[0.38]
Mexico	Indonesia			**1.74[0.01]***		0.65[0.26]
Indonesia	Russia	4873	25	**4.19[0.00]***	0.71	0.87[0.19]
Russia	Indonesia			**3.19[0.00]***		0.72[0.24]
Indonesia	Turkey	4859	13	**5.57[0.00]***	0.71	1.24[0.11]
Turkey	Indonesia			**9.69[0.00]***		1.45[0.73]
Mexico	Russia	5485	20	**1.76[0.02]***	0.68	-0.61[0.73]
Russia	Mexico			**3.11[0.00]***		0.30[0.38]
Mexico	Turkey	6303	21	1.44[0.09]	0.66	-0.67[0.74]
Turkey	Mexico			**5.28[0.00]***		0.66[0.25]
Russia	Turkey	5457	13	**2.75[0.00]***	0.68	1.24[0.11]
Turkey	Russia			**1.98[0.02]***		0.11[0.45]

* denotes rejection of the null hypothesis at the 0.05 level

Table 4.
Pairwise Granger Causality Analysis between countries listed in G7

Independent	**Dependent**	**No. of obser-vations**	**Lag**	**Linear Granger Causality**	**Bandwidth** $\varepsilon = \max(8n^{-\frac{2}{7}},\ 1.5)$	**Nonlinear Granger Causality**
				F-statistics [p value]		T-statistics [p value]
Canada	France	6956	5	**271.81[0.00]***	0.64	**2.03[0.02]***
France	Canada			1.28[0.27]		**2.08[0.02]***
Canada	Germany	7468	5	**9.36[0.00]***	0.62	**1.67[0.05]***
Germany	Canada			**20.50[0.00]***		**2.81[0.00]***
Canada	Italy	2041	4	**2.55[0.04]***	0.91	**2.78[0.00]***
Italy	Canada			**63.46[0.00]***		**3.40[0.00]***
Canada	Japan	8191	7	**3.95[0.00]***	0.61	0.69[0.24]
Japan	Canada			**139.40[0.00]***		-0.25[0.60]
Canada	UK	4201	5	**7.87[0.00]***	0.74	**3.03[0.00]***
UK	Canada			**44.46[0.00]***		**3.60[0.00]***
Canada	USA	8653	3	**113.76[0.00]***	0.60	**2.26[0.01]***
USA	Canada			**62.33[0.00]***		**2.61[0.00]***
France	Germany	6986	10	**8.34[0.00]***	0.64	0.89[0.19]
Germany	France			**109.70[0.00]***		0.08[0.47]
France	Italy	2097	4	**5.74[0.00]***	0.90	**3.30[0.00]***
Italy	France			**195.34[0.00]***		**4.08[0.00]***
France	Japan	6669	5	**4.32[0.00]***	0.65	**2.00[0.02]***

Japan	France			**131.97[0.00]***		**2.29[0.01]***
France	UK	4251	9	**2.09[0.03]***	0.73	**2.01[0.02]***
UK	France			**1.92[0.04]***		1.23[0.11]
France	USA	5889	18	**67.53[0.00]***	0.67	0.06[0.48]
USA	France			**2.45[0.00]***		0.20[0.42]
Germany	Italy	2076	4	**4.46[0.00]***	0.90	**2.84[0.00]***
Italy	Germany			**125.73[0.00]***		**3.37[0.00]***
Germany	Japan	7177	5	**2.36 [0.04]***	0.63	0.66[0.25]
Japan	Germany			**145.74[0.00]***		**1.65[0.05]***
Germany	UK	4222	5	**10.51[0.00]***	0.73	**2.08[0.02]***
UK	Germany			**5.08[0.01]***		**2.40[0.00]***
Germany	USA	6409	3	**264.71[0.00]***	0.65	**5.78[0.00]***
USA	Germany			0.55[0.57]		**4.58[0.00]***
Italy	Japan	1985	4	1.87[0.11]	0.91	**2.21[0.01]***
Japan	Italy			**6.73[0.00]***		1.24[0.11]
Italy	UK	1774	4	**79.59[0.00]***	0.97	**3.07[0.00]***
UK	Italy			**4.84 [0.00]***		**2.45[0.00]***
Italy	USA	1050	5	**73.44[0.00]***	1.10	**3.13[0.00]***
USA	Italy			2.01[0.07]		**2.68[0.00]***
Japan	UK	4049	7	**79.48[0.00]***		**1.83[0.03]***
UK	Japan			**2.36[0.02]***		1.38[0.08]
Japan	USA	7157	1	**1305.73[0.00]***	0.63	**7.50[0.00]***
USA	Japan			2.37[0.12]		**4.36[0.00]***
UK	USA	3185	3	**183.43[0.00]***	0.80	**5.79[0.00]***
USA	UK			**6.53[0.02]***		**5.15[0.00]***

* denotes rejection of the null hypothesis at the 0.05 level

Next, pairwise causality analysis between stock exchange of each country listed in G7 and each country among effectively eight countries listed in BRICS and E7 has been analyzed and the result is demonstrated in Table 5.

Table 5.

Pairwise Granger Causality Analysis between each country listed in G7 with each country among effectively eight countries listed in BRICS and E7

Indepen-dent	**Dependent**	**No. of obser vations**	**Lag**	**Linear Granger Causality**	**Bandwidth** $\varepsilon = \max(8n^{-\frac{2}{7}},\ 1.5)$	**Nonlinear Granger Causality**
				F-statistics [p value]		T-statistics [p value]
Canada	Brazil	6605	1(HIC)	0.85[0.35]	0.65	**5.97[0.00]***
Brazil	Canada			0.11[0.73]		1.55[0.06]
Canada	China	6709	1(HIC)	2.54[0.11]	0.64	**3.14[0.00]***
China	Canada			**31.24[0.00]***		**0.31[0.62]***

Canada	India	4948	1(HIC)	0.41[0.52]	0.70	**6.05[0.00]***
India	Canada			**173.66[0.00]***		**7.11[0.00]***
Canada	Indonesia	4888	17(AIC)	1.24[0.22]	0.71	0.47[0.32]
Indonesia	Canada			**24.08[0.00]***		1.18[0.12]
Canada	Mexico	6443	2(HIC)	**8.72[0.00]***	0.65	**4.59[0.00]***
Mexico	Canada			**5.82[0.00]***		**1.72[0.04]***
Canada	Russia	5525	1(HIC)	**12.65[0.00]***	0.68	**4.74[0.00]***
Russia	Canada			**239.55[0.00]***		**5.26[0.00]***
Canada	Turkey	6834	13(AIC)	**2.71[0.00]***	0.64	1.06[0.85]
Turkey	Canada			**7.88[0.00]***		0.68[0.75]
France	Brazil	6025	10(HIC)	**8.51[0.00]***	0.66	0.53[0.70]
Brazil	France			1.80[0.055]		0.50[0.69]
France	China	6709	15(AIC)	0.91[0.55]	0.64	1.04[0.15]
China	France			**2.95[0.00]***		0.82[0.21]
France	India	4999	14(AIC)	1.55[0.08]	0.70	0.68[0.25]
India	France			**11.62[0.00]***		0.85[0.20]
France	Indonesia	4933	5(AIC)	**2.58[0.00]***	0.70	**2.29[0.01]***
Indonesia	France			**45.83[0.00]***		**2.31[0.01]***
France	Mexico	6460	5(AIC)	**17.63[0.00]***	0.65	1.55[0.06]
Mexico	France			1.27[0.27]		**1.79[0.04]***
France	Russia	5558	5(AIC)	**6.45[0.00]***	0.68	**2.14[0.01]***
Russia	France			**13.20[0.00]***		**2.40[0.00]***
France	Turkey	6787	13(AIC)	1.50[0.11]	0.64	0.83[0.20]
Turkey	France			**2.09[0.01]***		0.63[0.74]
Germany	Brazil	6038	1(HIC)	**29.15[0.00]***	0.66	**6.43[0.00]***
Brazil	Germany			**3.92[0.04]***		**3.64[0.00]***
Germany	China	6686	10(AIC)	0.96[0.47]	0.65	**1.68[0.05]***
China	Germany			**3.35[0.00]***		0.37[0.32]
Germany	India	4968	3(AIC)	0.39[0.76]	0.70	**3.26[0.00]***
India	Germany			**45.68[0.00]***		**3.42[0.00]***
Germany	Indonesia	4923	5(AIC)	0.73[0.60]	0.70	**2.21[0.01]***
Indonesia	Germany			**46.72[0.00]***		1.42[0.08]
Germany	Mexico	6435	3(AIC)	**13.46[0.00]***	0.65	**2.56[0.00]***
Mexico	Germany			**2.64[0.05]***		1.05[0.15]
Germany	Russia	5530	4(HIC)	**6.13[0.00]***	0.68	**2.69[0.00]***
Russia	Germany			**19.32[0.00]***		**1.60[0.05]***
Germany	Turkey	6802	5(AIC)	1.45[0.20]	0.64	0.88[0.19]
Turkey	Germany			**7.14[0.00]***		0.82[0.21]
Italy	Brazil	2017	4(AIC)	**45.29[0.00]***	0.91	**2.61[0.00]***
Brazil	Italy			1.21[0.30]		**2.35[0.00]***
Italy	China	1984	9(AIC)	1.16[0.31]	0.91	**1.73[0.04]***
China	Italy			**2.77[0.00]***		1.43[0.07]
Italy	India	2005	4(AIC)	**4.44[0.00]***	0.91	1.53[0.06]
India	Italy			1.85[0.11]		1.62[0.053]
Italy	Indonesia	1987	7(AIC)	0.72[0.65]	0.91	**1.90[0.03]***
Indonesia	Italy			**2.17[0.03]***		1.42[0.08]
Italy	Mexico	2048	4(AIC)	**2.37[0.05]***	0.91	**2.28[0.01]***
Mexico	Italy			**51.10[0.00]***		**1.61[0.05]***

Italy	Russia	2019	6(AIC)	**14.11[0.00]***	0.91	**2.04[0.02]***
Russia	Italy			**2.20[0.04]***		**1.65[0.05]***
Italy	Turkey	2038	4(AIC)	**15.66[0.00]***	0.91	1.21[0.11]
Turkey	Italy			1.68[0.15]		1.14[0.13]
Japan	Brazil	5777	1(HIC)	**6.13[0.00]***	0.67	**267.29[0.00]***
Brazil	Japan			**3.46[0.00]***		0.54[0.46]
Japan	China	6499	4(AIC)	1.89[0.11]	0.65	**2.46[0.00]***
China	Japan			1.28[0.27]		0.55[0.29]
Japan	India	4757	3(AIC)	**20.82[0.00]***	0.71	**3.31[0.00]***
India	Japan			2.28[0.08]		1.23[0.11]
Japan	Indonesia	4717	13(AIC)	1.14[0.32]	0.71	1.13[0.13]
Indonesia	Japan			**2.46[0.00]***		0.33[0.37]
Japan	Mexico	6203	1(AIC)	**420.16[0.00]***	0.66	**6.47[0.00]***
Mexico	Japan			1.05[0.30]		**4.46[0.00]***
Japan	Russia	5371	2(AIC)	37.50[0.00]	0.69	**4.34[0.00]***
Russia	Japan			0.11[0.89]		**2.69[0.00]***
Japan	Turkey	6608	2(AIC)	**13.99[0.00]***	0.65	**3.89[0.00]***
Turkey	Japan			0.18[0.83]		**3.73[0.00]***
UK	Brazil	4096	4(HIC)	**34.91[0.00]***	0.74	**4.17[0.00]***
Brazil	UK			**3.83[0.01]***		**1.83[0.03]***
UK	China	4150	8(AIC)	**2.71[0.00]***	0.74	1.49[0.06]
China	UK			**8.85[0.00]***		0.91[0.18]
UK	India	4078	14(AIC)	1.25[0.23]	0.74	0.62[0.73]
India	UK			**12.28[0.00]***		0.51[0.30]
UK	Indonesia	4022	8(AIC)	**1.67[0.01]***	0.75	0.82[0.21]
Indonesia	UK			**23.08[0.00]***		**1.59[0.055]***
UK	Mexico	4163	5(AIC)	**22.02[0.00]***	0.74	**2.65[0.00]***
Mexico	UK			1.40[0.22]		0.60[0.27]
UK	Russia	4088	4(HIC)	**9.77[0.00]***	0.74	**2.50[0.01]***
Russia	UK			**24.46[0.00]***		**2.52[0.00]***
UK	Turkey	4131	6(AIC)	1.45[0.19]	0.74	**1.62[0.052]***
Turkey	UK			**3.78[0.00]***		1.30[0.09]
USA	Brazil	5958	10(HIC)	**5.23[0.00]***	0.67	1.26[0.10]
Brazil	USA			**3.93[0.00]***		1.01[0.15]
USA	China	6654	16(AIC)	1.38[0.14]	0.65	1.13[0.13]
China	USA			**2.98[0.00]***		-0.31[0.62]
USA	India	4913	19(AIC)	1.37[0.13]	0.70	1.10[0.13]
India	USA			**15.44[0.00]***		-0.61[0.73]
USA	Indonesia	4857	16(AIC)	**2.45[0.00]***	0.71	0.68[0.25]
Indonesia	USA			**28.59[0.00]***		1.27[0.10]
USA	Mexico	6389	13(AIC)	**6.16[0.00]***	0.65	1.37[0.08]
Mexico	USA			**7.85[0.00]***		1.05[0.15]
USA	Russia	5486	16(AIC)	**4.27[0.00]***	0.68	0.65[0.26]
Russia	USA			**19.54[0.00]***		0.89[0.19]
USA	Turkey	6776	12(AIC)	**2.88[0.00]***	0.64	-0.83[0.79]
Turkey	USA			**15.96[0.00]***		-0.22[0.59]
Canada	South Africa	1472	7	1.63[0.12]	0.99	1.10[0.13]

South Africa	Canada			**12.77[0.00]***		**1.89[0.03]***
France	South Africa	1508	6	**2.52[0.00]***	0.99	1.08[0.14]
South Africa	France			**4.74[0.00]***		0.57[0.28]
Germany	South Africa	1430	14	**3.47[0.00]***	0.99	0.21[0.58]
South Africa	Germany			**2.93[0.00]***		0.48[0.32]
Italy	South Africa	1903	4	**19.95[0.00]***	0.92	**1.76[0.04]***
South Africa	Italy			0.70[0.59]		0.62[0.27]
UK	South Africa	1491	4	**5.73[0.01]***	0.99	**1.81[0.03]***
South Africa	UK			**3.00[0.02]***		-0.04[0.51]
USA	South Africa	1471	3	1.30[0.27]	0.99	2.44[0.00]
South Africa	USA			**35.90[0.00]***		0.82[0.20]
Japan	South Africa	1425	2	**30.95[0.00]***	1.00	**2.41[0.00]***
South Africa	Japan			2.05[0.08]		**2.24[0.01]***

* denotes rejection of the null hypothesis at the 0.05 level

The following Figures 1-4 are sketched to demonstrate the pairwise intra and inter group relationships between the share markets of the countries in G7, E7 and BRICS using usual linear Granger causality and non-parametric (nonlinear) Granger causality separately. The countries are shown in dots and if any causality is found in any pair directive straight line (with arrow) is generated connecting the concerned pair of dots. If any straight line is visible connecting a pair of dots with both way arrows it indicates that the related pair of countries show both way causality.

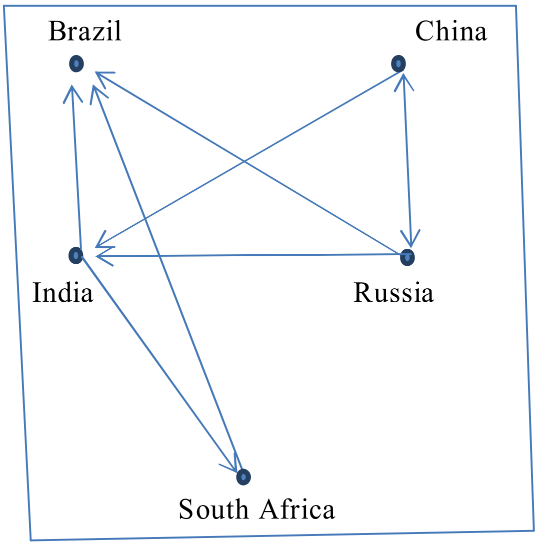

Figure 1a: Linear Granger Causality (BRICS)

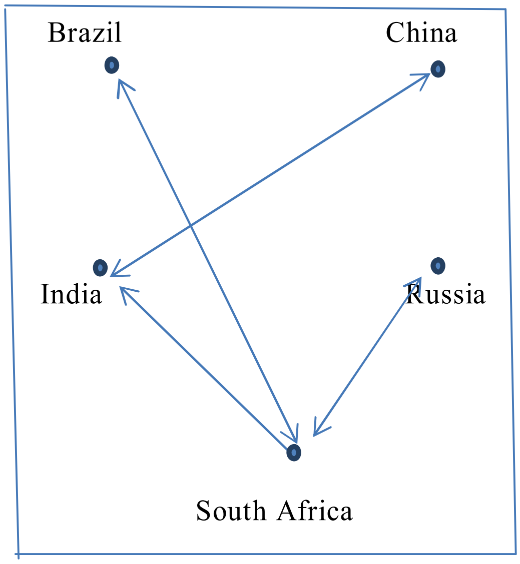

Figure 1b: Non- linear Granger Causality (BRICS)

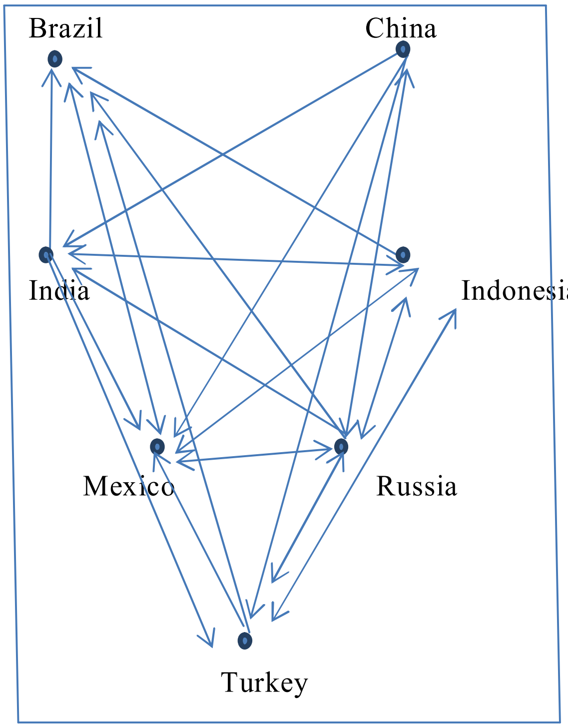

Figure 2a: Linear Granger Causality (E7)

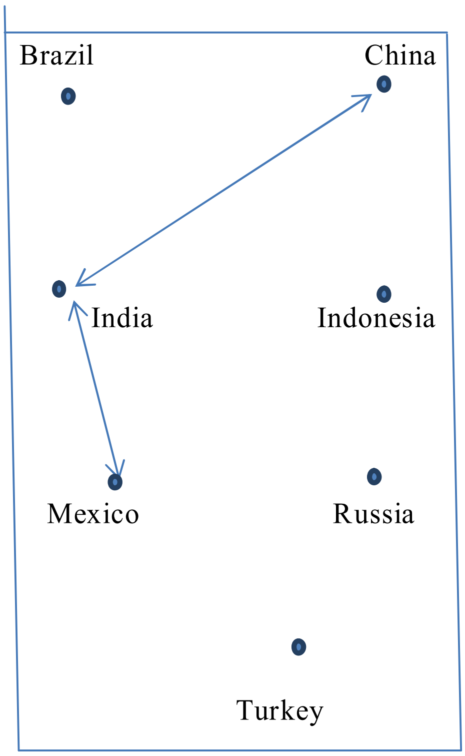

Figure 2b: Non-linear Granger Causality (E7).

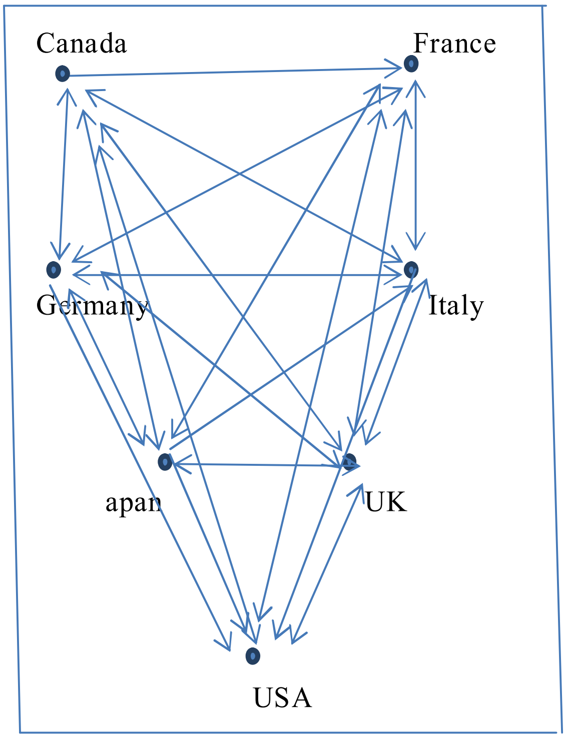

Figure 3a: Linear Granger Causality (G7).

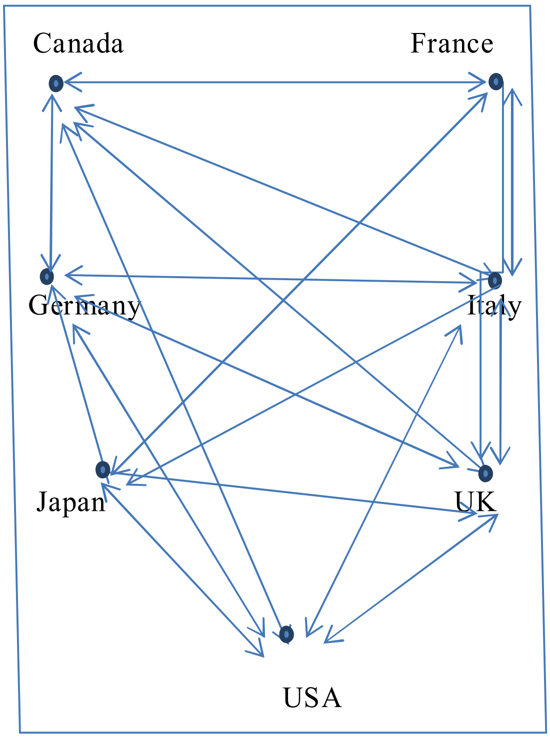

Figure 3b: Non-linear Granger Causality (G7).

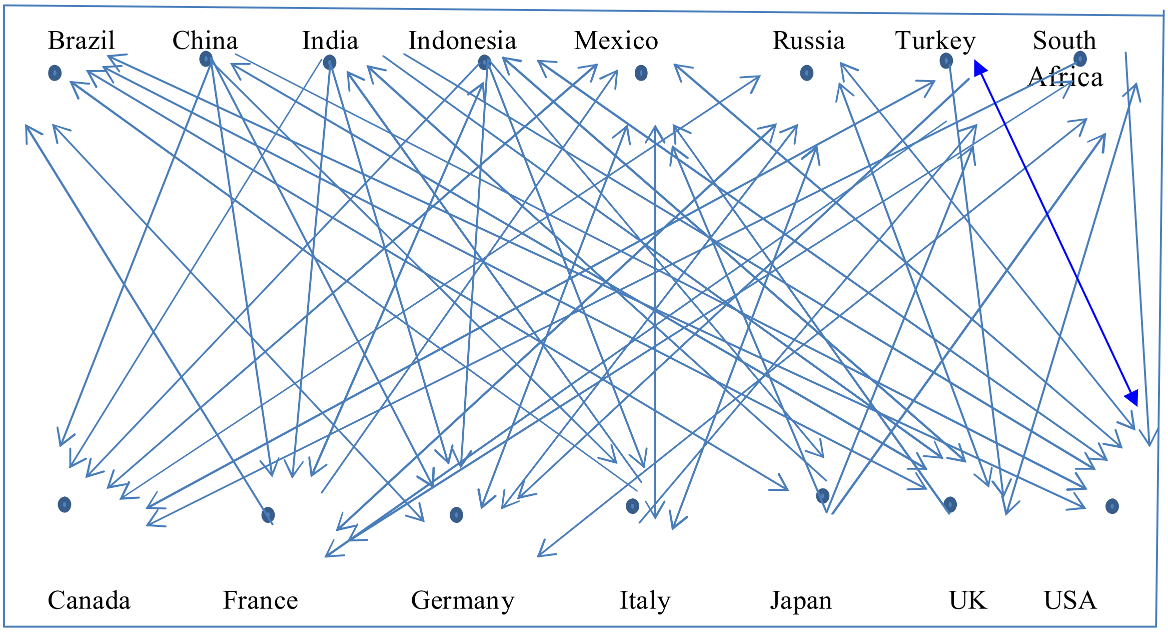

Figure 4a: Linear Granger Causality
(G7 with effectively eight countries listed in BRICS and E7).

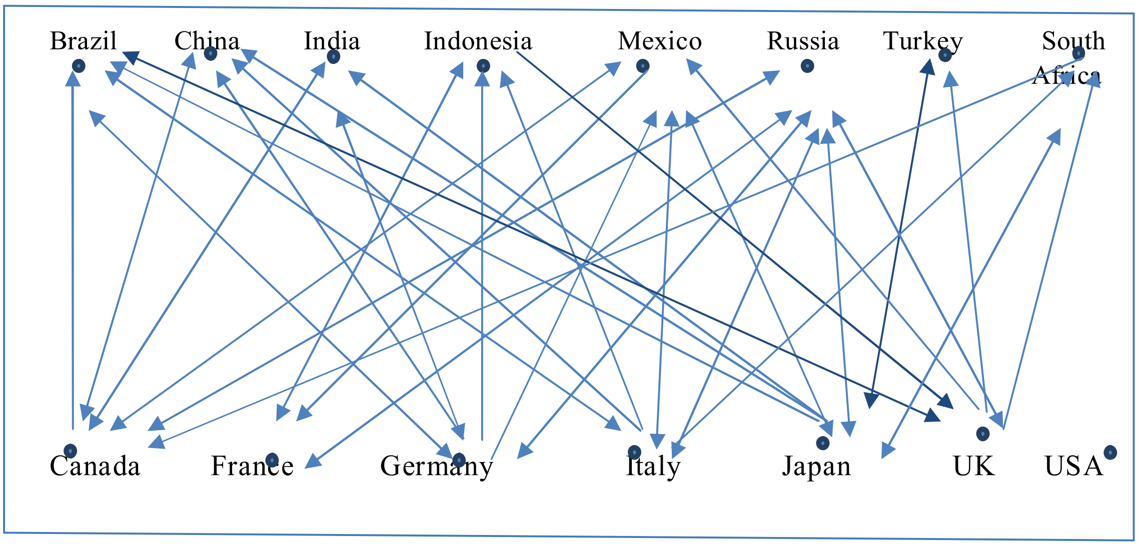

Figure 4b: Non-linear Granger Causality
(G7 with effectively eight countries listed in BRICS and E7).

4. Discussion and Conclusion

In the present paper, our main concern is to find both directed intra-relations and inter-relations between the share markets of the countries listed in BRICS, E7 and G7. From Table 2, it is evident that number of Granger causal relationships in BRICS is 8 (linear) and 7 (nonlinear) out of possible 20 relationships whereas from Table 3, it is clear that number of causal relationships in E7 is 27 (linear) and 4 (nonlinear). It is seen in Table 4 that number of causal relationships in G7 is 37 (linear) and 32 (nonlinear) out of possible 42 relationships. Hence, number as well as percentage of Granger causal relationship (both linear and nonlinear) is much more in case of G7 compared to BRICS and E7 which implies that G7 countries may be strongly connected and rise or fall of any stock exchange listed in G7 may affect other stock exchanges in that group.

It is seen from Table 2, Table 3 and Table 4 that Brazil (influenced by India, Russia and South Africa) in BRICS , Mexico (influenced by all other markets in E7) in E7 and France, UK and USA(influenced by all other markets in G7) in G7 are most endogenous stock markets when linear Granger cause analysis is performed. On the other hand, India (influenced by China and South Africa) and South Africa (influenced by Brazil and Russia) in BRICS, India (influenced by China and Mexico) in E7 and UK (influenced by all other markets in G7) in G7 exhibit most endogenous behaviour as nonlinear Granger causality is concerned. These countries have a high chance to be affected by other countries in the same group.

China (influenced by Russia), Russia (influenced by China) and South Africa (influenced by India) in BRICS, China (influenced by Russia) in E7 and Japan (influenced by Canada, France, Germany and UK) in G7 are most exogenous stock markets according to linear Granger causality analysis. Nonlinear Granger causality analysis shows that Brazil (influenced by South Africa), China (influenced by India) and Russia (influenced by South Africa) in BRICS, Brazil, Indonesia, Russia and Turkey (influenced by none) in E7 and France ((influenced by Canada, Italy and Japan) and Japan (influenced by France, Italy and USA) in G7 show most exogenous behavior. These countries may be unaffected by ups and downs of other markets in the same group and may behave independently.

When relationship between G7 and BRICS countries are tested, it is detected that Italy and UK impact most of the BRICS countries while Italy, UK and USA influence most of the E7 countries; China and Russia among BRICS and Indonesia among E7 Granger cause most of the G7 countries according to linear Granger causality test. It is suggested by nonlinear Granger causality analysis that Japan has the most impact on BRICS while Japan and Germany influence most of the E7 countries and Russia in BRICS and Indonesia E7 is the main factor for understanding the stock market behavior of G7 countries. Moreover, Russia has bidirectional linear Granger causality with most of the countries in its own group E7 (Brazil, Indonesia, Mexico and Turkey). Besides, Russia possesses both linear and non-linear Granger causality relationship with six countries of G7 (Canada, France, Germany, Italy, UK and USA for linear causality and Canada, France, Germany, Italy, Japan and USA for nonlinear causality). This possibly indicates that Russia plays a pivotal role in the dynamics of world economy as it has high degree connectivity with its partners in E7 and countries in G7.

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