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Research Article

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Abstract: This study investigates the aftermath of Tohoku earthquake to the structure of Asia-Pacific currencies. The M statistic and Minimum Spanning Tree (MST) are employed to study the stability of the covariance currencies structure and its causes, respectively. To filter the information from MST, we use a degree centrality measure. The results showed that the Tohoku earthquake that struck Japan on March 2011 had increased the volatility of currencies exchange and made currencies unstable. From the control chart, it shows that the currencies are not stable from Jan 2010 until Dec 2011. Based on sample data of Nov 2011, we can conclude that LKR and HKD are the unstable currencies among the others.

Keywords: Box's M, earthquake Tohoku, Japanese yen, network analysis

INTRODUCTION

The instability of political policy, global economic crisis (Jang *et al*., 2011), natural disaster such as earthquake, tsunamis, typhoons (Hallegatte and Dumas, 2009; Worthington, 2008; Moldovan, 2011) affect the economic performance and growth of countries around the globe. As example, Yamori and Kobayashi (2002) have found that Japanese stock market reappraise domestic insurance firm values after 1995-Awaji earthquake. This earthquake made insurance companies pay nearly 77 billion yen that is the largest payment since earthquake insurance was established. In addition, Karolyi (2002) examined the foreign investor trading behavior in Japan around the time of the Asia crisis and evaluated its impact on stock and currency returns.

On 11 March 2011, the Tohoku earthquake ripped apart the seafloor with 9.0 magnitudes. It shocked the pacific coast of northeastern part of Japan, which includes Sanriku, Miyagi, Fukushima and Ibaragi (Imamura and Anawat, 2011). It was very powerful it has moved Japan to nearly eight feet's from Asia. The earthquake has had a disturbing effect on people of Japan. Hood *et al*. (2013) has confirmed that the number of deaths has reached 15,883 and 2,671 missing. The main cause of death was the tsunami and most deaths happened in Tohoku: 57% in Miyagi state, 33% in Iwate state and 9% in Fukushima state (Mori *et al*., 2011). The early estimates of the insured losses were around 25 billion dollars and the total estimated economic lost exceeded 200 billion dollars. The greatest damage was done to the three nuclear reactors that had failed and exploded. The waves of tsunami had spread throughout the Pacific and destroyed many port and harbor areas in Hawaii, Oregon and California and buildings along costs of Guam and Chile. Thus, the greatest devastation happened in Japan (Satake, 2013).

On the other hand, the earthquake also impacted one of the biggest stock exchange in the world (Moldovan, 2011). The investigation on FTSE index, Dow Jones index and Nikkei index shows that three indices were stronger during the financial crisis. In addition, Tokyo exchange is the third largest stock exchange in the world. The daily average market is 20 billion dollars the stock market felt of the impact until the trading opened (Hood *et al*., 2013). Nevertheless, the earthquake not only affects the stocks, but the Japanese Yen (JPY). The JPY is the national currency for Japan, which is the third largest economy in the world. Which shows that the exchange rate may even change the monetary policies and it may fail to make a dent on the exchange rate volatility (Botman *et al*., 2013). Another impact on the economy of Japan is the reduction value of JPY. It produces certain changes in stock market of the world and influences the value of JPY against the major currencies in the world (Eric Fox, 2011). Here, it can be concluded that stocks market and currency exchange rate play a very important role in the economic growth.

Therefore, in this study, we focus on the investigation of Asia-Pacific currencies from the early of 2010 to end of 2011. The Box's M statistic is employed to capture the impact of earthquake towards the stability of currencies structures. To achieve this objective; in the next section, we explain on the data preparation as well as the stability test of covariance matrices.

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DATA PREPARATION CASE STUDY

In this study, we retrieved the daily data of 15 currencies from January 1, 2010 to December 31, 2011. The Asia Pacific countries are divided into three regions where are East Asia include Japan (JPY), South Korea (KRW), China (CNY), Taiwan (TWD) and Hong Kong (HKD), then South East Asia include Singapore (SGD), Philippines (PHP), Malaysia (MYR), Thailand (THB) and lastly, South Asia include India (INR), Sri Lanka (LKR), Pakistan (PKR) and Pacific include New Zealand (NZD), Australia (AUD) and Fiji (FJD). For base currency, precious metal such as gold, platinum and silver can be used (Mizuno *et al*., 2006). The result could be influenced by the variances of the prices of these metals Jang *et al*. (2011) suggested using the Special Drawing Right (SDR) as a base, which is usable freely on the currencies of international monetary. Therefore, we use the SDR as the base currency. The data is downloaded from Sauder School of Business (2011) Pacific exchange rate service.

Test for stability of covariance matrices using MSPC approach: In MSPC approach, the stability test of several independent samples of covariance matrices in certain time frame can be presented using control chart. Let k independent samples of size $n_1, n_2, \ldots, n_k$ drown from$p-$varite normal distributions $N_p(\mu_1, \Sigma_1), N_p(\mu_2, \Sigma_2), \ldots, N_p(\mu_k, \Sigma_k)$ and Σ_i denote the covariance matrix of the i-th population. Therefore, to test the hypothesis of two covariance matrices are equal, $H_0: \Sigma_i = \Sigma_0$versus $H_1: \Sigma_i \neq \Sigma_0$; $i = 1, 2, \ldots, k$. the M-statistic is as follows:

$$M = N ln|S_{pooled}| - \sum_{i=1}^{k} n_i ln|S_i| \quad (1)$$

where,

- $S_i isi\text{-}th$sample covariance matrix, $i = 1, 2, \ldots, k$
- $S_{pooled} = \frac{\sum n_i S_i}{N}$, is the pooled covariance matrix
- $N = n_1 + n_2 + \cdots + n_k$

Box (1949) shows that the statistic test, $\frac{M}{b}$ can be approximated by χ^2distribution:

- $a = \frac{2p^2+3p-1}{6(p+1)(k-1)}\left[\sum_{i=1}^{k}\frac{1}{n_i} - \frac{1}{N}\right]$
- $b = \frac{1}{1-\vartheta}$
- $\vartheta = \frac{p(p+1)(k-1)}{2}$

Therefore, to produce a multivariate statistical process control chart, at level of significance, α the upper control limit is $\chi^2_{\alpha,\vartheta}$ (Yusoff and Djauhari, 2013).

Testing the stability of covariance structures: In this section, we discuss on the stability test of covariance structures followed by network analysis in the next section. In general, this data set has around 5 trading days per week and 20 trading days per month. To construct the corresponding control chart, we conduct the Box's M statistics for each of 24 months from January 2010 until December 2011 to understand the stability (instability) of the covariance structure (Table 1).

Table 1: Box's M statistics of Asia pacific currencies

Monthly	M	M/b
Jan-10	259.11	191.41
Feb-10	267.99	197.97
Mar-10	266.06	206.33
Apr-10	277.97	209.09
May-10	351.73	259.82
Jun-10	258.88	197.89
Jul-10	223.04	167.77
Aug-10	252.24	189.74
Sep-10	252.40	189.86
Oct-10	270.07	199.50
Nov-10	224.25	168.68
Dec-10	243.33	183.04
Jan-11	260.17	192.19
Feb-11	279.22	206.26
Mar-11	248.80	192.95
Apr-11	231.38	170.92
May-11	238.30	179.25
Jun-11	278.02	212.52
Jul-11	303.72	224.36
Aug-11	221.56	169.36
Sep-11	306.94	230.88
Oct-11	296.50	219.03
Nov-11	396.44	298.21
Dec-11	256.56	189.52

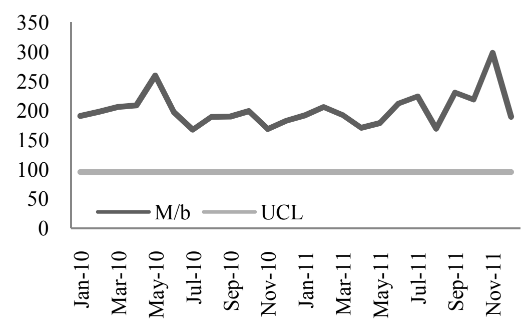


Fig. 1: Box M control chart

In order to monitor the covariance stability, we present the Box M control chart where it UCL = $\chi^2_{0.05,120}$ = 95.70464 (red colour) in Fig. 1. We reject the null hypothesis if Box M statistic falls outside the UCL. This signal shows that there is a change in covariance structures.

The vertical axis is the value of M/b and the horizontal axis is the month from January 2010 until December 2011. We learn from Fig. 1 that a signals of instability, of covariance structure occurs at the chart, all points in the chart are out of control that get more information about the history of process variability. There is a special cause in process because all points are beyond the control limits; the process is out of statistical control (unstable).

In the next step, we performed the correlation diagnostic analysis to identify the most dominance currency (ies) among the others by using a Minimum Spanning Tree (MST). For that purpose, we compare the data structure of November 2011 with the in-control covariance matrix, i.e., reference sample. In what follows, we provide a discussion on correlation diagnostics analysis.

Correlation diagnostic analysis: Originally, network analysis is an approach of human social interactions, developed for measuring social relations to better study the relationships between social structure and psychological. Network analysis is also, used to determine the relative significance of node in the network (Serrat, 2009). Sharif *et al*. (2012) proposed to use this methodology as a root causes analysis in monitoring process variability. The other techniques that can be used are neural network and Principal Component Analysis (PCA). MST is a kind of currency map that is used in financial portfolio of foreign exchange rate (Mizuno *et al*., 2006). Network analysis becomes a necessary tool to filter the most important information (Sharif *et al*., 2012).

To analyze that network, first the important information we filter it by using MST, second we describe the details by using a centrality measure (Sharif *et al*., 2012). In the present analysis, we investigate the interrelationship of 15 Asia Pacific currencies by using the network analysis which developed based on correlation matrix, the correlation is calculated between all pairs of each currencies, the node consist 15*(15-1)/2 = 105 links each of their correlation between currencies. We use Matlab 7.10.0.499 (R2010a) and Pajek (Batagelj and Mrvar, 2011) to understand the system, let P_i is the currencies under study. We calculate the logarithmic return of exchange rate R_i:

$$R_i = lnP_i(t+1) - lnP_i(t) \quad (2)$$

The correlation coefficient ρ_{ij} calculated from formula:

$$\rho_{ij} = \frac{\langle R_i R_j \rangle - \langle R_i \rangle \langle R_j \rangle}{\sqrt{(\langle R_i^2 \rangle - \langle R_i \rangle^2)(\langle R_j^2 \rangle - \langle R_j \rangle^2)}} \quad (3)$$

where, i and $j$are the currencies from $i = 1, 2, \ldots, p$ and we calculate R_i which is the logarithmic return exchange rate. We transform the correlation matrix into distance matrix D to analyse the network by using the formula:

$$d_{ij} = \sqrt{2(1-\rho_{ij})} \quad (4)$$

d_{ij} is a distance between the i-th and$j$-th of currency there are three properties must be conclude (i) $d_{ij} \geq 0$ and $d_{ij} = 0 \iff i = j$, because$\rho_{ij} = 1$ (ii) $d_{ij} = d_{ji}$ since $\rho_{ij} = \rho_{ji}$ (iii) $d_{ij} \leq d_{ik} + d_{kj}$, triangular inequality. Furthermore, $0 \leq d_{ij} \leq 2$ (Mantegna and Stanley, 2000).

The correlation matrix is asymmetric the main diagonal = 1 when $i = j$ and ρ_{ij} can vary from -1 (completely anti-correlated) to 1 (completely correlated), when $\rho_{ij} = 0$ the currencies uncorrelated (Mantegna, 1999). We calculate matrix of distance d_{ij} 15×15 to summarize the main information in the network by distance matrix, for that we use the idea of Sub-Dominant Ultrametric (SDU) which proposed by Mantegna and Stanley (2000). The SDU matrix 15×15 with $\hat{d}_{ij}$ element in i-th and j-th column where $\hat{d}_{ij} \leq d_{ij}$ for $i$and j from ultrametric distance there are properties will be achieved (i) $\hat{d}_{ij} = \hat{d}_{ji}$ for all i and j (ii) $\hat{d}_{ij}$= 0 $\Leftrightarrow i = j$ (iii) $\hat{d}_{ij} \leq \max\{\hat{d}_{ik}, \hat{d}_{kj}\}$ for all $i,j$and p = 1,2,…,15. We determined MST by using Kruskal algorithm (Kruskal, 1956) and we use degree centrality to explain the MST, the centrality can help to understand the importance and influence of each nods close to others (Abbasi and Altmann, 2011). Degree centrality denotes as the connectivity of currencies it gives information about the number of edges happening at a node the measure of degree of centrality defined as:

$$c_i = \sum_{j=1}^{P} a_{ij} \quad (5)$$

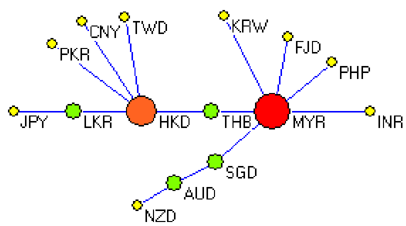
where, a_{ij} is the element in i-th row and j-th column in adjacent matrix. It is defined as the number of ties that the node has (Borgatti, 1995). We analyze 15*15 = 225 correlation elements we filter the information to 15*(15-1)/2 = 105 elements using MST for that we need the adjacency matrix that match or agree almost exactly to the MST. In adjacency matrix the element = 1 if the i-th and j-th nodes are linked and 0 otherwise where the matrix is symmetric with the diagonal elements are 0. Based on adjacency matrix we have 15-1 = 14 links to display their interrelationship.

To illustrate the information in Table 2, we present Fig. 2 and 3, respectively according to the colour and the size for importance.

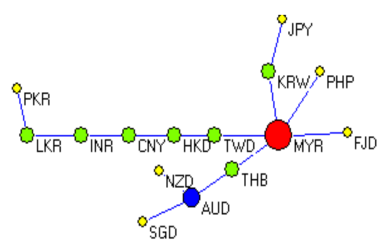
Figure 2a, it shows that MYR has the highest number of links there are 6 links (red colour) in the network. In the order of importance, HKD has 5links (orange colour). While AUD, LKR, SGD and THB, respectively have2 links (green colour). Finally, CNY, FJD, INR, JPY, NZD, PKR, PHP, KRW and TWD, respectively have 1 links (yellow colour) in the network. We show the MYR has the highest number of links that means MYR is the most influential currencies to the other currencies. From this figure, we learn that LKR, TWD, CNY and PKR currencies are dominated by HKD. While SGD, THB, PHP, INR, FJD and KRW dominated by MYR. In this analysis, we can conclude the currencies splitting into two big clusters where

Table 2: Degree and average of weights centrality

Currency	Reference sample: Degree centrality	Reference sample: Average of weights centrality	November 2011: Degree Centrality	November 2011: Average of weights centrality
AUD-Australian Dollar	2	0.77	3	0.66
CNY-Chinese Yuan	1	0.37	2	0.83
FJD-Fijian Dollar	1	1.17	1	0.91
HKD-Hong Kong Dollar	5	0.64	2	0.65
INR-Indonesian Rupiah	1	0.92	2	1.19
JPY-Japanese Yen	1	1.33	1	1.50
KRW-South Korean Won	1	0.93	2	1.18
LKR-Sri Lankan Rupee	2	0.92	2	1.58
MYR-Malaysia Ringgit	6	0.96	5	0.85
NZD-New Zealand Dollar	1	0.67	1	0.53
PKR-Pakistani Rupee	1	0.56	1	1.14
PHP-Philippine Peso	1	0.85	1	0.83
SGD-Singapore Dollar	2	0.96	1	0.61
TWD-New Taiwan Dollar	1	0.89	2	0.68
THB-Thai Bhat	2	0.90	2	0.98

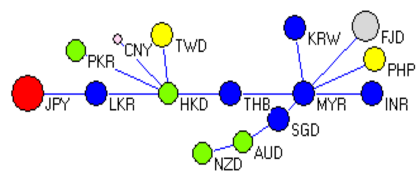


(a)

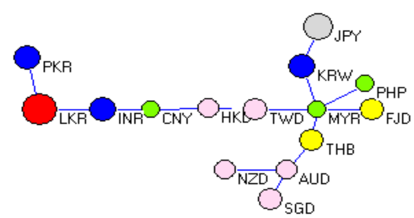


(b)

Fig. 2: Degree centrality (a) MST for reference sample and (b) November 2011 after Tohoku Earthquake



(a)



(b)

Fig. 3: Average of weight (a) MST for reference sample and (b) November 2011 after Tohoku Earthquake

MYR dominates in South East Asia, while HKD in East Asia. Besides, AUD acts as a key to the connectivity of NZD and SGD.

On the other hand, after the Tohoku earthquake, Figure 2b shows that MYR has the highest number of links 5 (red colour) and AUD has 3 links (blue colour). While CNY, HKD, INR, KRW, LKR, TWD and THB has 2 links, respectively (green colour) and FJD, JPY, NZD, PHP, PKR and SGD has 1 link, respectively (yellow colour). From this figure, we can see that there is only one cluster dominated by MYR and AUD still acts as a key to the connectivity among NZD and SGD.

To understand which currency has change on their centrality degree, we make a comparison between reference sample and the sample of November 2011. It shows that there is a change in AUD, CNY, HKD, INR, KRW, MYR, SGD and TWD and the other currencies are no change. Among those currencies, HKD is very unstable currency in November 2011, since their links is reducing from five to two numbers of links.

In degree centrality measure, we compute only the number of links in the network. By considering its weights, next we present average of weights centrality (Sharif *et al.*, 2012). Specifically, the average of weights is the sum of weights divided by number of links.

Based on average of weight centrality, JPY is the most influential (red colour), the second important FJD (grey colour), the third important (0.90-0.99) are MYR, SGD, KRW, INR, LKR, THB (blue colour) and the fourth important (0.80-0.89) TWD and PHP (yellow colour). While AUD, HKD, NZD and PKR (lime green colour) are the fifth important currencies, lastly CNY has a small average of weight (pink colour). Figure 3b the most influential currency is LKR (red colour), second important is JPY (grey colour), the third important after Tohoku earthquake are KRW, INR and PKR (blue colour), the fourth important (0.9-0.99) are FJD and THB (yellow colour). Moreover, CNY, MYR and PHP (green colour) are the fifth important currencies (0.80-0.89), lastly AUD, HKD, NZD, SGD and TWD have small average of weights.

To understand which currency has change on after Tohoku earthquake, we make a comparison between reference sample and the sample of November 2011. It shows that there is a change in all the currencies. Among those currencies, LKR is very unstable currencies in November 2011, since their average of weights is changing from 0.92 to 1.58. It is followed by PKR, CNY and SGD.

CONCLUDING REMARKS

In this study, we used MSPC approach as a procedure to understand the stability (or instability) of Asia-Pacific Currencies structure aftermath Tohoku earthquake. First, we construct Box's M control chart to monitor the process variability. It has increased the volatility of currency exchange and the currencies are unstable from Jan 2010 until Dec 2011. In the next step, when the out-of-control signal occurs, network analysis is performed to identify the influential currencies. We compare the corresponding sample to the current process variability, i.e., reference sample in identifying the problematic currencies. However, in this study, we only illustrate the network analysis for sample of November 2011, since it is having the largest Box's M statistics. Based on network analysis of reference sample, we can see that a minimum spanning tree produce two clusters. The cluster of South East Asia is dominated by MYR and East Asia is dominated by HKD. To clarify the details, degree centrality and average of weights centrality have been used. The larger the value is the more influence of that particular currency to the others. From the analysis, we can conclude that HKD and LKR are the unstable currencies.

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